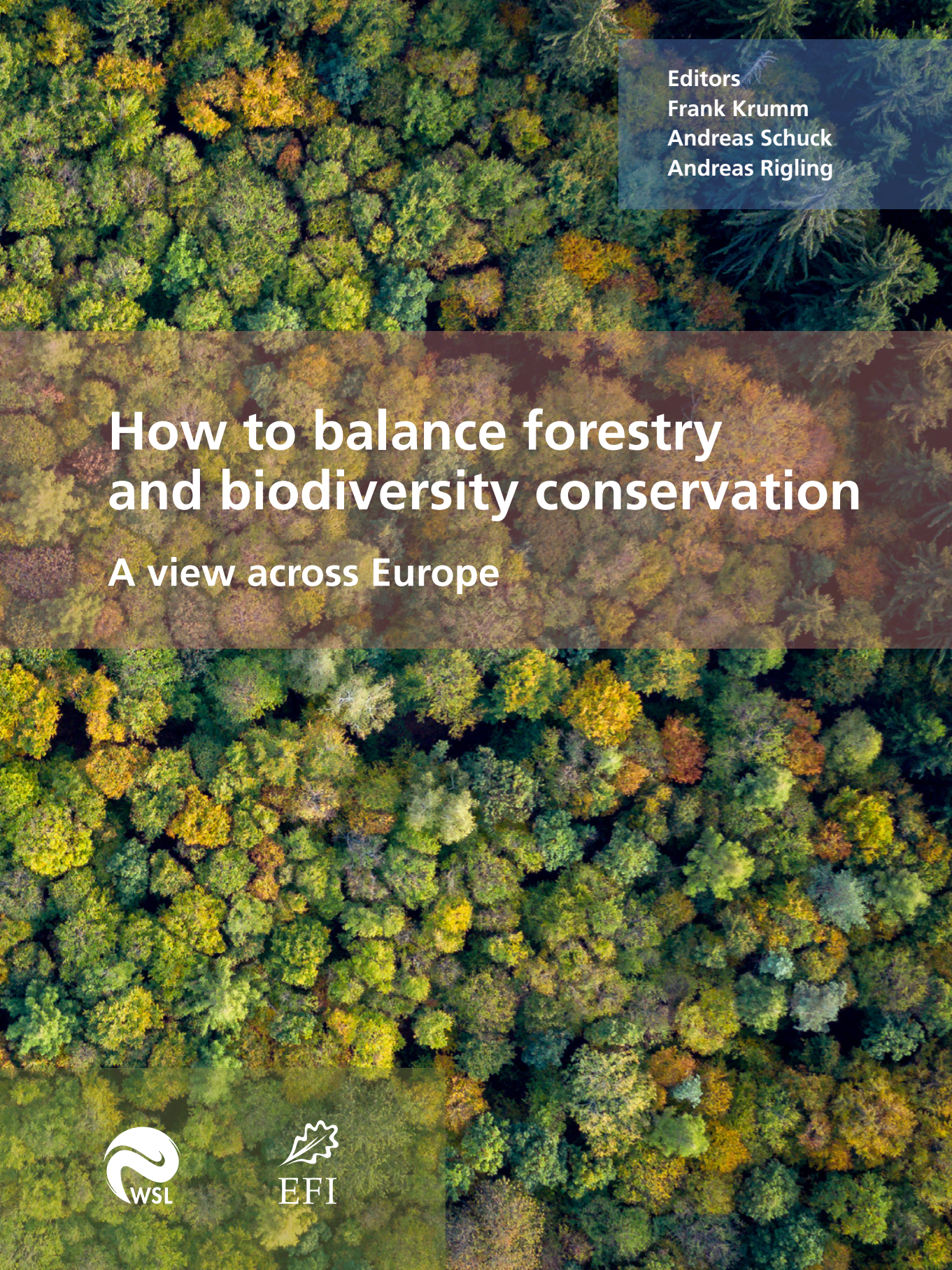

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How to balance forestry and biodiversity conservation

A view across Europe

WSL
EFI

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Foreword

How to balance forestry and biodiversity conservation – a view across Europe

Maintaining and enhancing the biodiversity and resilience of European forests is key to the sustainable provision of ecosystem services in a rapidly changing environment. More than ever, to do so requires an informed, fluent, and effective dialogue between scientists, policy makers, forest landowners, forest managers, and nature conservationists. The European Network INTEGRATE aims, on the basis of science and forestry, to provide a forum for such dialogue to further enhance the protection of forest-related biodiversity in the framework of sustainable forest management. This is timely and relevant for the ongoing international forest-related discussions, e.g. the post-2020 Biodiversity Framework of the Convention on Biological Diversity (CBD), and in the European Union for the EU Green Deal, and the EU Biodiversity and EU Forest Strategies. This publication, produced within the framework of the European Network Integrate, has been written by more than 150 researchers and practitioners from 50 institutions and 19 countries. It explores and describes different approaches and tools for the integration of nature conservation into forest management. In the first section, the theoretical framing, the past and current context and framework conditions, and future challenges and solutions for integrated forest management are broadly discussed in 12 chapters. The second part of the book highlights 32 selected examples of forest enterprises, forest owners and regional initiatives from all over Europe. This Tour d'Europe presents an amazing variety of innovative regional- to local-scale approaches of how to balance biodiversity conservation with other ecosystem services in sustainable forest management. The last section of the book presents a toolbox of integrative measures derived from the examples; local forest owners and managers can use this toolbox to get an overview of measures that have been successfully applied.

One objective of this book is to be a directory of innovative, adapted, and applied management options for professionals working in forestry and nature conservation. Other objectives are to inform interested actors about policies related to forests and nature conservation, and to inform the interested public that both timber production as well as nature conservation can be compatible and need not be treated as mutually exclusive if the forests are appropriately managed. Establishing forest reserves without human interventions remains important for nature conservation; however, the book shows that well-targeted measures in the framework of sustainable forest management can be an effective and efficient way to enhance the biodiversity value of managed forests. This is an important contribution to safeguarding biodiversity for coming generations while at the same time ensuring the global and local provision of

other important forest ecosystems services (e.g. carbon sequestration, renewable wood products, clean ground and drinking water, health and recreation, from erosion and natural hazards). With the increasingly visible impact of climate change the need to ensure the adaptation and resilience of our forests to deliver all these services will continue to increase in importance.

This publication is a valuable document for all experts working in the field of forestry and nature conservation. We hope that you find the content interesting and informative, and that the practical solutions described are a source of inspiration and support.

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Fig. A 1. Flowering cherry tree in a large-scale uniform Scots pine plantation (Photo: Andreas Rigling).

Context and solutions for integrating nature conservation into forest management: an overview

A

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As the human population grows, demands for ecosystem services in general, and thus also for forest goods and services (fig. A 2) are increasing (MEA 2005). The growing population needs forests to: provide clean drinking water, recreational opportunities, protection against natural hazards and soil erosion, moderate the climate at local level, and mitigate climate change by storing CO_2 (Renaud *et al.* 2011; Zellweger *et al.* 2020; Canadell and Raupach 2008; FAO 2020). Managed and unmanaged forests provide these services to a different extent, but some services can only be provided in the required quality and quantity by targeted management. The rise in demand for forest goods and services, but also for agricultural land and resources on a global scale has exacerbated the current global biodiversity crisis (Díaz *et al.* 2019) since forests are of paramount importance as biodiversity hot-spots (Zisenis *et al.* 2010). As not all goods and services can be provisioned simultaneously from the same area, decisions about targeted services need to be made, ideally taking advantage of synergies to optimise the provision. In a globalised world, however, taking such decisions in one region almost

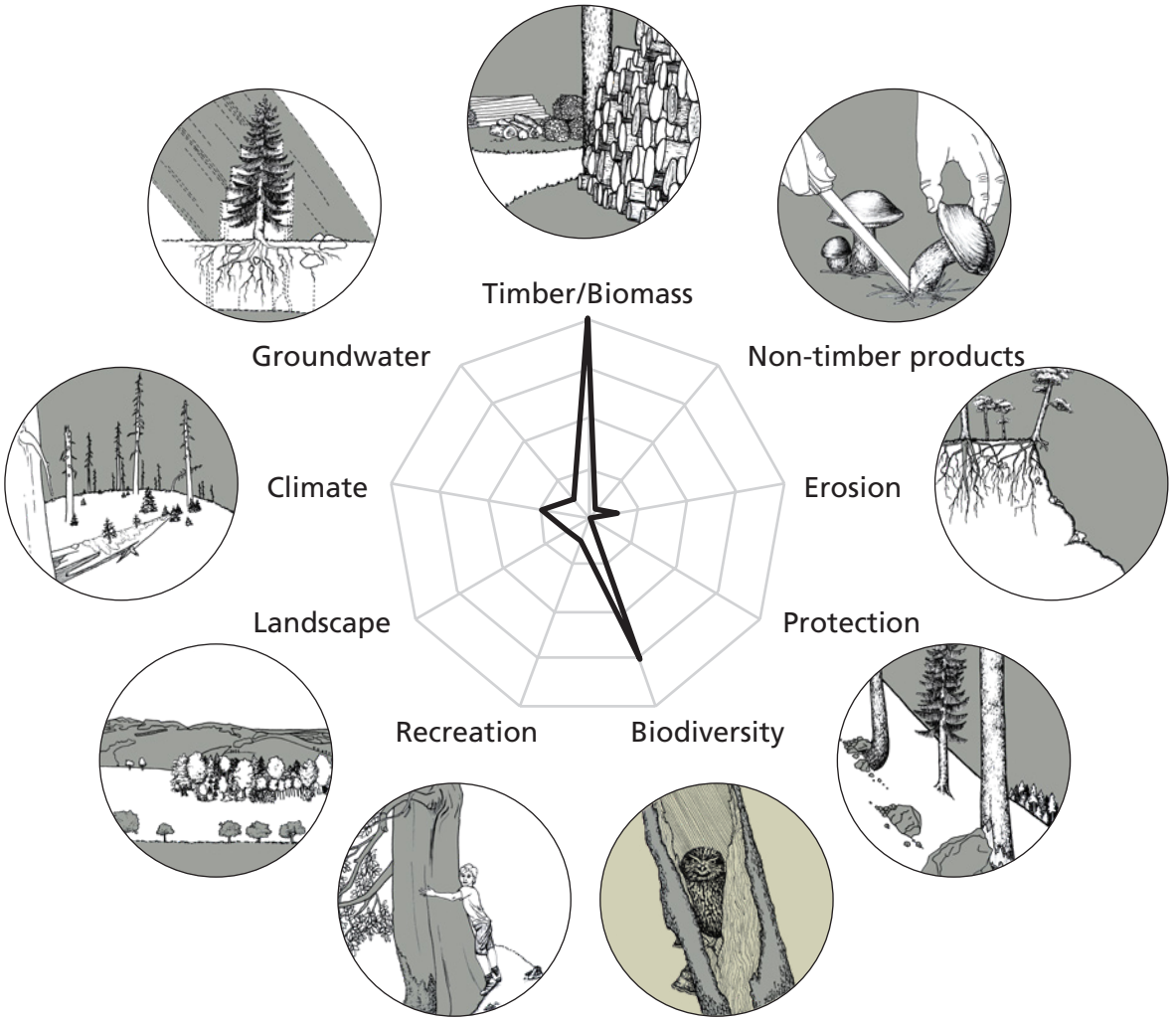


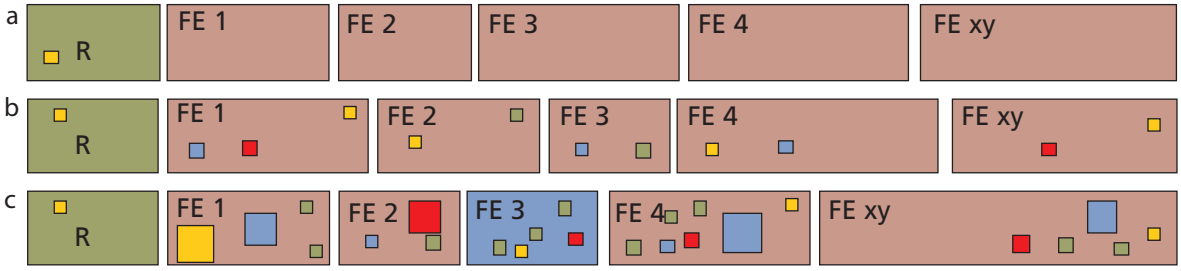
Fig. A 2. Ecosystem goods and services (adapted from MEA 2005) delivered by forests as the basis of a holistic view on forest management. The spider-graph indicates the weighting of the individual goods and services in respect to their importance, financial resources invested, or work power applied in a forest enterprise. This graph will be applied to all practice examples presented in the third part of this book in the Chapters C 1–C 32 (Illustrations by Vivanne Dubach).

always affects forests in other regions. Moreover, most people do not experience the consequences of their choices for particular forest products directly and they also have little knowledge about the underlying production processes and their consequences for the environment and humankind. Finally, governance failures and the prevalence of short-term economic gains increase the already high pressure on forests. Attempts to remediate this situation include valuable international efforts to secure higher production standards by developing certification schemes (e.g. Auld *et al.* 2008) and further agreements between local population, national governments, and trade organisations (e.g. REDD+, https://redd.unfccc.int).

One strategy to maximise the effectivity in providing different products and services is 'spatial segregation' (fig. A 3). This strategy has been applied, for example, to mitigate the conflicts between agriculture and forestry in central Europe (Suda and Pukall 2014). Industrial plantations are usually given as examples of segregation (Bemmann *et al.* 2008); however, the concept may also encompass relatively uniform and highly productive stands of managed forests that are nonetheless based on natural regeneration and allow the appearance of additional species (Borchers 2010). The creation of strictly protected areas for conservation and enhancement of biodiversity also follows a segregative approach. However, as the future demand for wood for industrial and fuel purposes is increasing or at least sustained (Sloan and Sayer 2015; Bais *et al.* 2015), and the demand for non-timber forest services and products (including biodiversity conservation) is also increasing (Sheppard *et al.* 2020), resolving resource use conflicts by withdrawing large forest areas from production of such goods would further aggravate the pressure on the remaining natural forests worldwide.

An alternative pathway to the segregation approach is to deliver multiple ecosystem goods and services simultaneously on the same forest area, applying 'multiple service forestry' (Wagner *et al.* 2013; Gómez-Bagghetun *et al.* 2010) (fig. A 3). A third possibility is a combination of both concepts, the 'integrative forest management' (Kraus and Krumm 2013; Sotirov and Aerts 2018), which strives to fulfil multiple objectives at different spatial scales (from the single tree, to the cohort, to the stand, and up to the landscape levels). In this approach, forests are dynamically managed with different time horizons including temporary or unlimited protection of single trees or entire forest areas (Box A 1 and fig. A 3).

What integrative forest management means and how it can be achieved in practice is the topic



FE: Independent forest enterprise with different priority services

a Full segregation between forest reserves and wood production (e.g. plantation forestry).

b Full segregation between forest reserves and wood production, with forest managementautomatical and random delivery of additional services ('wake water' forest management)

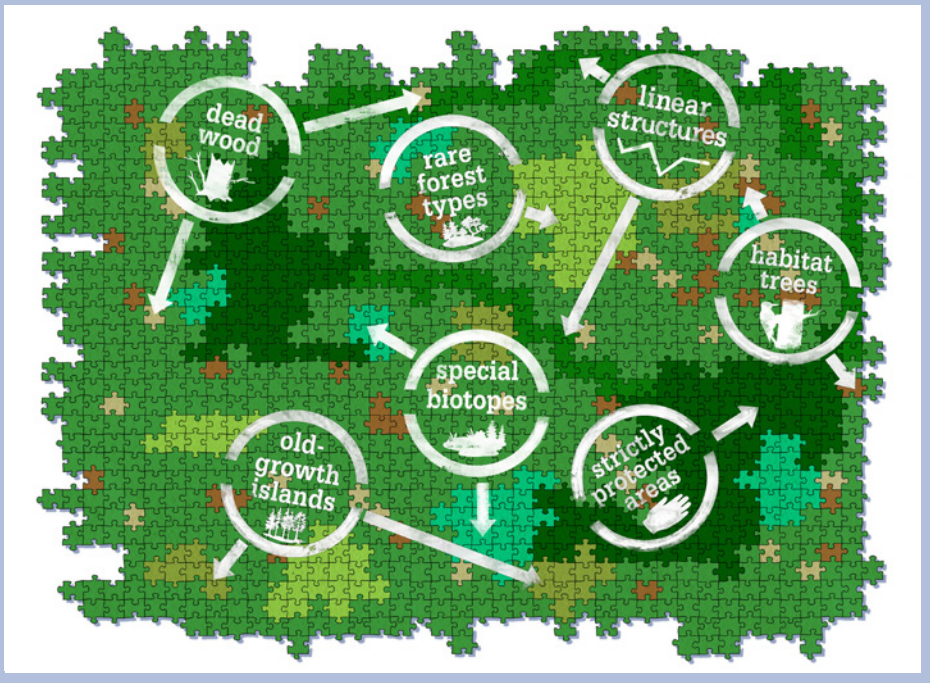
c Segregation between forest reserves and wood production, but with targeted promotion of different forest goods and services, incl. selected biodiversity measures (multi-service forestry).

Fig. A 3. Schematic presentation of fully segregative and multi-service forestry (Bollmann and Braunisch 2013, adapted). According to Kraus and Krumm (2013) integrative forest management can be seen as dual concept of segregative and multipurpose management elements.

Box A 1. Definition of integrated forest management.

Integrated forest management

According to Kraus and Krumm (2013), integrated forest management is an approach which aims at the sustainable delivery of multiple forest goods and services from the same area but at different spatial scales (from the single tree (fig. A 4), to the cohort, to the stand, and up to the landscape levels). The measures have different time horizons including temporary or unlimited protection of single trees or entire forest areas. Hence, it can be seen as a dual strategy including both, integrative and segregative management approaches (Bollmann and Braunisch 2013) aiming at preservation of forest biota in forest landscapes representative of the different development stages of a forest (Kraus and Krumm 2013).



Integration of different ecosystem goods and services depends on the spatial scale. The main focus in this book will be on the management unit – in this book mainly the forest enterprise level – where forest planning gets traction and leaves impact on the ground. Additional aspects of higher and lower levels, which are important for the enterprise level, are elaborated and discussed.

Integrative forest management aims to maximise the synergies between the main goals of forestry: production, protection, and conservation. Referring to the definition of the Millennium Ecosystem Assessment (MEA 2005), we distinguish between production of timber and non-timber forest products, protection against natural hazards and climate disturbances, protection of soil as well as groundwater and drinking water, and conservation of landscape aesthetics and recreation. Although biodiversity can be seen as a fundamental concept and base for all ecosystem services (MEA 2005), it is added and treated in this book as an additional ecosystem service (fig. A 2).

of this book. It focuses on European forests, which are mostly part of old cultural landscapes with legacy effects of a long history of human use and cultivation for several thousands of years. Moreover, European forests are part of landscapes characterised by high (although variable) densities of population and infrastructure, limited space, and high fragmentation. As a result of past management, primary forests have almost completely disappeared and near-natural ecosystems have become rare in several parts of Europe (Sabatini *et al.* 2018; Sabatini *et al.* 2020). Protected areas (e.g. national parks and other forest ecosystems with high conservation value) are often of relatively small size (less than 250 km²). As a consequence, processes of natural forest dynamics are limited and some habitats present in primary forests should be maintained also in managed forests by integrated forest management (Bütler *et al.* 2013; Lachat *et al.* 2013; Ranius and Jonsson 2007; Gossner *et al.* 2013).

With the shift in focus of forest management from mainly timber to a wide array of forest goods and services, integrative approaches have undergone important changes. Fifty years ago, the so-called 'wake-water theory' ('Kielwasser-Theorie') (Rupf 1960) (fig. A 3) postulated, mainly in the German speaking countries, that managing for timber would automatically ensure delivery of all other forest goods and services, in particular since management often integrated natural processes and conservation aspects in 'close-to-nature silviculture' (Schütz 1999; Brang *et al.* 2014). While this approach seems suitable for the integration of some ecosystem services, e.g. the protection against natural hazards (Brang *et al.* 2006), it sometimes fails in conserving important facets of biodiversity, such as deadwood (fig. A 5), old habitat trees (fig. A 4), or rare non-profitable tree species (Bauhus *et al.* 2013). The close-to-nature silviculture concept is very general and is often loosely defined. Hence, the quality of its implementation strongly depends on attitudes and education of local forest managers. Consequently, a broad variety of interpretations has led to manifold applications considering specific ecological and socio-economic properties. Schall *et al.* (2020) nicely show that the diversity of management approaches on small scales might promote biodiversity conservation in beech forest landscapes.

Nevertheless, in some European regions, because of the widely implemented close-to-nature silviculture, forests can still be seen, relative to the often negative developments in agriculture, as near-natural habitats with a relatively rich community of forest species. In other regions of Europe, however, industrial plantation forestry, partly on former agricultural land, has resulted in monospecific and even-aged forests with poor biodiversity. Especially in Europe and North America, the public attitude towards forestry has drastically changed since the 1980s as a consequence of a growing understanding about the importance of forest biodiversity, and also an increasing urbanisation of society (Puettmann *et al.* 2009). Forests and forest biodiversity have been specifically acknowledged by the UN Convention on Biological Diversity (CBD), particularly at the CBD's tenth Conference of Parties (COP 10) with the adoption of the Aichi Biodiversity Targets (CBD 2010). Hence, there is growing political agreement not only about the need to contain the loss of biodiversity in forests but also about the need to actively increase and promote forest biodiversity.

While species richness and diversity have gained in importance, it is increasingly acknowledged that biodiversity goals cannot be stable over time and vary from place to place. They are influenced by the history of a particular forest, by its site conditions, and by the societal values with respect to different facets of forest biodiversity. At time-scales of decades to hundreds of years, forest biodiversity must be viewed as a shifting target driven by changes in societal values.

On top of this, climate change is expected to result in significant altitudinal and latitudinal shifts of vegetation zones (e.g. Hanewinkel *et al.* 2013; Zimmermann *et al.* 2016; Frehner et al 2018), entailing range shifts of associated species which might disappear in certain areas and invade new ecotones. The frequency and severity of extreme climatic events, like the hot and dry spells 2003, 2015, 2018, 2019, and 2020 in central Europe, and related disturbances (e.g. bark beetles) will shape these range shifts and thus future forest condition (Schuldt *et al.* 2020), and are likely to lead to temporary or permanent loss of specific forest habitats. With a view to biodiversity conservation, these dynamics and the associated large uncertainties may be buffered best by fostering diversity to create resilient forest ecosystems. Integrated forest management is fully compatible with this strategy.

Hence, locating the conflict between forest management and nature conservation has become

Fig. A 4. Methuselah oak tree in the midst of a Scots pine plantation, near Eberswalde, Germany. Preserving single trees rich in micro-habitats is one effective measure to improve biodiversity (Photo: Andreas Rigling).

more challenging with the increasing number of demands placed on forest management and the growing uncertainties caused by climate change. Although conflicts of interest between wood production and biodiversity conservation may still constitute a main conflict, additional potential contradictions between biodiversity conservation and other ecosystem services have emerged (Fabian *et al.* 2019). Climate change may mean that the nature of the conflict may shift towards a competition between adaptation strategies (e.g. Winkel 2013).

This book has a special focus on forest management approaches that aim to improve the integration of biodiversity conservation while simultaneously promoting different forest ecosystem goods and services in a changing environment. The resulting conflicts and synergies will highly depend on the context of the ultimate decision-maker, the forest enterprise. Questions about *What type of biodiversity is aspired to? and Which forest management traditions and what types of forest owner structures can be built upon?* will affect the nature of the conflicts, but also potential synergies. Comprehensive identification of these frame conditions is crucial for developing optimised solutions tailored to the specific setting of a forest enterprise.

The conceptual foundations and boundary conditions of integrated forest management

The second part of this book (Chapters B 1–B 12) provides the conceptual foundations for the various dimensions and frame conditions of integrated forest management. This theoretical framing describes the contexts and prevailing trade-offs of the examples from practice that have been assembled in the third part of the book (Chapters C 1–C 32) as well as the solutions suggested. To begin with, a unifying theoretical framework for integrative forest management at the landscape level is introduced (Chapter B 1; Bollmann *et al.*). Deciding about how to best integrate biodiversity conservation into the provision of other forest goods and services requires knowledge about how, where, and to what degree forest management practices can be adapted to contribute to biodiversity objectives without impair-

Fig. A 5. Deadwood is another important component of biodiversity conservation in forests. Consistent availability in sufficient quantity and different qualities (tree species, dimension, decay stage) is vitally important (Photo: Andreas Rigling).

ing the provision of competing ecosystem services, or perhaps even exploiting potential synergies. To this end, the main approaches and instruments of forest biodiversity conservation are reviewed and their potential and limitation to conserve and restore native biodiversity are discussed.

To understand the current situation in European forests, it is important to realise how forest management and biodiversity have developed historically, bridging forest history with cultural heritage (Chapter B 2; Bürgi *et al.*). Based on six case studies the potential of local forests for an integrated provision of ecosystem services is discussed in a broader European context. Two specific challenges are postulated for the future: (1) on the one hand, in order to preserve the biological and cultural heritage of our European forests, it is vital to understand its value; and (2) on the other hand, historical management practices are often useful as an inspiration for future integrated forest management systems. Addressing these two challenges will contribute to better adapt forest management to future challenges and changing demands in forest goods and services, including biodiversity conservation.

This leads to further important framework conditions of Europe that are characteristic of its heterogeneous landscape: the highly diverse policy and legal framework relevant for the integration of production and conservation in European forests (Chapter B 3; Sotirov *et al.*). Rules and implementation structures for biodiversity conservation through integrative forest management had evolved within very different national and even regional contexts. While the nature conservation directives of the EU have improved the coordination between forest and nature conservation policies at the national level, the local implementation of these directives has also benefitted from a further development of the rules to promote forest biodiversity. Which forest biodiversity rules are introduced and how they are being implemented, however, is contingent on the forest ownership structure, the socio-economic and policy priorities of the forest sector, but also to some extent on how competences are distributed across levels of government. Although improving the integration of biodiversity conservation into forest management can receive impulses and framing from national or

Fig. A 6. Small, structured forest landscape influenced by topography and ownership structures (Photo: Andreas Rigling).

continental levels, it nonetheless requires regional rooting.

Ownership structures are significant for forest management (fig. A 6). Biodiversity promotion measures are compared across four countries (Sweden, Austria, Germany, and Switzerland) (Chapter C 4; Wilkes-Allemann and Lieberherr). While some private or public forest owners hold more than 1000 ha, or sometimes even 100 000 ha, of forest land, millions of private persons own areas smaller than one hectare. On the one hand, this large diversity in ownership complicates forest legislation and its implementation (Chapter A 3; Sotirov *et al.*); on the other hand, it has triggered the development of a great variety of forest management types that have contributed to the diverse European forest landscape (Chapter C 2; Bürgi *et al.*). The main drivers of changing ownership structures are privatisation and restitution (e.g. Germany and Sweden) and changing lifestyles of forest owners (e.g. Austria, Germany, Sweden, and Switzerland). Because of urbanisation, small inherited forest patches are financially irrelevant (or even a burden) for many forest owners and often their interest and know-how in traditional timber production is fading away. While these changes imply a need for revisions to forest management approaches and policy instruments supporting forest owners in managing their forests, it can also be

Fig. A 7. Promoting the bioeconomy includes the intensified use of the renewable, but limited wood resource produced by integrated and sustainable forest management (Photo: Andreas Rigling).

seen as an opportunity for innovation creating a diverse pool of interests, ideas, and management preferences promoting a diversity of approaches.

In the transition from a fossil-based to a bio-based economy, the forest and wood sectors play a crucial role (fig. A 7), given their substantial climate mitigation potential through carbon sequestration and substitution of fossil energy intensive materials. The objective must be to use the renewable, but limited wood resource efficiently and sustainably. Part of the solution can be to integrate the concepts of circular economy and cascading resource use into the bioeconomy concept (Chapter B 5; Weber-Blaschke and Muys), respecting the ecological, economic, and social impacts of wood and other ecosystem services over the full life cycle. Hence, the development of a sustainable wood-based bioeconomy will have considerable impacts on forest management because of the increased demand for wood supply, and in turn this will have implications for all ecosystem services including biodiversity. The promotion of particular elements (e.g. deadwood, fig. A 5) and the shift to more broadleaved forests has had a dramatic impact on the wood-processing industries as they are widely set up for the processing of coniferous wood. These industries will have to adapt to a different variety of wood assortments.

As long as human activities and infrastructure used by residents and tourists are still increasing, the demand for protection from natural hazards by current protection forests will also increase (fig. A 8). In Switzerland, for example, at least 50 % of the forest area are designated as protection forest (BAFU 2013), which is considered to be the most cost-effective insurance against natural hazards. Maintaining the protective effect of the forest by fostering the capacity of these ecosystems to absorb disturbances and increase its resilience is a particular challenge given the changing climate. Maintaining the resilience of such ecosystems requires promotion of a diversity of structures and species; this can be seen as a kind of natural insurance, and thus as generating additional economic value (Chapter B 6; Antkowiak *et al.*). Even protection forests that are privately owned provide public goods, as the local residents and tourists are the largest group of beneficiaries. Although a more proactive management for forest resilience can be profitable in some areas, structural misalignments between ownership, decision-making, and actual consumption of ecosystem services lead to a low willingness to pay for natural insurance services. Hence, integrated forest management might help to promote diverse and resilient forests serving all targeted goods and services.

Fig. A 8. In mountain areas forests protect people and infrastructure from natural hazards. Maintaining the resilience of such forests suggests promoting a diversity of structures and species; this has an indirect economic value. If these forests cannot anymore provide sufficient protection, costly technical constructions must be installed (Photo: Ulrich Wasem).

The relation between forestry and hunting has become very direct with mutual impact in the past decades. Past hunting practices have strongly influenced the distribution and abundance of predators such as lynx *(Lynx lynx)* or wolves *(Canis lupus),* but also of ungulates such as roe deer *(Capreolus capreolus)* (fig. A 9), red deer *(Cervus elaphus),* and moose *(Alces alces)* in European forests. These changes in species composition, abundance, and trophic relationships have influenced forest dynamic processes in the last centuries, and therefore also forest biodiversity (Gill 1992a and 1992b). Conversely, forest management may have a fundamental impact on forest flora and fauna, including ungulate populations, although these are, of course, strongly influenced by hunting activities. These interactions can result in conflicting interests that are particularly difficult to reconcile as the causes can be manifold, and there may be economic dependencies for both hunting and forestry, and sometimes deep-rooted beliefs and long-standing

Fig. A 9. Integrated wildlife management should involve all stakeholder groups across the sectors and should not stop at the edge of the forest areas (Photo: Ulrich Wasem).

traditions prevent compromise. Hunters exert strong influence on forest management approaches, which is often addressed in hunting regimes. Nowadays, nature conservation comes into play as a third interest group since forest biodiversity is influenced by both forest management and hunting (see also Chapter B 10; Höltermann). Hence integrated wildlife management, respecting and involving all stakeholder groups, is urgently needed to reduce conflicting management goals and to promote the various forest goods and services for the future (Chapter B 7; Ehrhardt *et al.*), including biodiversity promotion.

There are many reasons why biodiversity is important, and for many people this is simply a question of ethics. From a natural science perspective, adaptive capacity for environmental changes depends on diversity. As human influences – i.e. introduced species, land-use changes, or climatic changes – induce manifold structural changes in forests, it is crucial to maintain or increase the capacity of forests to adapt to changes in order to keep them and neighbouring production systems vital and productive. The pool for adaptation depends on diversity, which is probably the most important argument for the maintenance and fostering of biodiversity. However, which type of biodiversity should be aspired to and what might be the appropriate nature conservation measures are still debated between nature conservationists and foresters. Disagreement remains with respect to the reference point for biodiversity: Is it the maximum degree of biodiversity reached under historical management regimes, or is it the amount of biodiversity provided by the primary forests of the past? Which past – 100, 1800, or 5000 years ago? In Chapter B 8, (Gossner and Wohlgemuth), two trajectories of nature conservation are discussed: (1) To protect a multitude of species by research-based evidence on optimum habitat requirements – for this purpose, the number of species, the number of ecosystem services, and even productivity at a larger spatial scale considering trade-offs in multipurpose forest management must be optimised; or (2) Natural processes can be well protected in unmanaged areas, and in particular in large unmanaged areas, where many disturbances can take place stochastically and create diverse habitats –

Fig. A 10. Large-scale calamities by the spruce bark beetle are a natural process which creates habitat for specialised species and deserves protection. It can be starting point and accelerator to increase biodiversity (e.g. Bavarian Forest National Park) (Photo: Ulrich Wasem).

this approach does not address the controlling ecosystem states, but may, in contrast, provide reference for mimicking natural dynamics in managed ecosystems and serve as a source as well as a refuge for populations of highly demanding species.

In the past one to two centuries, European forestry has invested much in overcoming large-scale deforestation and forest degradation. Today the main challenges are the economic difficulties of forest owners, the restoration of lost biodiversity, and the maintenance of multiple forest goods and services under uncertain impacts of climate change. As our traditional forest management is increasingly challenged by unprecedented and more frequent abiotic and biotic extreme events (fig. A 10, 11) alternative concepts are needed. In this respect, the resilience concept can be seen as a possibility to support forest management to better cope with these challenges (Chapter B 9; Lindner *et al.*). One important aspect would be an indicator-based resilience assessment for monitoring changes of forest vulnerability and resilience as a basis for developing risk management strategies. This would be a crucial instrument to safeguard future forest goods

Fig. A 11. Spruce bark beetle infestations are often managed by large-scale salvage harvesting with direct impacts on the wood markets, and also biodiversity. Disturbances can have dramatic economic consequences for forest owners, but they also create opportunities to adapt and steer forest composition to increase resilience to a changing climate. Photo taken in Austria, near Retz in 2019 (Photo: Andreas Rigling).

and services, including the conservation of biodiversity, in times of changing societal demands and climate change.

Besides the various boundary conditions for integrating biodiversity conservation into forest management, the second part of the book also provides visions for integrative forest management developed from the perspective of nature conservation administrations at the national level for Germany (German Federal Agency for Nature Conservation (BfN), Chapter B 10; Höltermann) and Switzerland (Federal Office for the Environment, FOEN, Chapter B 11; de Sassi *et al.*). BfN and FOEN agree on several key points in their long-term visions: the main challenge for the future is identified as preserving and developing resilient forests and forest landscapes to ensure the continued provision of different production, protection, and conservation ecosystem services (MEA 2005) under the conditions of climate change. Structurally rich forests composed of multiple species are more resilient in the face of climate change and deliver multiple ecosystem services that are important for humans. Hence, future forests should: (1) be rich in species composition and genetic diversity, (2) regenerate naturally, and (3) provide suitable habitat for a regionally representative forest fauna and flora. To support this vision a combination of integrative and segregative measures are needed to maintain biodiversity in forests, and to enhance it where deficits are identified. For effective guidance in policy and management, forest monitoring should include associated quantitative and qualitative indicators on biodiversity; these should also address the dynamics of biodiversity targets because of the growing impact of climate change. This will complement more production-oriented parameters in current forest monitoring and result in a holistic assessment of forest condition.

The German Federal Ministry for Food and Agriculture (BMEL), the ministry responsible for the German forests, underlines the necessity of further enhancing forest biodiversity but also puts emphasis on harvesting timber as a renewable and sus-

Fig. A 12. According to nature conservationists, future forests should be near natural with respect to species composition and genetic diversity, and they should regenerate naturally and provide suitable habitat for the full spectrum of forest fauna and flora (Photo: Andreas Rigling).

tainable resource as a key task for future forest management (Box B 1). One important measure is practice-oriented and science-based knowledge sharing under the European Network Integrate (https://integratenetwork.org), as an active contribution to implementing the Forest Strategy of the European Union by further enhancing nature protection within sustainable forest management.

The effects of forest management on biodiversity are increasingly well studied but less is known about the motivations and possibilities of foresters and forest owners to use integrated management in their forests (Chapter B 12; Derks *et al.*). In the frame of the project InForMar (https://integratenetwork.org), 42 forest managers and national experts in conservation and forest management from nine European countries were interviewed using in-depth interview guidelines and standardised questionnaires. Measures to increase forest resilience can be similar to nature conservation actions since they often focus on promoting diversity. Hence, in many cases integrated forest management is able to bridge biodiversity conservation and other forest goods and services in a changing climate when considering regional and local contexts.

Integrated forest management at the enterprise level – success stories

The main motivation for this book is to demonstrate that, beside forest planning at a superordinate level, integrated forest management approaches applied at the enterprise level can successfully contribute to balancing the trade-offs between forest utilisation and conservation while considering highly varying local contexts. Integrated forest management needs to be developed at the enterprise level where adequate and pragmatic solutions beneficial for nature conservation and other important forest goods and services can be identified and implemented. The third part of this book showcases 32 practice examples of forest enterprises, forest owners, and regional initiatives, which were successful in developing locally adapted management concepts (Chapters C 1–C 32). These examples will take the reader on a Tour d'Europe from Spain to Norway and from Ireland to Slovakia. The examples cover very different management foci and ownership. The 32 cases show how forest managers integrate diverse goods and services in innovative ways. Further, views beyond Europe and to specific aspects are presented in 20 short box contributions that highlight approaches, attitudes, and measures towards integrating different ecosystem services into forest management. The cases illustrate the breadth and the diversity of the topic. Discussions about the issues covered by the book are similar to discussions taking place in other regions of the world, and therefore we can learn from experiences elsewhere (Boxes C 8, C 11, C 12, C 14, C 19). Drawing from these case studies and box contributions, a toolbox of integrative measures is developed that is intended to support forest owners and managers to choose appropriate measures for targeted integrated management in their areas. This toolbox is presented in the synthesis chapter. The toolbox is evaluated and missing links and possible actions for future integrative forest management are discussed.

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Naturwald-
reservat
Naturschutzgebiet
Achtung
Gefahr durch
Totholz und
trockene Äste

A unifying framework for the conservation of biodiversity in multi-functional European forests

B 1

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The maintenance and conservation of forest biodiversity has become a pivotal task of ecologically sustainable forest management. It depends on the appropriate management of forest composition and structure and the clever application of different, complementary instruments with respect to biodiversity and ecosystem functions. Most commonly, segregative approaches such as setting aside old-growth refuges, rare forest types, and biodiversity hotspots as protected areas are the preferred conservation instruments due to the high local impact and effectiveness. However, considering the high proportion of multi-functional forests in Europe, the conservation and restoration of forest biodiversity in managed forests make a crucial contribution to the persistence of viable populations of forest-dwelling species since the large majority of the forest area will continue to be managed for various ecosystem functions and services. Some of these services, like timber production, CO_2-sequestration, and recreation, can conflict with forest biodiversity conservation. Therefore, the integration of structural attributes such as old-growth stand relicts, patches of open and light forest, ecotones, disturbance gaps, habitat trees, and standing and downed deadwood into managed forests is essential for an ecological, multi-functional forest management. In this chapter, we review the main approaches and instruments of forest biodiversity conservation, discuss their potential and limitation, and analyse to what extent an integrative approach supports the conservation and restoration of native biota in multi-functional forest landscapes. This chapter presents a unifying conceptual framework for the application of a broad set of conservation instruments in an integrated forest management.

Introduction

The provisioning of multiple ecosystem functions and services such as timber production, protection against natural hazards, biodiversity conservation, water purification, CO_2 sequestration and recreation is the central objective of modern sustainable forestry (Chapin *et al.* 2009; Messier *et al.* 2014). Although the global community agrees on these general services (Isbell *et al.* 2017; IPBES 2019),

< Fig. B 1.1. "Nature forest reserve – nature conservation area – Attention! Danger from deadwood and dry branches". A variety of signposts indicate the trade-off when provisioning different forest goods and services in a Central European forest (Photo: Andreas Rigling).

multifunctional management involves trade-offs and there is a debate about the strength of each function and the appropriate methods for the provision of these services (Byrnes *et al.* 2014; van der Plas *et al.* 2017). Not least, timber production and biodiversity conservation shows some inevitable incompatibilities (Paillet *et al.* 2010; Bouget *et al.* 2012; Newbold *et al.* 2015; Nagel *et al.* 2017), for instance with regard to tree species composition, amounts of old-growth forests and natural deadwood, and structural stand heterogeneity related to natural disturbances. After a long period of deforestation in the Middle Ages in Western, Central and Eastern Europe (Bradshaw 2004; Bradshaw and Hannon, 2004; Pausas *et al.* 2008), forests were heavily exploited in the pre-industrial and early industrial periods (Kaplan *et al.* 2009) as a resource for timber, wood, fuel, charcoal, litter, fruits, seeds, fodder, and game, largely shaping the structure and composition of today's forest landscapes (Peterken 1996). As a consequence, pristine forests have become very rare and only 0.4–0.7 % of Europe's forest area is left to develop naturally (Parviainen 2005; Bücking 2007; Sabatini *et al.* 2018). By the end of the seventeenth century, the pressure on forest resources resulted in an increasing shortage of timber and a strong need for restoration of the protective function of forest to stop the progressive erosion of the soil, in particular in mountain regions. Therefore, governmental organisations restricted the exploitation of forest resources in Central Europe by new legislations and built up a state-regulated forestry in the eighteenth century. These new systems aimed for re-stocking the former forest area and to build-up sustainable timber resources. The frequently devastated and degraded forest landscapes resembled often open, park-like stands with few old relict trees (Kirby and Watkins 2015). Litter raking and other intensive biomass extraction additionally caused nutrient export from most forest soils.

The forest history in the boreal parts of Europe is slightly different. Here the large-scale use of forests commenced in the early nineteenth century as the forest resources in central Europe diminished and attention was turned to the large tracts of unexploited forests in the north. A timber frontier moved from southwestern Fennoscandia towards northeast and by the early decades of the twentieth century resulted in a significant reduction in standing timber volumes and stands with low growth rate (Kuuluvainen *et al.* 2012; Lundmark *et al.* 2013). Subsequently, forestry has been conducted in Fennoscandia, and since the last decades also in the Baltic, through more intensive clear-cutting forestry including harvesting, ditching, soil scarification, and commonly regeneration with trees from plant breeding programmes. Although highly successful in restoring timber volume and high growth rates, the resulting forests have lost significant aspects of the natural conditions present in the early nineteenth century (Kuuluvainen 2009).

In order to avert a shortage of wood in central Europe, from the middle of the nineteenth century onwards, the deforested areas were often re-stocked with Norway spruce or Scots pine in the frame of government programmes. These fast-growing tree species are better able to cope with the ecological conditions on clearcut areas than beech or fir, and rapidly restored overharvested areas. Accordingly, management concepts with a focus on productive and vital stands with regular high yields became widespread in Central Europe (Otto 1993). Depending on landscape properties and forest history, this has favoured two main forestry systems: (1) the clear-cutting or group shelterwood systems resulting in even-aged and mostly single-species stands which are widespread in large parts of Central-eastern and Northern Europe, and (2) irregular shelterwood and single tree/group selection systems (e.g. "Femelschlag" and "Plenterwald/Jardinage") resulting in uneven-aged or irregular, multi-species stands, typically found in mountainous regions in Switzerland, France, Germany, and Slovenia (Heyder 1986; Schütz 1993; Bauhus and Pyttel 2015). The latter group is often associated with close-to-nature forestry or continuous cover forest ("Dauerwald") management as the prevailing silvicultural philosophy.

Even though the two systems differ greatly in biological, ecological, and technical principles, both are directed to optimise regular timber yields of desired species in targeted dimensions (Jacobsen 2001). These diameters correspond to production cycles of about 80–140 years (oaks to 160–180 years) that deviate in many structural and compositional characteristics from natural forests as complex, multi-scaled hierarchical ecosystems with a succession cycle of several hundreds of years in temperate and boreal regions (Franklin *et al.* 2002; Puettmann

et al. 2009; Angelstam and Kuuluvainen 2004; Lilja *et al.* 2006). Uneven-aged as well as even-aged management with regular harvesting interventions impedes the development of characteristic structures of mature natural forests (Franklin *et al.* 1981; Kuuluvainen 2002b) and excludes the species-rich, old-growth communities (Siitonen 2001; Honnay *et al.* 2004; Winter and Möller 2008; Palo *et al.* 2013). In addition, the early seral, pre-forest phase of succession is under-represented (Hilmers *et al.* 2018) because pre-regeneration and planting accelerate stand development and hamper the establishment of species-rich pioneer plant and animal communities (Swanson 2011; Winter *et al.* 2015). However, from the forest management perspective, concerns have also been raised about the future of monocultures because of their susceptibility to insect calamities, and about the sensitivity to natural disturbances of even-aged stands (Jactel *et al.* 2009; Seidl *et al.* 2011). Examples include the large storm events in the early and late 1990s in Central Europe and in 2005 in Scandinavia and the strong bark beetle outbreaks in both regions in recent years. Moreover, even-aged forests with little between-stand variability are expected to contribute less to multi-functionality than heterogeneous forests because their species communities are less diverse and show higher functional similarity (Blüthgen *et al.* 2016; van der Plas *et al.* 2017; Craven *et al.* 2018). However, recent work (Redon *et al.* 2014; Schall *et al.* 2017) has shown that gamma diversity of forest-dwelling species can be higher in landscapes comprised of combinations of even-aged stands at different development stages.

These findings in combination with a better understanding of the effects of forest management on biodiversity (Lindenmayer *et al.* 2006; Paillet *et al.* 2010; Newbold *et al.* 2015; Kaufmann *et al.* 2018) and ecosystem functions (Gamfeldt *et al.* 2013; van der Plas *et al.* 2016; Ratcliffe *et al.* 2017) caused a momentum for new, biodiversity-friendly and sustainable forest management practices in the last 10 to 20 years (Felton *et al.* 2010; Bollmann and Braunisch 2013; Fedrowitz *et al.* 2014; MacDicken *et al.* 2015). The new practices integrate the requests and needs of various stakeholders while at the same time considering the diversity and heterogeneity of mature stands with their structures, functions, and species. However, current policies for more 'bioeconomy' in the European Union (Winkel 2017) support an intensified use of renewable resources such as wood and wood residues from forests. This development can significantly impede the recent progress for more biodiversity-friendly, sustainable forestry systems if no accompanying measures are taken for the preservation of biodiversity as basis for forest goods and services (Bauhus *et al.* 2017).

Most initiatives for biodiversity-friendly forest management systems are based on the concept of graded forest-use intensities across the landscape (Bollmann and Braunisch 2013), or the concepts of land sharing and land sparing and their effectiveness for different forest functions (Edwards *et al.* 2014; Kremen 2015; Balmford *et al.* 2019). In general, there are three forest management approaches that combine these concepts in different ways and strive to supply the demand for timber and other forest products while minimising the negative impacts on forest biodiversity (Table B 1.1). The first and integrative approach supports the concept of multifunctional forest management by aiming at satisfying the environmental, social, and economic functions on the same forest land, often implying moderate timber yields (Lindenmayer *et al.* 2012). In the second and segregative approach, one part of the landscape is dedicated to high yield timber production, the other is free of harvesting and completely dedicated to conservation (Paquette and Messier 2010). The third approach, called TRIAD, divides the forest into three separate zones of complementary functions, namely intensive timber production (high yield), multiple use forestry (moderate yield), and biodiversity conservation (no yield) (Seymour and Hunter 1999). All three approaches have advantages and disadvantages and the usefulness and applicability of one or the other approach depends on the natural and cultural legacy of a forest landscape and national policy rules (Table B 1.1). While the TRIAD system has gained popularity in some areas of North America (Côté *et al.* 2010; Tittler *et al.* 2012), segregative approaches can be found in regions with subsistence agriculture, plantation or clearcut forestry (Scharlemann *et al.* 2010; Hansen *et al.* 2013; Keenan *et al.* 2015; Morales-Hidalgo *et al.* 2015). The integrative approach is traditionally considered in various selection harvest systems in old cultural, multifunctional landscapes with high ownership densities (Bauhus *et al.* 2013), such as Mediterranean, temperate, and montane Europe. In Central Europe, integrative approaches are cur-

rently largely directed towards retention of habitat trees and deadwood (Gustafsson *et al.* 2020a). Such measures are also essential in boreal north Europe as are leaving buffer zones along watercourses and around wetlands, and retention of forest patches (Gustafsson *et al.* 2020b), partly through the introduction of forest certification (Gustafsson *et al.* 2020a). In Europe, the share of forest area available for wood supply amounts to 79 % (Forest Europe 2015), 52 % is primarily designated for production (Köhl *et al.* 2015), and 9 % are classified as plantations. Europe's long history of deforestation and area-wide cultivation with multi-purpose forest systems such as wood pastures and coppice silviculture (Kirby and Watkins 2015), and the consequent shortage of pristine forests (Sabatini *et al.* 2018) as well as recent periods of intensive forest use with changing preferences for certain tree species (i.e. oak, spruce) may be the main reasons for the popularity of the integrative approach.

Forest biodiversity conservation: current practices and future requirements

Preserving habitats from human influence by separating natural forests and biodiversity hotspots from detrimental processes is the traditional conser-

Table B 1.1. Comparison of different management systems and their strengths, weaknesses, and appropriateness for forest biodiversity conservation.

	Integrative management system	Segregative management system	TRIAD-system
Strengths	An area-wide representation of minimal habitat quality for general forest biodiversity; regular distribution of key habitat features; gradual ecological differences between forests; often natural regeneration and self-thinning processes; flexibility to respond to unforeseen developments	Spatially explicit production and conservation zones; spatially concentrated harvesting activities within forest landscape; reduced extent of road system; supports natural processes in relatively large conservation zones	Clearly defined zonation system; superior ecosystem service per zone; concentrated harvesting activities within forest landscape; significant amounts of area are devoted to forest biodiversity; supports natural and dynamic forest development in a significant share of the landscape
Weaknesses	Multiple management directions per forest – can be ineffective and create conflicts between stakeholders; can impair the conservation of specialist forest species due to the rarity of old-growth forests; extended forest road system; regular management interventions; emphasis on managing small areas as multi-species, uneven-aged stands may lead to static forest landscapes; can discriminate light-demanding species	Patchy and often isolated distribution of forest biodiversity zones; mostly embedded in a matrix of production or non-forest; fixed spatio-temporal zoning with superior functions; sharp ecological differences between zones; regeneration in production zone through planting and sowing; can increase resource vulnerability to disturbance or pathogens in production zone	Requires relatively large and continuous forest landscapes with large properties; distinct habitat quality differences between zones; fixed spatio-temporal zoning; regeneration in production zone often through planting and sowing; partial isolation of biodiversity zones
Appropriateness	Regions with a long tradition of area-wide forest use and an extensive road network; regions with a patchy distribution of forest in an intensively used matrix and a clear under-representation of primeval forests; regions with high ownership density and stakeholder participation	Regions with a significant amount of remote, primeval and old-growth forests, and an above-average proportion of endemism; regions with distinct zones of production forestry; regions with low proportion of forest area under management plan and high demands for wood fuel	Regions with large forest landscapes, low human population densities and different development standards of the forest road network; allows addressing bioeconomic and conservation objectives in spatial explicit, neighbouring zones; need for large forest properties (public or companies) and limited stakeholder participation

vation approach and is still considered the "cornerstone" of national and regional conservation strategies (Margules and Pressey 2000; Gustafsson and Perhans 2010; Watson *et al.* 2014). Forest areas designated primarily for biodiversity conservation account for 13 % of the world's forest (FAO 2010), and 16 % (5 % in Europe, incl. Russian Fed.) are legally protected areas (Morales-Hidalgo *et al.* 2015). Some larger intact forest landscapes still occur in Europe, e.g. in the Carpathians, the Dianaric mountains, in the "green belts" along the Finnish–Russian border and on the eastern slopes of the Scandinavian Mountain range (Potapov *et al.* 2017; Sabatini *et al.* 2018, Jonsson *et al.* 2019). However, these remnants of pristine forests are exceptions and even a significantly enlarged reserve network is considered to be insufficient to preserve biodiversity (Bengtsson *et al.* 2003 ; Sabatini *et al.* 2020). The large majority of the forest area will continue to be used and an embedded network of a limited number of spatially segregated reserves is unlikely to support viable populations of all native, forest-dwelling species (Fahrig 2020). Therefore, many countries combine set-aside measures for the last remaining pieces of natural and old-growth forests (Parviainen *et al.* 2000; MCPFE 2003) with an integrative approach on the managed forest area. Such a dual approach corresponds to the Aichi targets #7 (reduce pressure on biodiversity by sustainable use) and #11 (improve status of biodiversity by safeguarding ecosystems) of the Convention on Biological Diversity (CBD 2011). There is a strong need for innovative systems dealing with the promotion of biodiversity in managed forests. Integrative measures strive to increase the structural diversity and resource availability by retaining and creating important, permanent or semi-permanent habitat elements such as habitat trees, deadwood and forest gaps at the single forest stand scale (Bauhus *et al.* 2009; Puettmann *et al.* 2009; Bollmann and Braunisch 2013; Emberger *et al.* 2013; Messier *et al.* 2014). Case studies on integrative management approaches have shown that restoration measures can significantly improve habitat quality and biodiversity at the stand and forest scale within a decade time period (e.g. Doerfler *et al.* 2017; Roth *et al.* 2019). Although there is still an ongoing debate regarding the appropriateness and effectiveness of integrative measures (e.g. Gustafsson *et al.* 2012), in particular the quantities and threshold needed for optimal conservation, it is unlikely that they will be enough to restore the integrity of European forest and biodiversity (e.g. Bollmann and Braunisch 2013). A structural retention approach in managed forests in combination with the currently small area share of forest reserves is unlikely to represent the entire spectrum of ecological conditions of natural forest ecosystems (Sabatini *et al.* 2020). Natural disturbance agents such as wind, fire, snow, and water are important ecological drivers of natural forests and have strongly influenced the co-evolution of forest biodiversity (Bengtsson *et al.* 2000; Franklin *et al.* 2002; Kuuluvainen 2002a). Wind, fire, and water create stands with large amounts of deadwood (i.e. resource pulse) and associated saproxylic species community (Seibold *et al.* 2016). These structurally heterogeneous stands provide favourable microclimatic conditions in their early seral stage for the natural establishment of a rich herb and shrub layer with the associated insect community (Winter *et al.* 2015). Hence, the integration of disturbed stands and early seral stages in forest and biodiversity management is an important element of future conservation strategies. The permanent or temporary delineation of disturbed areas as post-disturbance patches will support forest restructuring and adaptation processes and thereby complement traditional integrative conservation measures (Bollmann and Braunisch 2013). The integration of naturally disturbed stands in forest management will gain in importance under climate change conditions and offers the opportunity to adapt conservation objectives situationally and to accelerate adaptations. The post-disturbance patches should be segregated from management in the first phase of forest succession (15–25 years) and can be later integrated in the area-wide forest management. The combination of integrative and segeregative measures with disturbed forest patches for a pre-defined period in a forest enterprise results in mosaic-like forests with structurally rich stands in different successional stages (Krumm *et al.* 2013). This is considered favourable for biodiversity conservation as mosaic forest landscapes have been shown to support a high diversity of species and taxa at the regional scale (i.e. multi-taxa gamma-diversity; Schall *et al.* 2017; Fahrig *et al.* 2019).

In this book chapter, we present a conceptual framework and the instruments for the conservation of species-rich forest communities. We refer to ecological forest management that intends to keep forests within their natural range of composition, struc-

ture and function and hereby provides habitats for viable populations of native forest species. We briefly present the limiting factors with respect to maintaining viable populations and put a special emphasis on comparing the main instruments for the conservation of biodiversity in the frame of an ecologically sustainable forest management. Influenced by forest ownership, biophysical conditions and socio-economic demands, forest management can create structurally and compositionally heterogeneous forests that provide a multitude of niches for the conservation of forest-dwelling species from stand to landscape scales. We further stress that, although operational management mainly takes place within single stands, landscape structure, composition and connectivity must be included in strategic planning of prioritised conservation approaches to build functional green infrastructures (European Commission 2013).

Limiting factors to forest biodiversity

Forest ecosystems comprise thousands of interacting species that are affected by a variety of abiotic and biotic factors (Noss 1990; Landres *et al.* 1999). Typical forest-dwelling taxa such as fungi, lichens, beetles, and snails depend on long-term successional processes that are significantly influenced by the life-history of trees and the spatio-temporal dynamics of forest stands (Speight 1989; Siitonen and Saaristo 2000; Lassauce *et al.* 2011; Dymytrova *et al.* 2013). Large, senescent trees with their microhabitats and deadwood are characteristic of old-growth, primary forests, and are the main resources of saproxylic organisms that contribute about 20–30 % of forest species richness (Siitonen 2001; Larrieu *et al.* 2018; Stokland *et al.* 2012). Even-aged production stands with rotation cycles of about 80–140 years, as being common in several parts of Europe, are structurally homogeneous and differ considerably from natural forests. Only 0.7 % of European forests remain pristine – with key areas in Finland, Sweden, the Carpathians, and the Balkans (Sabatini *et al.* 2018). Hence, there is an urgent need to strictly protect the last remnants of pristine forests and segregate them from demands of other forest functions, a call clearly expressed in the recent EU Biodiversity strategy (European Commission 2020; Sabatini *et al.* 2020). These forests are characterised by habitat continuity, shaped by long-term successional processes, and modulated by periodic natural disturbances (White and Pickett 1985; Attiwill 1994; Korpel 1995). Large old-growth and pristine forests can contain structurally complex stands with notable amounts of deadwood and large giant trees with plenty of microhabitats, and thus, a high variety of saproxylic species (e.g. Stokland *et al.* 2012). In particular, "Urwald relict" species have been shown to be strongly dependent on habitat continuity (Martikainen *et al.* 2000; Müller *et al.* 2005; Moning *et al.* 2009; but see also Ohlson *et al.* 1997). Delineating formerly managed forests as forest reserves is a possibility to trigger natural processes and the development of old-growth characteristics within multi-purpose forest landscapes (Vandekerkhove *et al.* 2009; Motta *et al.* 2015; Paillet *et al.* 2015). In summary, native forest biodiversity depends on several factors that should be considered in conservation strategies for production forest landscapes: (a) structure, (b) resources, (c) composition, and (d) processes (Jonsson and Siitonen 2013). These factors vary with the tree, stand, forest, and landscape scales.

(a) **Structures:** forest structures like old trees, tree microhabitats, multi-layered stands, standing and lying deadwood, and pits and mounds are more abundant in long-term unmanaged forest (Winter *et al.* 2005; Larrieu *et al.* 2012) and have been shown to be positively related to saproxylic species richness (Angelstam *et al.* 2003; Jonsson *et al.* 2005; Lachat *et al.* 2012; see also Rolstad *et al.* 2004) but also to mammals and birds (Harmon *et al.* 1986; Angelstam *et al.* 2003; Nagel *et al.* 2017; Mikusiński *et al.* 2019).

(b) **Resources:** abiotic or biotic factors like water, light, nutrients, food, breeding sites, and their spatial abundance and distribution – that are related to area and connectivity – influence species communities of forest ecosystems. Shortage in any of these factors may negatively impact on species presence and abundance (Kimmins 2004).

(c) **Tree species composition:** trees, dead or alive, are the most abundant organisms regarding biomass and structure. Thus, the co-occurrence and trophic relationship between tree species and herbivores, granivores, and frugivores varies with tree species composition. Tree species richness and functional diversity have been shown to be key drivers of forest-associated biodiversity and trophic interactions at the

Fig. B 1.2. The restoration of former coppice with standard forests is an effective measure for the conservation of threatened, light-demanding forest species such as the scarce heath *(Coenonympha hero)* in this project area (Photo: Kurt Bollmann).

Table B 1.2. Important structural and compositional factors of high-diversity forest stands.

Site factors	Soil conditions and local climate are essential factors for plant and tree species composition
Light and microclimate	Large variation in light and temperature promotes diversity of herbs, forbs, shrubs, trees, and insects of forest stands
Stand structure	Large vertical and horizontal variation in stand structure creates many ecological niches and promotes species diversity
Old and dead trees of various decaying stages	Many species from the diverse groups of saproxylic insects, bryophytes, lichens, and fungi are habitat specific with regard to type of wood and decaying stage
Tree microhabitats	Coarsely fissured bark, branch and rot holes, fruit-bearing shrubs, lianas, and trees can serve as key structures which improve habitat quality for lichens, bats, small mammals, and insects
Continuity and maturity	The continuous development and the maturity of a forest ecosystem often increase ecological niches and the complexity of food-networks. Some fungi are dependent on late decaying stages of deadwood, others on years of undisturbed litter for the development of their mycelia
Disturbances	Disturbances such as browsing, pathogens, windthrows, wildfire and snow breaks increase the number of dead trees and usually creates gaps and other irregularities, and hereby promotes early-successional species, some of which may be uncommon
Early successional habitats	Early successional habitats originating from clearings and natural disturbances are rich in pioneer and light-demanding species, but underrepresented in many forestry systems due to planting and salvage logging activities
Edgeline effects	Transition zones between clearings and natural gaps (e.g. disturbance gaps, mires) and closed forests create an edgeline effect with highly different temperature and light conditions at small scales. Such ecotones have often a positive effect on species diversity, but can threaten typical forest species through competition by open habitat or edge species in fragmented forest landscapes
Mosaic of different vegetation types	Spatial heterogeneity in vegetation types (patchiness) increases the diversity of ecological niches for forest dwelling species. The asynchronous development of such patches creates a successional mosaic cycle
Size and connectivity of habitats	Size and degree of spatial isolation of forest stands (fragmentation) affect the probability of local extinctions and recolonisation of species

stand level (Ampoorter *et al.* 2020; Staab *et al.* 2015). Some tree species like oak (*Quercus* spp.), hornbeam (*Carpinus* spp.), and poplar/aspen (*Populus* spp.) are known to provide habitat for several hundreds of forest organisms (e.g. Kennedy and Southwood 1984).

(d) **Processes and disturbances:** two types of processes are crucial in forests; disturbance and succession (Holling 1987; Mori 2011). They are closely linked and influence the availability and quality of habitat resources and their spatio-temporal occurrence (Kuuluvainen 2002b). They support a mosaic-cyclic-succession (Bengtsson *et al.* 2000) and are increasingly considered as being important for natural adaptation and transition processes under climate change (Dietz *et al.* 2020; Millar *et al.* 2007).

Factors that increase the structural and compositional heterogeneity of forests stands are an important pre-requisite for high diversity in forest landscapes. They include abiotic site factors, the occurrence of old and decaying trees, microhabitat structures, the abundance and distribution of disturbances and ecotones, and the size and connectivity of various habitat patches (Table B 1.2). Modern forest management integrates the spatial occurrence and distribution of these factors into biodiversity conservation planning under consideration of the regional environmental properties and policy rules.

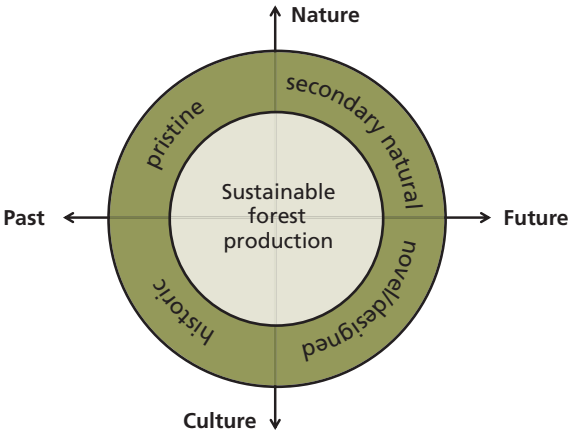

Fig. B 1.3. Anthropogenic impact on forest biodiversity is conceptually related to two dimensions Naturalness (from nature to culture) and Time (from past to future) with two reference condition: past/historic and future/novel. Sustainable forest production covers the central part (light brown) of the concept and makes the basic contribution to biodiversity conservation by integrating retention measures (i.e. integrative forestry). Segregative measures aiming at preserving, restoring, designing and re-wilding areas of high conservation values make a complementary contribution (green) to the effects of integrative forestry. They should be applied in areas where they can achieve the best effect for biodiversity conservation within one of the four reference sectors (secondary natural, novel/designed, historic, and pristine).

Conceptual framework and conservation instruments

Conservation actions in human-dominated, multi-purpose landscapes can be arranged along two dimensions with four reference conditions. The first dimension covers the gradient between nature and culture (naturalness), and the second dimension represents the temporal axis ranging from the past to the future (time) (fig. B 1.3). Reference conditions for the past correspond to pristine forests or to historic forest types of high conservation value (e.g. coppice with standards (fig. B 1.2), forest pastures, chestnut orchards). Today's remnants of historic forest management systems benefit forest species that are promoted by light and temperature and are associated with a mosaic of open and stocked habitats (e.g. Lassauce *et al.* 2012; Mullerova *et al.* 2015; Miklin *et al.* 2018). One means to restore natural processes is to withdraw forests from use and let them develop freely within the borders of a strict forest reserve. However, such secondary natural forests need centuries to develop typical habitat characteristics of primary forest (Lilja *et al.* 2006; Paillet *et al.* 2015; Paillet *et al.* 2017; Braunisch *et al.* 2019). A second reference condition for the future are to design forests towards a desired ecosystem service such as timber production, CO_2-sequestration, or recreation. Proactive approaches for the promotion of biodiversity under novel forms of production forestry have not been sufficiently evaluated so far. However, "Nature by design" (Higgs 2003) has already become a form of biodiversity promotion in human-dominated landscapes (e.g. Koh and Gardner 2010) and is an option to be considered in regions with large areas of plantation forests (Brockerhoff *et al.* 2008; Bernes *et al.* 2015).

A conceptual framework that distinguishes between these axes and reference conditions incor-

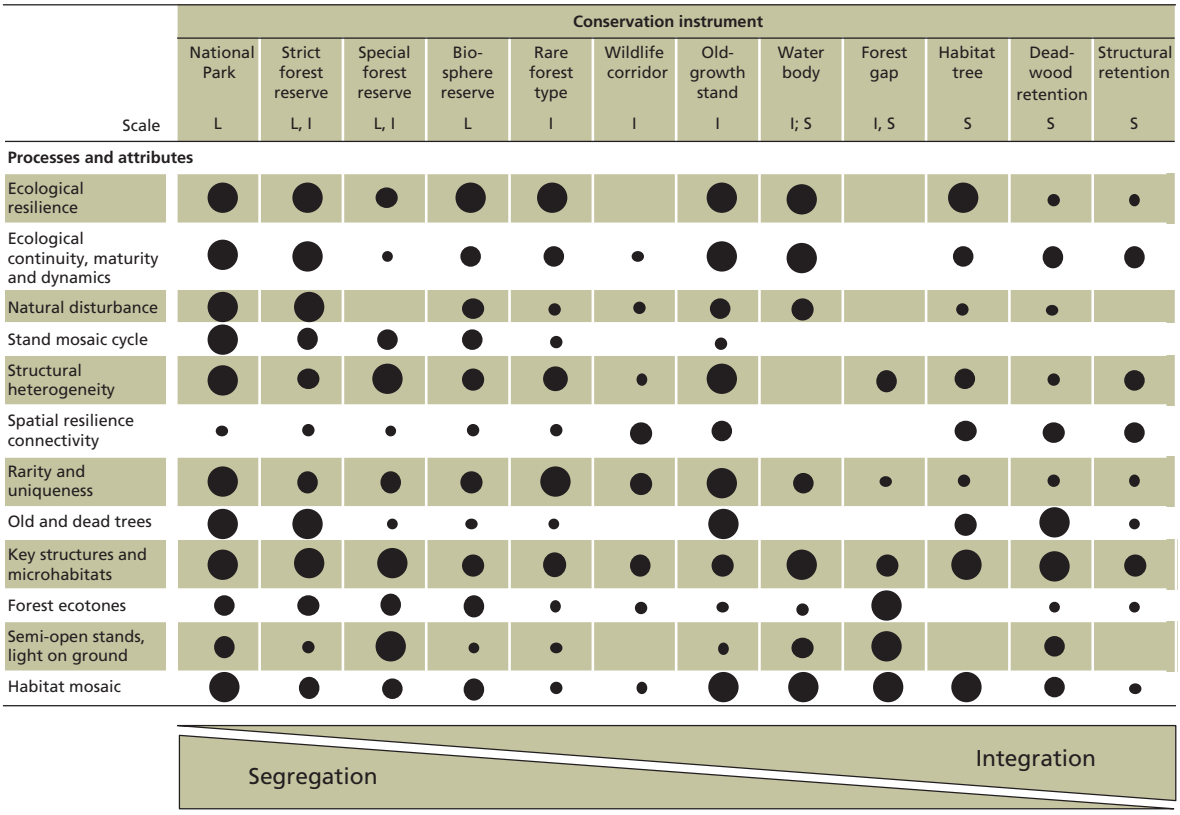

Fig. B 1.4. Conservation instruments to consider important processes and attributes of forest biodiversity. The effective application of the instruments depends on the appropriate scale (L[arge] = regional or forest scale; I[ntermediate] = stand scale; S[mall] = tree scale), and therefore are better suited for integrative or segregative approaches. The supposed conservation impact of the different instruments is indicated with bullets (● = high; • = moderate; · = low). Strict forest reserve: conservation area left to natural development without interventions, Special forest reserve: area with conservation measures through active management, Biosphere reserve: protected landscape with three zones of graded land-use intensities (preservation, sustainable use, socio-economic development).

porates past and future temporal dimensions and offers both the opportunity to preserve remnants of natural and cultural legacies and the opportunity to restore and create forests with biodiversity-friendly forest management practices next to self-organising habitats (e.g. secondary natural forests, wilderness areas).

There are different instruments of the conceptual framework that can be used in a given forest enterprise (fig. B 1.4). The effective use and appropriateness of the instruments depend on the particular situation with regard to the natural species pool, the biophysical conditions, ownership structure and economic demands.

A clever, systematic, and area-specific combination of different conservation instruments

In a systematic conservation approach, integrative and segregative conservation instruments are combined and applied along the dimensions time and naturalness in the conceptual framework (fig. B 1.3). Sustainable production forestry sets the ecological baseline by providing a minimum habitat quality for generalist forest species on the overall forest area (Bollmann *et al.* 2009). The application of different conservation instruments, some of them more suitable for an integrative approach, others for a segregative approach, make an addi-

Fig. B 1.5. Standing and downed deadwood provide habitat for 20–30 % of total forest species (Photo: Kurt Bollmann).

tional contribution to the conservation of a representative forest biota (fig. B 1.4). Tree species diverse forests in combination with the conservation of important structures such as old trees with microhabitats, rocky outcrops, aquatic elements, gaps, and structured forest edges can be an integral part of an area-wide sustainable forest production. The same applies to crucial resources such as standing and downed deadwood (fig. B 1.5) that constitute a limiting factor in most managed forests (reviewed by Jonsson *et al.* 2005; Stokland *et al.* 2012; Müller and Bütler 2010; Lassauce *et al.* 2011). The potential for the integration of rare forest types and biotopes into managed forests depends on the size of the objects, and segregation is the appropriate approach for larger areas of high conservation value (e.g. national park, strict forest reserve, rare forest type, historic conservation forest, wildlife corridor) that require a separate and permanent protection and management.

A biodiversity conservation strategy that combines the advantages of integrative and segregative instruments improves habitat quality across managed forests and landscapes due to the area-wide retention of important habitat features at the tree (e.g. 'methuselah' trees) (fig. B 1.6) and stand (e.g. old-growth or early seral) scale and the preservation of entire forests or stands of high conservation concern (e.g. forest reserve, rare forest type) (Doerfler *et al.* 2018). According to new findings (Fahrig 2020), such an approach is considered to be effective because it puts more emphasis to the conservation of small key structures and patches than on larger reserves which will continue to be the rarer conservation elements in managed forest landscapes. As a consequence, conservation efforts may vary across the forest enterprise in relation to site specificity, rarity and uniqueness of the different habitats or stands. Thus, the strategy can be adapted flexibly to regional forest and conservation

Fig. B 1.6. Retaining old trees is a widespread conservation measure of integrative forestry (Photo: Kurt Bollmann).

planning or to the occurrence of natural disturbances (fig. B 1.7). It is applicable under different ecological, societal, and economic conditions and can be adapted to various ownership situations. A conservation strategy that combines integrative and segregative measures and increasingly considers disturbance agents and processes in the forest management places a special emphasis on biodiversity conservation on the entire forest landscape while simultaneously supporting adaptive processes. Such a combined forest management approach increases overall habitat suitability, functionality, and connectivity. If carefully designed, and taking landscape connectivity into account, it will significantly improve the possibility to establish a functional green infrastructure (e.g. Arts *et al.* 2017; Mergner 2018; Angelstam *et al.* 2020).

Conclusions

Maintaining and restoring representative autochthonous forest biota, from genes to entire species communities, requires a comprehensive hierarchical concept that combines segregative (reserves) and integrative (off-reserve) conservation instruments at different spatial scales from single trees to forest landscapes. Such a dual concept tries to optimise the advantages and disadvantages of a pure segregative or integrative forest management. Optimally, it retains and conserves important and rare habitat elements across the entire forest landscape and complements it with a network of reserves and post-disturbance patches. The reserves can develop into secondary, old-growth forests, thus providing habitat for viable populations of rare forest species in a multi-purpose landscape. They serve as biodiversity refuges and functionally link the biodiversity trends in the reserves with species communities in the production forests and post-disturbance patches.

Such a unifying framework provides a flexible ap-proach for foresters and conservationists to take measures in favour of the regional conservation objectives. A broad spectrum of instruments that can take advantage of a large variety of ecological, societal, and economic properties seems to be especially helpful when it comes to applying them in different cultural and political situations (see Synthesis chapter). The measures should be planned at the regional scale according to the four reference conditions of the conceptual framework (fig. B 1.3) and consider the natural history and cultural legacy of the landscape, as well as the future needs of the different stakeholders.

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Fig. B 1.7. Natural disturbance agents such as wind have strongly influenced the evolution of forest biodiversity. Therefore, the integration of disturbed stands in forest management supports adaptive ecological processes and the promotion of a rich biodiversity that depends on a favourable microclimate and/or large deadwood amounts (Photo: Kurt Bollmann).

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Where do we come from? Cultural heritage in forests and forest management

B 2

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Introduction

Forests are of great importance, not least as an integral part of complex land-use systems shaping the European cultural landscape. Compared to the rates of change of open land, forests are relatively persistent landscape elements. Still, over a longer term, forests have been very dynamic with respect to spatial extent, internal structure, and species composition. Forest expansion after the last Ice Age was followed by shrinking of the forest area owing to the expansion of agriculture and settlements, i.e. the classic frontier situation, which lasted in Europe over a long period. However, there have also been periods of temporary forest expansion, e.g. caused by the Black Death (Rudel 2009; Lagerås 2007). Forest transition (Mather 1992), i.e. the more recent change from forest decline to forest expansion, has taken place at different times throughout Europe, e.g. in Switzerland (Loran *et al.* 2016) and Germany (Johann *et al.* 2004) already in the first half of the nineteenth century.

The changes in forest area triggered successional patterns which were overprinted by human impacts, i.e. forest use and management (Kirby and Watkins 2015). Over time, societal demands changed and often diversified from various forest products to the full range of ecosystem services which today are in demand. The corresponding changes in forest structure and composition were reflected in changes in ecological characteristics, including biodiversity (Kirby and Watkins 1998). The diversity of these linkages between forest use and management and forest ecosystems has been addressed in a series of international conferences (e.g. Salbitano 1988; Agnoletti und Anderson 2000; Honnay *et al.* 2004). Lately, more weight has been given to aspects of cultural heritage (e.g. MCPFE 2006; Parrotta *et al.* 2006), and the concepts of 'biocultural diversity' (Agnoletti and Rotherham 2015) and 'biological cultural heritage' (BCH) (Eriksson 2018) have been promoted to foster an integrative perspective on cultural and natural heritage.

In this chapter we illustrate, in a series of six case studies from different parts of Europe

< Fig. B 2.1. Coppice with standards – a forest use system historically widespread across Europe. This silvicultural approach was tailored to produce firewood and construction wood for local people. At the same time, it turned out to support many light-demanding forest species and – where still present - has developed today into biodiversity hotspots (Photo: Hans Burger, Archive WSL 1925).

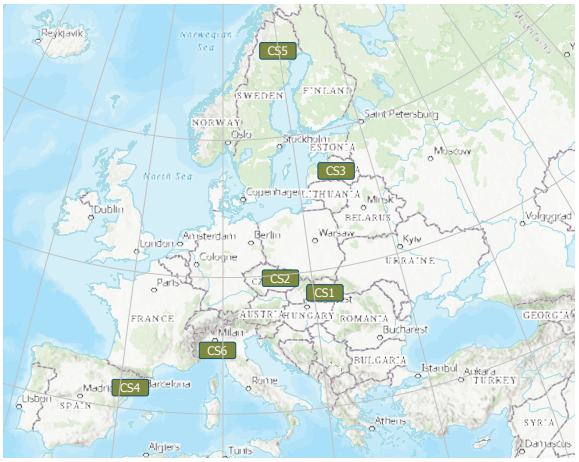

Fig. B 2.2. Location of the six case studies (CS1 to CS6) presented in this chapter.

(fig. B 2.2), how centuries of forest use and management have left imprints on forest ecosystems, and how acknowledging the legacy effects of the long-term inter-relationship between societies and their forests provides valuable background for sustainable forest management.

Case studies

CS1: Diversity of forest uses in floodplain forests of the border region of Hungary and Ukraine

Hardwood floodplain forests of Bereg Plain (Upper-Tisza region in Hungary and Ukraine) have been managed to provide a wide range of forest products for centuries (Takács and Udvari 1996; Demeter 2016). Pannage (i.e. the practice of feeding and fattening domestic pigs on acorns, worms, fish, and forest grasses) has been at the core of forest use, as old oak (mainly *Quercus robur*) forests on rich and moist sites are suitable for the production of high-quality oak timber and pigs (Sas 1928; Csiszár 1971). Oak trees were sold at auction and cut selectively by smallholders, providing construction timber, barrel staves for vineries, and other products to local communities. A continuous increase of the number of pigs was reported in the region from the mid seventeenth to the end of the nineteenth century (Lehoczky 1881). The importance of floodplain oak forest in pig breeding was also reflected in commons and village laws: *"One who cuts mast producing oak tree must be fined 12 forint"* (Belényesy 1957). In this period, 90 % of the oak forest in the region were high forest (Fekete 1888) and most of them were old semi-natural forests (Fekete 1890). As large old oak trees produced much larger acorn crops, it was in the interest of local communities to preserve them. Bereg Plain was split after World War I and divided between Hungary and the Ukrainian Soviet Socialist Republic. The resulting changes in legal and socio-economic circumstances contributed to the development of different trajectories for forest management and corresponding forest structure.

To document the diversity of forest uses in the second half of the twentieth century, 22 oral history interviews with local forest users were conducted (11 on the Hungarian side and 11 on the Ukrainian side) and the ecological impact of the uses recorded was assessed (Table B 2.1). Results show that in this recent period, local to international demand for oak railway sleepers, barrel staves, and construction wood triggered the development of the selection logging system. These timber uses together with pig grazing have also had the highest ecological impact.

Legal differences between the two countries led to different developments in forest uses systems. On the Ukrainian side, forestry law did not contain a clear regulation on forest grazing. Consequently, just as in the case of non-timber forest products, forest grazing can theoretically be practiced by the local population in the not-strictly-protected forest, provided they do not cause damage to the ecosystem (Forest Code of Ukraine 1994). In practice, it is up to the local forestry administration to control this activity. Nationalisation of goods in the Soviet period led to the abandonment of pig grazing by 1970, but selection logging is still a vital part of forest management (Demeter 2016). Until the end of the 1990s, a sanitary selection logging system and the above-mentioned pannage system fostered the preservation of several forests with near-natural structure (e.g. including large to very large trees) on the Ukrainian side (Demeter 2016; Demeter *et al.* 2017).

On the Hungarian side, timber shortage after 1920 led to a significant intensification of forest management and rotation forestry was preferred over low intensity selection system. Homogenisation of forest use with a rotation cycle of 80 to 100

Table. B 2.1. Forest uses mentioned for the second half of the twentieth century in at least 20 % of the oral history interviews conducted (11 interviews in each region). The values for spatial extent and biomass removal are adopted from Bürgi *et al.* (2013). Spatial extent: 3 = large proportion of forest area affected; 2 = about half of forest area affected; 1 = small proportion of forest area affected; 0 = part of other use. Biomass removal: 3 = massive removal; 2 = medium removal; 1 = little removal; 0 = part of other use. Listed according to the Ecological impact which is the product of spatial extent and biomass removal.

Forest uses and products	Hungary % mentions	Ukraine % mentions	Spatial extent	Biomass removal	Ecological impact
Logging/fuel wood	100	100	3	3	9
Logging/ construction wood	100	100	3	3	9
Hunting/sport	100	100	3	3	9
Collecting/litter/fuel wood	55	100	3	3	9
Logging/barrel staves	36	73	3	3	9
Logging/railway sleeper	18	45	3	3	9
Grazing/grass/acorn/pig	0	82	2	3	6
Collecting/acorn/sowing	100	100	2	2	4
Logging/grape stakes/poles	0	55	2	2	4
Collecting/mushrooms	55	100	3	1	3
Mowing/forest meadow/hay	45	82	1	3	3
Logging/wooden tools	9	91	3	1	3
Logging/oak grave marker	0	82	3	1	3
Collecting/fertile soil	9	55	1	3	3
Raking leaves/litter	9	45	1	3	3
Collecting/flowers	36	91	1	2	2
Collecting/acorn/fodder	9	73	1	2	2
Grazing/grass/leaves/sheep	45	9	1	2	2
Tourism/hiking	100	45	1	1	1
Grazing/grass/leaves/cattle	36	73	1	1	1
Collecting/wild fruits	0	55	1	1	1
Fishing	27	91	0	0	0

years has led to the significant loss of old stands and the homogenisation of forest structure (Demeter *et al.* 2017). Grazing of domestic animals in the forest was restricted from 1920, totally banned in 1961, and consequently abandoned in the studied landscape. At the same time, forestry changed from multiple-use towards single commodity forestry, resulting in an even-aged (middle-aged and mature) closed canopy, high forests with less old-growth characteristics (e.g. without large old trees and without large lying deadwood) (Demeter *et al.* 2020). Therefore, continuation and targeted restoration of selection systems and application of multiple-use management (e.g. grazing according to local demand) should be considered to diversify management and to restore the former structure of floodplain oak forests of the Pannonian region.

CS2: Historical forests in lowlands in the Czech Republic – game parks, designed landscapes, and biodiversity hotspots

The total forest cover of the Czech Republic is 33.5 % but the cover is distributed unequally (Bičík *et al.* 2015). In central Bohemia and southern Moravia, which have been continuously inhabited since the Neolithic Age, the forest cover is significantly below the national average. Some of these forests have important cultural and historical values and they are hotspots of biodiversity in an otherwise intensively used landscape (Šantrůčková *et al.* 2017).

Forest landscape development has been studied closely in a 113 km^2 region in central Bohemia, east of Prague, where the climate is moderate, and

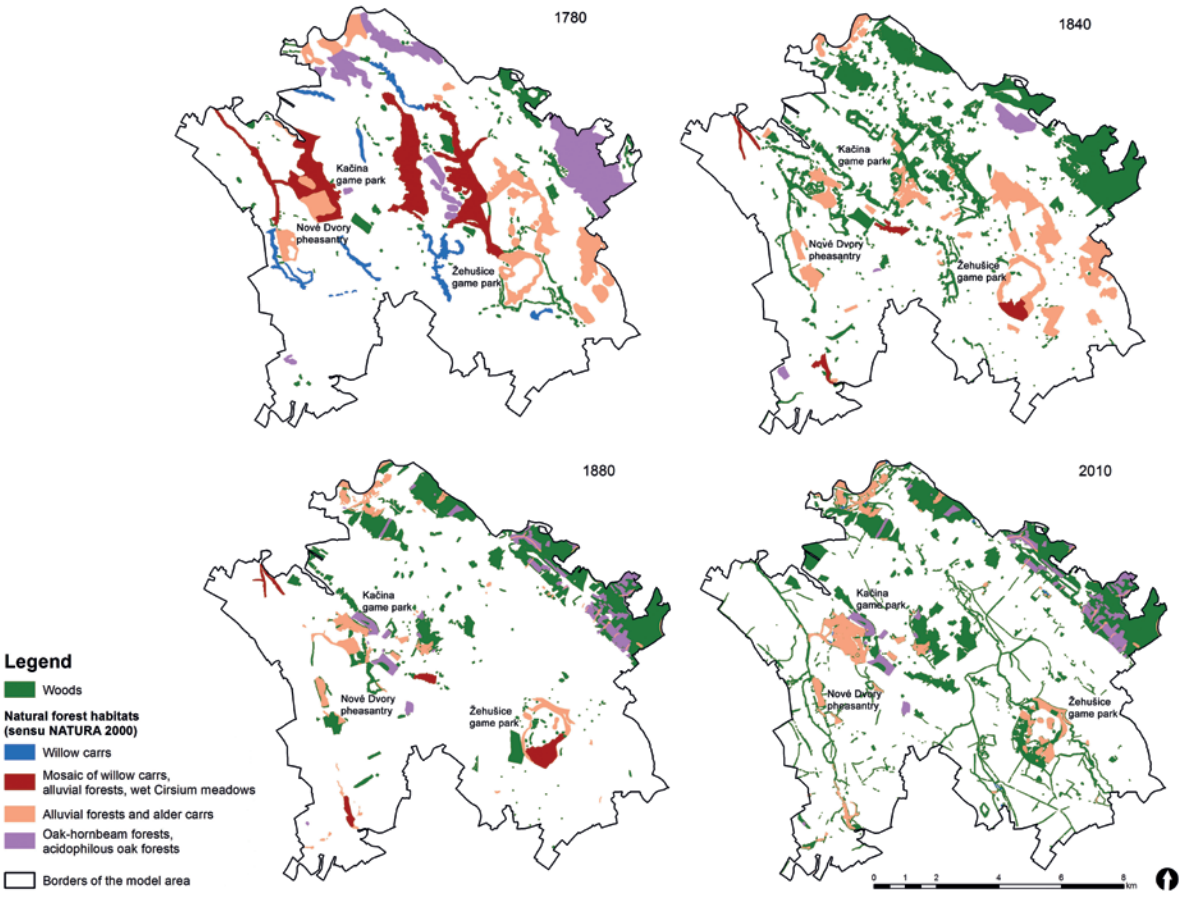

Fig. B 2.3. Development of all forests and forest types which today are classified as natural forest habitats (sensu Natura 2000 in Chytrý *et al.* 2010) in the study area in central Bohemia.

the altitude ranges from 200 to 250 m a.s.l. Forest cover has remained rather stable over time: 16.6 % in the 1780s; 17.98 % in the 1840s; 12.13 % in the 1870s; and 16.64 % in the 2000s (Skaloš *et al.* 2012). However, the location of the forest has changed a lot (fig. B 2.3). In the early eighteenth century, Baroque designed landscapes with game parks and pheasantries (i.e. areas where pheasants are bred and reared for the specific purpose of hunting) were established in this area. At the beginning of the nineteenth century, the gardens were redesigned. The newly created landscapes incorporated the Baroque game parks, and they were also enlarged. In the same period, the total area was also changed with respect to inner structure, function, and species diversity, as shown in the following example. In the eighteenth century, tall broadleaved woods dominated in game parks, whereas on slopes, coppice and scattered and shrubby woods prevailed. Over the course of the nineteenth and twentieth centuries, many small and scattered woodlots disappeared because of agricultural intensification (Jepsen *et al.* 2015; Szabó *et al.* 2018; Skaloš *et al.* 2011). Broadleaved woods on slopes were either converted into orchards or to intensively managed coniferous forests with a focus on wood production. Species-rich forests were retained almost only in (former) game parks and pheasantries near manors (Skaloš *et al.* 2012; Šantrůčková *et al.* 2015, 2017), making them important for cultural and natural heritage.

Despite their relatively small area and similar origin, these heritage forests are not a homogeneous group (fig. B 2.3). Žehušice game park has been continuously used for deer grazing since the 1820s; today this game park is privately owned. The area is

a mixture of alluvial forests, alder carrs, and mesic meadows. The Kačina game park and Nové Dvory pheasantry were nationalised in the 1940s, and they are still owned by the state. Hunting was abandoned several decades ago, the intensity of forest management decreased, and they are currently managed with a low intensity. The former mosaic of alluvial forests (dominated by *Salix alba* and *Populus nigra* or *Quercus robur, Ulmus minor, Fraxinus excelsior, Prunus padus*), alder carrs *(Alnus glutinosa)*, willow carrs (dominated by *Salix aurita, S. cinerea, S. pentandra*), oak-hornbeam forests/acidophilous oak forests (dominated by *Quercus petraea, Q. robur, Carpinus betulus*), and mesic *Arrhenatherum* and wet *Cirsium* meadows changed, as meadows were replaced by oak–hornbeam forests mainly in the nineteenth century and by alluvial forest and alder carrs in the twentieth century (Šantrůčková *et al.* 2015). Both game parks are protected as natural monuments and they are managed with nature conservation as a specific objective. Kačina game park is also listed as a special area of conservation under the European Union Habitats Directive (92/43/EEC).

CS3: Legacy effects of industry in forests contributes to the cultural-historical as well as their ecological value – forest biodiversity in Latvia

In a case study carried out in Zemgale (southern Latvia), we examined whether biodiversity hotspots, known in northern Europe as woodland key habitats (Timonen *et al.* 2010, 2011), occur in continuous forest land and to what degree scale matters in this process. The presence of 2797 key habitats was analysed at five spatial scales (with neighbourhood radii (r_n) of 80, 800, 1400, 2500, and 5500 m, upscaled by moving window averaging) and referring to forest cover in four reference years (1790, 1860, 1910, and 2010, according to historical maps; Fescenko *et al.* 2016). Zemgale (with total area 5178 km^2) was chosen as a study area, representing the most intense and diverse land-use history over the last three centuries in Latvia (Fescenko *et al.* 2014), and exhibiting a relatively high percentage of woodland key habitats.

The results showed that settlement activities of the recent past (occurring over less than a century), iron manufacture activities, and medium-intense logging during the eighteenth century had resulted in today's highly diverse forest pattern (Fescenko and Wohlgemuth 2017). This can be illustrated in the area surrounding the largest historic iron manufacturing centre Dzelzamurs of the Duchy of Courland/Semigallia, where ironworks ran from 1648 to at least 1705. Today, this area has one of the highest densities (5.1–30 %) of woodland key habitats (fig. B 2.4). Moreover, the woodland key habitats have had a surprisingly diverse and dynamic land-use history, indicating that such structurally and taxonomically diverse forest stands are linked to both the presence of old-growth and to heavily anthropogenically shaped forests. Regression models showed that short-term (50–70 years) and small (up to 250 m) gaps in past forest cover were significant positive predictors of woodland key habitat presence, and the resulting patterns resembled those caused by – in terms of frequency and intensity – intermediate natural disturbances. Overall, 73 % of woodland key habitats is located in forests – with non-centres continuous forest cover (details in Fescenko and Wohlgemuth 2017), a finding which is in line with several studies that have illustrated the importance of land-use legacy effects on today's diversity at various scales (Lunt and Spooner 2005; Fischer *et al.* 2006; Wohlgemuth *et al.* 2008; Boucher *et al.* 2014). Compared to other parts of central and southern Europe, intensification of land use in Latvia started relatively late and by the end of the seventeenth century, forests still covered about 65 % of the territory (Kaplan *et al.* 2009). Rapid development of agriculture and industry in the eighteenth and nineteenth centuries resulted in the lowest level of forest area (24 %) in the 1920s, lasting for just a few decades. From the 1940s onwards, forest cover started to increase again, reaching 55 % in 2012 (Fescenko *et al.* 2014). This relative short period of lowest forest cover, as well as the closeness of old forest patches throughout the landscape, could be essential for successful re-colonisation for old-growth dependent species, dwelling in the current woodland key habitats of Zemgale. Additionally, differences in soil, tree species composition, and legacies of old trees were important in the formation of today's species rich areas and about one third of woodland key habitats with diverse land-use history were found in wet alder woods or broadleaved forests, where old solitary trees were common (Fescenko and Wohlgemuth 2017).

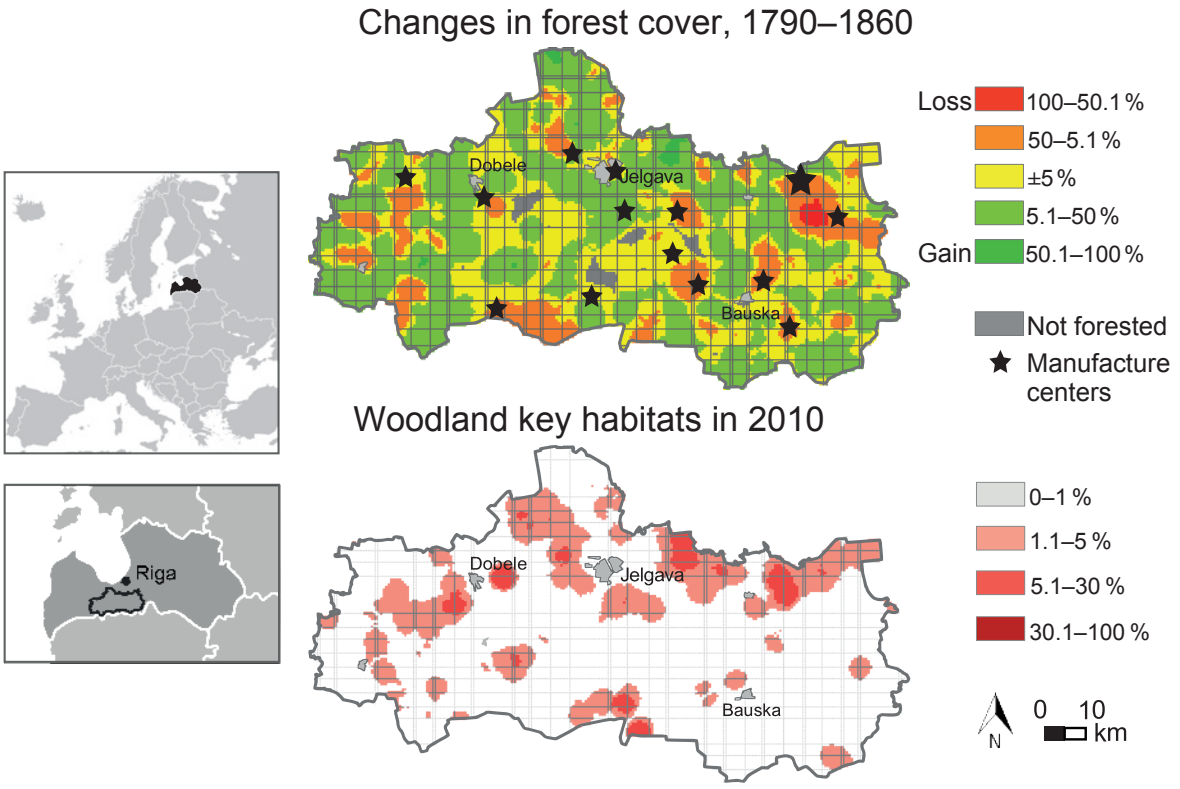

Fig. B 2.4. Location of the study area Zemgale (southern Latvia). Forest cover changes from 1790 to 1860 and distribution of woodland key habitats in 2010 in the study area. Landscape scale has a neighbourhood radius $r_n = 2500$ m. Percentages refer to grid cells of 500 x 500 m. Gain and loss of forest cover refer to the percent change in the corresponding grid cell. Stars denote locations of manufacturing centres before industrialisation in the nineteenth century. The biggest star (top right) denotes the location of the largest iron manufacturing centre Dzelzamurs of the Duchy of Courland/Semigallia. For details, see Fescenko and Wohlgemuth (2017).

Apart from the 'disturbance effect', the industrial activities in Zemgale's forests during the seventeenth to nineteenth centuries also had a 'conservation effect' by creating specific cultural structures and landforms, which safeguarded and even promoted forest biodiversity. For example, old slag-hills on the banks of forest streams around past iron manufactures prevented these streams from becoming dredged and straightened during the extensive melioration that occurred in the twentieth century, thus keeping the natural riverbed untouched up to the present time.

To some extent, industrial activities and intermediate logging 200 years ago, have replaced natural disturbances in Zemgale as the principal agent of dynamics in forests, creating spatially heterogeneous and bio-culturally diverse forest pattern. From a conservation perspective, today's forest management, therefore, should consider the historical continuity of habitat fragments, and maintain a set of structurally rich forests of mid- to late-successional stages at broader scales. Biodiversity would also be promoted by forest management based on emulating natural disturbances and focus on reducing differences between protected and managed landscapes.

CS4: From deforestation to 'spasmodic forestry' in a Mediterranean landscape of Catalonia, 1868–2005

Mediterranean forests have generally experienced overexploitation and deforestation for long periods up until the mid-twentieth century, often followed by expansion of forest owing to agricultural

abandonment after a turning point, which is referred to as 'forest transition' (Mather 1992; Meyfroidt and Lambin, 2011). The spatial scope and temporality of this historical process was different in different locations, and has affected the current ecological quality of forests; this can be understood by considering their site-specific socioecological transition (Otero *et al.* 2015). Up to the 1950s, the intensive use, together with cropland expansion, minimised forest extent and additionally reduced the quality of the remaining woodlands. The subsequent fast and widespread forest transition following rural exodus has entailed a woodland expansion; however, this has often occurred without recovery of the ecological processes and associated biodiversity (Marull *et al.* 2014). Therefore, Mediterranean forests in many places became less resilient and more vulnerable to climate change (Kröel-Dulay *et al.* 2015). The re-growing secondary forests are caught in a low ecological quality trap.

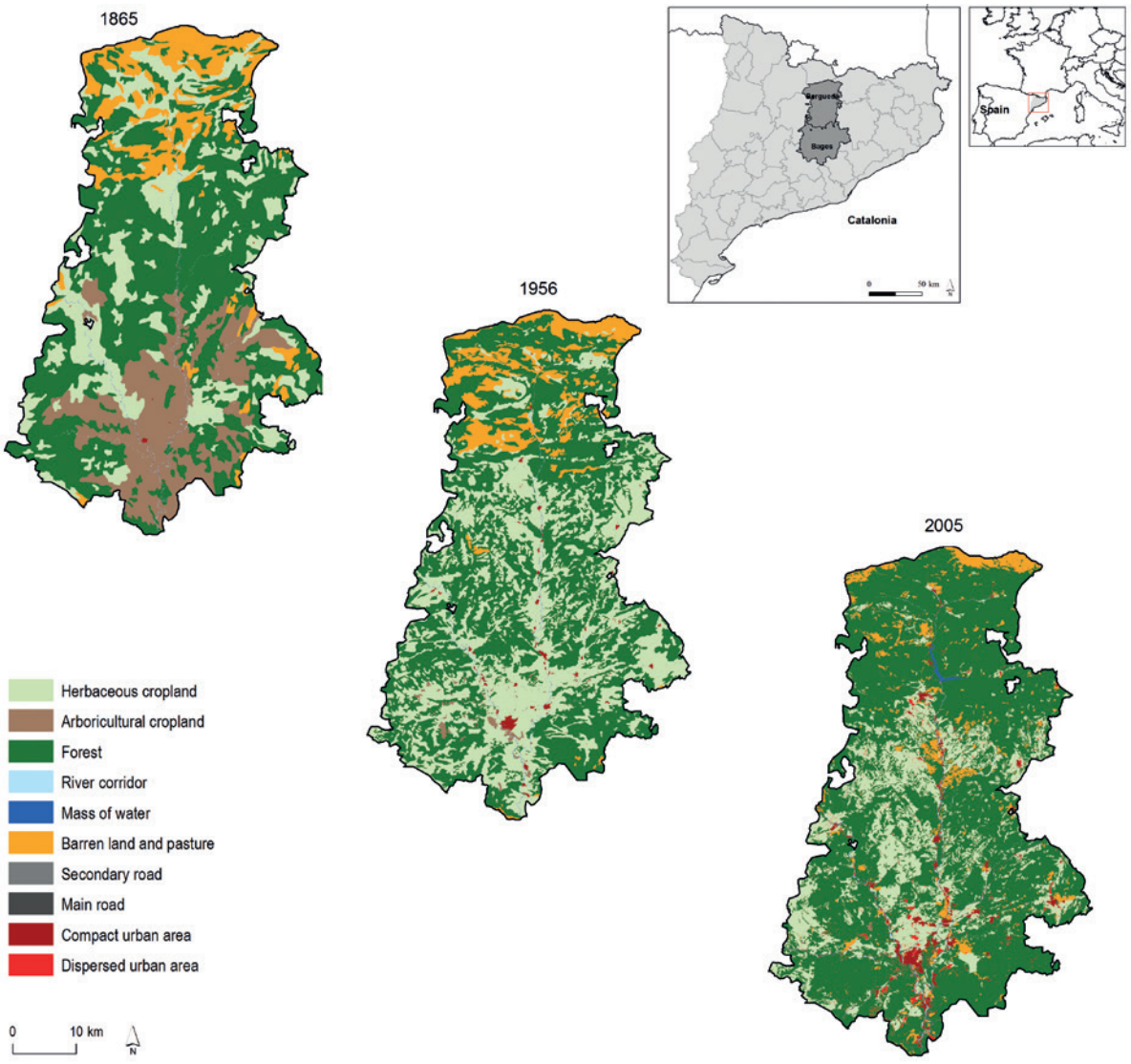

Fig. B 2.5. Land cover maps of the study area in Catalonia (1868, 1956, and 2005). Source: Metropolitan Laboratory of Ecology and Territory of Barcelona.

Their low resilience prevents them from maturing, and their low maturity keeps them in a low resilience state.

This process can be illustrated by the example of the study area in Catalonia (fig. B 2.5), which has experienced forest regrowth following rural abandonment during the last 60 years. The GIS reconstruction of three land-use maps of 1868, 1956, and 2005 shows how forests have encroached on former cropland and pastureland from the 1950s onwards, after a previous wave of deforestation. Forest inventories show the intensive use of woodlands up to the 1950s, and their poor ecological status in terms of age structure, diversity, and maturity. Today's forests are prone to wildfires, which in turn can force wood harvest, contributing to a vicious circle: the lack of appropriate forest management increases wildfires, and leads to the forced harvesting of fallen or burnt trees after these seemingly 'natural' disturbances – a sort of 'spasmodic forestry' (Cervera *et al.* 2019). The restoration of landscape mosaics could offer the chance of an alternative, more sustainable development pathway. An analysis of historical forestland trends can identify those areas where the mosaic structure of cultural landscapes can be restored by recovering pastures and croplands. This would entail restarting an intermediate disturbance that can improve biodiversity (Tscharntke *et al.* 2012). Those lands with forest cover after rural abandonment have to be differentiated from areas of continuous forest cover, with the potential to develop into mature forests, with older trees and richer soils, which should be preserved.

In general, Mediterranean forests combined with agroforestry mosaics (i.e. heterogeneous landscapes characterised by a set of land uses possessing contrasting disturbances) provide a synergetic contribution to biodiversity conservation based on the 'virtuous triangle' of forest cover, human appropriation of net primary production, and biodiversity (Marull *et al.* 2018). The lack of appropriate forest management can lead to increased wildfires, which in turn can lead to the 'spasmodic forestry' as described above. To break this vicious circle, we suggest combining sustainable forestry with farming and extensive livestock breeding as a means to perform an active ecological restoration. Historical knowledge can help in this task, by discovering the previous dynamics of current woodlands and providing a guidance to differentiate the scarce old forests from the forests that are younger as a result of the overuse up to the mid-twentieth century, and from many other forests that have regrown since the 1950s in abandoned steep lands.

CS5: Sami land use meeting the timber frontier in nineteenth century Sweden – consequences for today's forest management

During the last 200 years, the boreal forest of northern Scandinavia has witnessed tremendous changes and the human use of the forest has gone from low intensity use by indigenous peoples, to high intense use by an industrialised society.

The indigenous Sami people have lived in and used the north European coniferous forest landscape for several millennia. Their homeland, today called Sapmi, crosses the Swedish, Finnish, Norwegian, and Russian borders. In the northern inland parts of Sweden, Sami people have been the dominant ethnic group until modern times, and even today traditional Sami reindeer herding is a very important livelihood. Nomadic families move on a yearly basis between different locations in the landscape. Each site is visited at a specific time of the year and provide a specific set of resources. Performed over centuries and even millennia, this has created gradients in the forest landscape with more intensively used hot spots in a 'sea' of less intensively used forests (Ericsson 2001; Berg 2010). Scots pine *(Pinus sylvestris)* forest was especially important. Open sparse old-growth pine heaths with recurring forest fires provide ground and pendulous lichens for the reindeer in the winter, and naturally occurring dead pines are used for firewood and the inner bark is collected for food (Rautio *et al.* 2014). The long duration of low intensity land use has left a unique historical legacy over thousands of square kilometres of northern forests. Trees with cultural marks (Östlund *et al.* 2009; Rautio *et al.* 2014 – Fig. B 2.6), changes in fire frequencies and vegetation pattern (Hörnberg *et al.* 2018), and traces of resource use, such as cutting of trees for lichen harvest (Berg *et al.* 2011), all tell the story of the long-term Sami land use.

At the end of the nineteenth century, a timber frontier swept over these same forests (Björklund 1984), driven by the industrial revolution and the need for wood products in Western Europe. Mil-

lions of very old Scots pine trees were cut and the overall forest structure changed dramatically (Linder and Östlund 1998). At the same time, the Swedish state claimed supreme ownership of most of the forestland of which the Sami people had previously been regarded as the supreme landowners. The timber frontier and a parallel colonisation frontier pushed the Sami people westwards and left them without proper tenure of their homelands. This remained an unresolved issue which has been repeatedly brought into courts over recent decades (Östlund *et al.* 2020).

Today most of the forest in northern Sweden is used intensively for the production of timber and wood for bioenergy. During most of the twentieth century, there was an ever-increasing focus on high forest yield and intensive management methods, such as the use of herbicides and nitrogen fertilisers, large-scale clearcutting and mechanised harvest (Östlund *et al.* 1997). Towards the end of the twentieth century, strong environmental criticism led to less intensive forestry methods (Simonsson *et al.* 2015). Even more recently, there has been an increased understanding of the challenges by the Sami reindeer herders. The possibilities for their livelihood are successively being more and more constrained in the managed forest of today. The main problem for the Sami reindeer herders is that the forest is becoming younger and denser, and thus provides less ground lichens for the reindeers to forage in winter (Sandström *et al.* 2016). To overcome this problem, new forms of interaction between reindeer herders and the forestry sector are being developed (Sandström *et al.* 2006) with incorporation of traditional ecological knowledge from the reindeer herders (Roturier 2009; Roturier

Fig. B 2.6. The old-growth Scots pine dominated forest landscape north of Lake Tjeggelvas in northern Sweden, traditionally used by several Sami families. The forest, which today is a forest reserve covers more than 50 000 ha and has high numbers of cultural remains (i.e. hearths, huts, culturally modified trees). Insert: a picture of an old Scots pine with a Sami bark peeling scar (Photos: Lars Östlund).

and Roue 2009). This is, however, a great challenge because there is an unbalanced relationship – on one side, the forest owners including the state have tenure of the forests, and on the other side, the reindeer herders only have the traditional right to use the grazing resources in the forest.

CS6: Hidden environmental heritage in the forests of the Apennines

Similar to the Catalonian case study (CS4), also the forests of the Apennines (the mountain range running down the length of peninsular Italy) have experienced a long history of intensive use. Until the enactment of the first state forestry laws instituted in 1822 in the Kingdom of Sardinia, and during the Napoleonic administration in other pre-unitarian states, the woodlands in the northwestern parts of the Apennine mountain range, were managed for production of a variety of products and services using different and multiple management systems; these systems involved grazing and mowing practices, and even temporary agricultural uses of forest soil (Moreno 2018; Cevasco 2004). The ecology of this 'land bearing trees', a termed used by Grove and Rackham (2003) for Mediterranean savannah, was largely influenced by the use of controlled fire, in particular in the beech *(Fagus sylvatica)* and Turkey oak *(Quercus cerris)* woodlands, as well as in rangeland bearing trees (Moreno *et al.* 2019), in combination with transhumance systems (i.e. seasonal movement of livestock from pastures at lower altitudes in winter to pastures at higher altitudes in summer) (Moreno and Raggio 1990; Cevasco *et al.* 2018). In the Upper Trebbia and Aveto valleys (in the Ligurian–Emilian Apennines) this particular type of woodland management, including different types of controlled fire to sow temporary crops (called *ronco*), has been used since the early Middle Ages for the management of white alder *(Alnus incana)* woodlands (Cevasco 2010; Agnoletti 2013; Molinari and Montanari 2016).

Long before the scientific observation of the nitrogen-fixing Frankia soil microorganisms in the late nineteenth century (1880s), the nitrogen-fixing and fertilising ability of the alder was well known to local naturalistic knowledge. The management cycle in eighteenth to nineteenth centuries was based on a 6- to 12-year rotation that included coppicing of alder (use of wood for cooking and heating and use of leaves as a green manure), turf stripping, turf burning, sowing of cereals (oats, *Avena sativa*; rye, *Secale cereale*) for one to two years, wood pasture, and alder regeneration from coppiced stools.

These production systems - involving the beech *(Fagus sylvatica)*, the Turkey oak *(Quercus cerris)* and the white alder *(Alnus incana)* woodlands – were particularly widespread in the common lands, and were abandoned in the decades between 1850 and 1950. The main causes for abandonment were the progressive abolition of local rights on common land and the development of 'improvement' policies sustained by the emerging agronomic disciplines in favour of intensive livestock production and modern forestry management. However, though forgotten, these systems have left a diverse environmental legacy, both in the current composition and structure of woodlands (relict pollarded and/or shredded trees (pollarding being the removal of branches at a certain height above ground and shredding being the repeated removal of all side branches leaving the main stem and top growth), repeatedly coppiced stumps, vegetal hedges used for the protection of temporary crops, etc.), in the soils (microcharcoals), and in the present biodiversity of the sites (e.g. presence of non-woody species and persistence of *Alnus incana* in these valleys). Similar alder-based farming systems are still widespread throughout the Himalayas (though the systems have been discouraged by governments since the 1960s owing to the 'environmental degradation' as a result of swidden agriculture, see Gros 2014) and now included in the proposed Globally Important Agricultural Heritage System (GIAHS; Koohafkan and Altieri 2017).

Archaeological and textual evidence has revealed that locally controlled fire practices, such as those in the *ronco* system, entail complex cycles with precise historical chronologies embedded within specific topographical systems of rights of use (Beltrametti *et al.* 2014). The experimental reconstruction and reintroduction of controlled fire practices could be a means to maintain the historically grown and anthropogenically determined biodiversity (Bürgi *et al.* 2013) and to preserve and reactivate the rich heritage and traditional knowledge which characterise the specific wood and wood pasture management in the Apennines (Cevasco and Moreno 2015).

Conclusions and outlook

Today's forests are shaped by the long-term inter-relationship between developing societal and political needs, the resulting impact on forest ecosystems, and the legacy effects of former natural and anthropogenic processes (Bürgi *et al.* 2017). The six case studies presented show the diversity of past forest uses in a broader European perspective; this perspective has developed in accordance with the potential of local forests to provide resources, ranging from acorns for pig pasture to bark for human nutrition, and to the specific fertilising ability of alder trees. Uses were not only determined by supply and demand, but the demand put upon the forests was modified by specific local legal restrictions and ownership, which for example led to forests being dedicated as game parks and hunting grounds in feudal societies or forest being shaped by long-term industrial activities. All these factors change over time, and what we call legacy effects in ecosystems contribute greatly to the cultural heritage of European forests – including values, such as high biodiversity or resilience of forest ecosystems. As illustrated by case studies 1 and 5, these values can be threatened by a change from a management primarily oriented towards local demand to an orientation towards an international market.

The analysis of the historical roots of today's forest ecosystems reveals two specific challenges for the future. The first challenge is to understand, value, and protect the biocultural heritage of forests. More historical research is needed to disentangle the complex relationship between people and forest over time, and particularly in such a way to encourage collaboration between researchers in different fields such as archaeology, ecology, and history (Agnoletti and Andersson 2000; Honnay *et al.* 2004). The second challenge is to use historical knowledge as an inspiration and guideline for future multiple-use oriented forest management systems (Swetnam *et al.* 1999). This is an even more complex task owing to the broad variation in the forest history of Europe and the always-existing mix of natural dynamics and anthropogenic influence over forest ecosystems.

To develop a site and history specific forest management, we suggest therefore a step-wise approach: (1) clarify the history of the area in question based on existing research or new, targeted analysis; (2) analyse the historical range of variability of the area including both natural and anthropogenic changes over time; (3) set up targets for restoration and management which take into consideration these historical aspects and especially the past multifunctionality of landscapes and the cultural legacy; and (4) make sure that management plans for the future integrate local demand and the history of land-use management as part of the site-specific bio-cultural heritage.

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Fig. B 2.7. Larch – "Wytweide", pasture system in Volleges, Le Biolley sur chemin in southwestern Switzerland (Valais). The "carpet-like" gras is typical for these historical pastures in mountain forests (Photo: Franz Fankhauser, 1919 Archive WSL)

Policy and legal framework for integrating production and biodiversity conservation in European forests

B 3

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This chapter investigates how policies governing integrative and segregative nature protection in forests have evolved at the international and European level. It also reviews the design and implementation of these policies in different national and sub-national contexts. The chapter compiles the available evidence from different policy levels and across various European countries. Based on this, it identifies the institutional determinants of an effective and integrated provision of production and conservation objectives in forest management: forest ownership structure (private vs. public), socio-economic and policy priorities of the forest sector (socio-economic vs. socio-ecological vs. multifunctional), and type of the political system (federal vs. central state).

Governing the forest biodiversity nexus at the global level

There is no single institutional locus for providing a policy framework and guidance on how to sustainably manage and conserve forest ecosystems available at the global level. Biodiversity and nature conservation aspects of a sustainable use of forests are governed through legally-binding multilateral United Nations (UN) conventions on 'global environmental commons' which are expected to help achieving the broader and forest-specific Sustainable Development Goals (SDGs) formulated under the UN Global Agenda 2030. They mainly include the Convention of Biological Diversity (CBD) and the UN Framework Convention on Climate Change (UNFCCC). Non-legally binding international forest policy under the UN (UN Forum on Forests, UNFF and the International Arrangement on Forests, IAF) and economic and trade-focused international policies (International Tropical Timber Agreement, ITTA and Forest Law Enforcement, Governance and Trade, FLEGT) provide another important foundation for global action at the forest biodiversity nexus. International forest certification standards that have emerged from private initiative to increase market transparency are a further relevant aspect of global forest governance (Rayner *et al.* 2010; Sotirov *et al.* 2020).

< Fig. B 3.1. This mosaic landscape in a mountain area is a showcase for the variety of ecosystem services produced within a limited area. Wood production, protection against natural hazards, biodiversity, forest pastures and agricultural areas result in an attractive landscape with high value for recreation. Planning of all of these requested goods and services ask for a holistic view across compartments and sectors. Example from the Simmental, near Zweisimmen, Switzerland (Photo: Andreas Rigling).

The International Arrangement on Forests (IAF)

Following the 1992 United Nations Conference on Environment and Development (UNCED) and the repeated failures to agree on a Global Forest Convention (Dimitrov 2005), the so-called 'International Arrangement on Forests' (IAF) has developed. It consists of several sub-elements that are based on international soft law on forests. In the early stage, countries participating in the UNCED adopted two documents directly related to forests: the 'Non-Legally Binding Authoritative Statement

of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests' (known as the 'Forest Principles'), and Chapter 11 ('Combating Deforestation') of the Agenda 21. The latter highlighted forest loss as a recognised concern, but contained no goals committing national countries to its reversal (Rayner *et al.* 2010). In 2007, the participating countries adopted the UN Non-Legally Binding Instrument on all types of forests (NLBI) which was renamed as the United Nations Forest Instrument (UNFI) in 2015. In 2017, the UN Strategic Plan for Forests 2030 (UNSPF) was adopted. The main policy aim of the IAF – as specified in the 'Forest Principles', NLBI/UNFI, and UNSPF – refers to strengthening political commitment and action at all levels to effectively implement Sustainable Forest Management (SFM) for all types of forests.

The IAF recommends countries, on a voluntary basis, to present national implementation progress reports towards SFM, and suggests the elaboration and implementation of National Forest Programmes (NFPs) that strive to render forest policy decision-making participatory, more rational, more oriented to the long term, and better coordinated across sectors (Sotirov *et al.* 2020), as well as the development and application of criteria and indicators (C&I) for SFM. In this context, regional processes of C&I for SFM have flourished.

The Convention on Biological Diversity (CBD)

The CBD is an international environmental legally binding treaty agreed by national governments that entered into force in 1993. It stipulates a comprehensive approach towards the preservation and use of biological diversity, which is further substantiated by decisions of the Conference of the Parties (COP) to the CBD, such as the 2020 Aichi Biodiversity Strategic Goals and Targets (CBD 2010).

The CBD's main impact results from legally-binding goals without compliance mechanisms that are taken up, and implemented respectively, in national policies by signatory states (Umhauer and Sotirov 2019). National biodiversity strategies, plans, or programmes (NBSAPs) and the programme of work (POW) on forest biological diversity are the main CBD policy tools concerning forests. Their impact depends greatly on how far they are integrated into other policy sectors (e.g. forestry, agriculture) and across sectors (e.g. sustainable development), and facilitated by consultative mechanisms for implementation, monitoring, evaluation, and periodic revision (CBD 2002).

However, a review of actions towards implementing the NBSAP (UNEP 2018), the main CBD instrument, shows that by the deadline of December 2015, almost half of all parties had not submitted their post-2010 NBSAP at all or did submit NBSAP, but without consideration of the 2020 Aichi Targets according to the new Strategic Plan for Biodiversity (CBD 2010).

Forest sustainability certification

Sustainability certification of forest management, later to also include sustainability certification of timber supply chains, has emerged since the 1990s. It is a supply-side, non-state market-based instrument for ensuring SFM at the management unit level and resulted from a cooperation between environmental NGOs, forest-based industries, and scientists, often supported by distinct national governments. It builds on third-party auditing against private stipulations consisting of SFM standards, principles and C&I, and a corresponding labelling of economic operators. The auditing is carried out by experts accredited by the non-state rule-setting organisation, and, depending on the scheme, the labelling provides access to ecologically sensitive consumer markets in developed countries (e.g. Europe) implying improved firm reputation, a social license to operate granted by NGOs, and possibly even price premiums (Cashore 2002; Rametsteiner and Simula 2003).

Two main approaches to forest certification have emerged globally. The Forest Stewardship Council (FSC) was introduced first (Auld *et al.* 2008). Although the forest industry was included in the definition of its standards, the decision-making power it granted to social and environmental interests were seen as a threat by many forest producers (Cashore *et al.* 2004). Consequently, the Programme for the Endorsement of Forest Certification – initially named 'Pan European Forest Certification' – (PEFC) was initiated mainly by forest owner associations. The FSC generally has more stringent environmental requirements and restricts certain economic activities, such as, e.g. the use of genetically modified organisms, which are permitted by PEFC schemes. However, significant variations in national standards and implementation practices within the FSC and PEFC programmes makes com-

parisons difficult without accounting for these differences (Clark and Kozar 2011). The impact of forest certification on forest biodiversity remains somewhat unclear, as a systematic scientific evaluation of such effects is lacking (Visseren-Hamakers and Pattberg 2013).

Governing the forest biodiversity nexus in Europe

Governing sustainable forest management and forest biodiversity through Pan-European policies

At the pan-European level (that includes the EU countries and further European states, including Russia) the Ministerial Conference on the Protection of Forests in Europe (MCPFE), later renamed FOREST EUROPE, has significantly contributed to the definition of SFM through resolutions and sets of criteria (including Criterion 4 on Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems) and indicators, about which the member countries have to report periodically (Pülzl and Hogl 2013).

The signatory countries inter alia reported about the policy mix applied to promote biodiversity-related management in forests (Forest Europe 2015). According to these reports, regulatory instruments play an essential role, inter alia through the EU's biodiversity policy and, specifically, the EU's nature directives (Birds and Habitats Directives), which are considered to be the most important trigger for policy and legal changes at the national level in EU countries. At the same time, and as reported by the countries, specific references to the implementation of commitments in relation to the CBD, the UNFCCC, or the UNFI are scarce (Forest Europe 2015). Grants or subsidies are the most commonly reported financial instruments employed, mostly for forest biodiversity, i.e. protected areas. Financial support is also directed towards forest inventories, management planning, and the protection of soil and water. Informational instruments, such as monitoring, education, and advisory services are also widely applied across all reporting countries to integrate environmental objectives into SFM.

Data from 17 signatory countries in Europe about their total allocations of public expenditure across the six criteria for SFM (Forest Europe 2015) indicate that, on average, around 10 % of all funds are allocated each to health and vitality, biodiversity and socio-economic functions of forests. The countries indicate very different priorities, though.

Governing the forest biodiversity nexus through EU nature protection regulatory policies

At present, there is no overarching, cohesive or binding policy regime for forest management at the European Union (EU) level. The non-binding EU Forestry Strategy (EC 2013) and the EU Forest Action Plan (EC 2006) aim to improve the coordination of EU forest policy through the proposal of forest-related activities.

The two cornerstones of EU nature conservation policy are the EU Birds Directive (EU 2009) and the EU Habitats Directive (CEC 1992). The key instrument to meet their biodiversity conservation objectives is the establishment and management of an EU-wide network of special protection areas (SPAs) and special areas of conservation (SACs), called Natura 2000. While strict reserves are included, the larger part of Natura 2000 sites are managed sites. Over half of all Natura 2000 sites are forest areas, accounting for 23 % of the total forest area of the EU-28 (Sotirov 2017). In 2015, the European Commission published a 'Natura 2000 and Forests' guideline (EC 2015). It is one of the latest examples of a ('soft law') governance process geared towards the integration between nature conservation and forestry.

Another crucial component of the EU nature conservation policy was the EU 2020 Biodiversity Strategy. It suggested a mix of measures such as conservation and restoration of forest habitats and species, integration of biodiversity concerns into forest management plans, and funding and monitoring to improve biodiversity through SFM (EC 2011). However, the 2015 Mid-Term Review of the EU Biodiversity Strategy to 2020 found no significant progress. Comparing these assessments with that of the previous State of Nature report for the period 2001–2006 reveals that while there is some improvement in knowledge about the conservation status of forest habitats and species, the percentage of forest habitat types assessed as having 'unfavourable' conservation status is even higher than before (80 % as compared to 63 %) (EEA 2015). One reason for this might be ineffectiveness of conservation policy through cross-sectoral policy incoherence and corresponding implementation challenges that can be identified in almost all EU-28

countries. The domestic implementation of the integrative approach of the Natura 2000 network of conservation sites (for habitats and species conservation) proved to be a lengthy and politically controversial process (Sotirov *et al.* 2017). The transposition into national law and the establishment of the network of Natura 2000 sites were often substantially delayed or misdirected, which triggered corrective enforcement actions through EU institutions in line with the legal provisions. In many EU member states, Natura 2000 management plans are typically worded rather vaguely or remain non-mandatory for the majority of forest owners (Winter *et al.* 2014). Effective management of Natura 2000 sites in forests is often compromised when no funding or only limited financial support is made available (Geitzenauer *et al.* 2016), or when nature conservation objectives threaten to contradict economic objectives of forestry practices (Weiss *et al.* 2017b; Winkel *et al.* 2015).

To address these concerns, and in the framework of the EU Green Deal policy, the new EU Biodiversity Strategy, adopted in May 2020, sets out three key objectives that need to be reached until 2030: (i) to legally protect at least 30 % of EU land area (an extra 4 % for land as compared to today) and integrate ecological corridors, as part of a true Trans-European Nature Network; (ii) to strictly protect at least a third of the EU's protected areas (representing 10 % of EU land), including all remaining EU primary and old-growth forests; and to (iii) effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring them appropriately. Designations should help to complete the Natura 2000 network or national protection schemes. As part of its new EU Nature Restoration Plan, the Biodiversity Strategy demands further that the share of forest areas covered by management plans should cover all managed public forests and an increased number of private forests, and biodiversity-friendly practices such as closer-to-nature-forestry should continue and be further developed. To support this, the Commission will develop guidelines on biodiversity-friendly afforestation and reforestation and closer-to-nature-forestry practices. This will be done in parallel with the adoption of the new EU Forest Strategy in 2021 (EC 2020).

Governing the forest biodiversity nexus through EU rural development funding policies

Beyond the project-based EU funding scheme under the LIFE+ instrument for the environment, the majority of the potentially available EU-level funding for nature conservation is provided by the EU Rural Development Policy (RDP). Following an integrated approach, the RDP funds should compensate landowners and forest managers for the costs associated with the implementation of conservation measures in the designated Natura 2000 sites in (managed) forests. Yet, research shows that different factors related to implementation (particularly the short time-horizon for planning and monitoring) prevents the use of these funding opportunities for biodiversity conservation (de Buren *et al.* 2016), and moreover, countries tend to prioritize competitiveness of the agricultural and forest sectors rather than biodiversity conservation in their allocation of the available resources (Geitzenauer *et al.* 2017; Sarvašová *et al.* 2017; Sarvašová *et al.* 2018; Weiss *et al.* 2017a). No data exists, however, to quantify the biodiversity effects of forest management practices supported by EU rural development funds (Alliance Environment 2017). This situation results in a funding gap that is not filled sufficiently by national or alternative funding sources and existing funds. For the EU programming period 2014–2020, there are two relevant financial measures from RDP available: one specifically for Natura 2000 forest areas (M12.2) and another more general one for forest protection and the provision of forest ecosystem services (M15). However, by the end of 2017 M12.2 had been chosen to be implemented in only 10 Member States (Weiss *et al.* 2017a). There are also problems in defining the baseline forest management requirements (above which compensation payments are calculated) making implementation even more difficult (Alliance Environment 2017). Hence, the effectiveness and efficiency of EU rural development funding in terms of supporting an integrated approach towards forest biodiversity conservation remains a challenging endeavour (Sarvašová *et al.* 2017)

Governing the forest biodiversity nexus through the national level

The previous section suggests that the implementation of biodiversity conservation measures in forest management depends on several conditions at the

Tab. B 3.1. Regional patterns of forest management and policy across Europe (adapted after Glück 1994; Kankaanpää and Carter 2004; Rametsteiner *et al.* 2008; Volz 2002; Winkel *et al.* 2011, pp. 366–367).

Policy paradigm	**Sustainable Timber Production**	**Multiple Service Forestry**		**Ecosystem Management**	
Goal	Focus on periodic timber yields	Focus on periodic yields in terms of timber and other forest services		Focus on ecological improvement or maintenance of forests	
	Regional patterns				
Regions (selected countries distributed approximately)	**Northern Europe**	**Western, Central and Eastern Europe**	**Western Europe**	**Southern Europe**	**Western Europe**
	Sweden Finland Estonia	Parts of France Croatia Romania Austria	United Kingdom Germany Switzerland	Parts of France Parts of Spain and Portugal	Parts of Portugal and Spain Italy Greece	Belgium The Netherlands Luxembourg
Forest area (relative share)	Large	Medium	Small	Medium	Small
Economic importance forest sector	Great	Moderate	Little	Little	Little
Key services of forest ecosystems for society	**Wood production** **Other services** (recreation, biodiversity) mostly in protected areas	**Wood production** **Other services** (recreation, biodiversity) partly integrated in sustainable forest management, partly in protected areas	**Wood production** **Other services** (recreation, biodiversity) or products also important Semi-natural forests for recreation and biodiversity	**Different forest products** (e.g. game, fuelwood) Other forest services (e.g. soil and water protection)	**Nature conservation and recreation** **Wood production**

national and regional level, such as different ecological (climatic, topography, vegetation) conditions, different forest policy priorities and socio-economic developments, forest ownership structures, and forest management traditions (Schulz *et al.* 2014; Winkel *et al.* 2011; Winkel and Sotirov 2016). National and even sub-national forest policy frameworks evolved over decades and different variants of an SFM paradigm have been formulated in domestic forest law and reinforced in national forest strategies to meet the variety of increasing and often competing societal demands towards the forest. SFM, which is often put on equal footing with the paradigm of 'Multifunctional Forestry' (MFF), also known as 'Multi-Purpose', 'Multifunctional' or 'Multiple Services' Forestry (Borrass *et al.* 2017; Wiersum 1995; Winkel *et al.* 2011) is the key management and behavioural principle at the operational level in forestry practice (MCPFE 1993).

Integration of biodiversity conservation into forest management within different forest management traditions

Table B 3.1 illustrates the important variety in the understandings of those forest policy paradigms amongst the different regions of Europe, which can be characterised by a 'segregation–integration' continuum. The first approach towards forest biodiversity in the 1980s followed a segregative paradigm: forest areas were taken out of utilisation (Bennett 2015). In some European countries adhering to the 'sustainable timber production tradition' (e.g. parts of France, Ireland, Lithuania, Latvia, Sweden, Finland), this is still the dominant approach.

In many other countries, however, the main policy paradigm is to strive for the combined delivery of economic functions of forestry (e.g. timber production) and nature conservation within the same forest areas (spatial integration). Yet, segregation

also plays a role in these countries. For instance, the German federal biodiversity strategy of 2007 aims, next to integrated forest management, at setting aside of 5 % of all forests as strict nature reserves. This goal is heavily debated between nature conservation and forestry experts (Umhauer and Sotirov 2019) and also not accepted at some sub-national contexts (e.g. in Bavaria), where a strongly integrative approach is emphasised partially in opposition to segregative nature conservation (Sotirov and Storch 2018). Such integrative forest management concepts have been elaborated since the 1990s, i.e. even before the implementation of the Natura 2000 programme, particularly but of course not exclusively in these contexts (Borrass 2014; Borrass *et al.* 2017). They are gradually becoming more and more elaborated (compare Selzer 2018, for state forest concepts in Germany) and are also combined with corresponding financial support instruments for the private forest (compare for example Heilingbrunner *et al.* 2013, for a description of the Austrian Forest Ecology Program). Chapters B10 (Höltermann) and B 11 (de Sassi *et al.*) and Box B 1 in this book provide a detailed account of the respective national forest biodiversity provision and strategies, particularly for Switzerland and Germany.

In the Netherlands, which is rather an example of the 'ecosystem services management' tradition, most of the forest area lies within Natura 2000 protection sites or is part of the National Ecological Network. This implies a strong commitment to an integrated forest management approach that emphasizes natural processes, biodiversity conservation and the 'beauty' of the forested landscape (Sotirov and Storch 2018).

More recently, 'Integrated Forest Management' (IFM) has been promoted as a promising approach to help integrate and find a balance between production and conservation aspects in forest management at different management levels, e.g. landscapes, forest stands, or single trees (Aggestam *et al.* 2020; Kraus and Krumm 2013; Lazdinis *et al.* 2019; Sotirov and Arts 2018). There is no common or shared definition about these scales, and, de facto, integrative forest policy principles are frequently implemented through segregating forest uses at the forest management level. Examples include the establishment of spatial and functional 'forest groups' of biodiversity conservation and water protection in Lithuania (Hinterseer *et al.* 2014), the extension of forest protected areas in Bulgaria and Slovakia, and also economically-oriented forestry practices or the separation of commercial forest managed for timber production from biodiversity hotspots in Bulgaria, France, Slovakia, and Sweden (Brodrechtova *et al.* 2018; Brukas *et al.* 2018; Deuffic *et al.* 2018). Likewise, Hautdidier *et al.* (2018) demonstrate that private forest owners, public forest managers and local forest industries in southwestern France (Landes de Gascogne) support *Pinus pinaster* monocultures as part of a cultivated, multifunctional and integrated forest landscape in a shared conviction that timber production is essential for and should be able to pay for a variety of environmental and social forest ecosystem services (biodiversity conservation, climate change mitigation, hiking, mushroom picking).

Implementation success and problems

An examination of best-practice examples from the Natura 2000 context (Sotirov *et al.* 2017) reveals that successful implementation is fostered by the involvement of and cooperation with various stakeholders, landowners, and forest managers, as well as the coordination between public agencies and other state organisations. The importance of a participative and inclusive approach is also confirmed elsewhere (Blondet *et al.* 2017).

Yet, it needs to be emphasised that the implementation of Natura 2000 is connected to several challenges (Winkel *et al.* 2015), ranging from trade-offs with wood production to conflicts related to forest management paradigms (sustainable wood production or conservation) or climate change impacts, and which significantly compromise the conservation effectiveness of the policy (Winter *et al.* 2014). Good examples of forest species management are mainly driven by conservationists' interest or arise from 'win–win' situations, in which species conservation depends on more open habitats that can be provided by timber production and may additionally be supported by compensation payments. Further, the most successful examples of Natura 2000 forest habitat management can be found in non-commercially managed public forests, which are ecologically valuable (Sotirov *et al.* 2017).

Beyond these best-practice examples, it still heavily depends on the previous forest management paradigm, whether or not forest biodiversity can be implemented by combining segregative and integrative approaches. Sergent *et al.* (2018) and

Sotirov and Storch (2018) show that even though multiple services forestry is a primary forest policy objective in countries such as France, Germany, Ireland, Sweden, and Portugal, policy and management practice puts a main priority towards wood production, and environmental policy objectives (and biodiversity conservation in particular) are still frequently considered as a constraint or even threat to (production-oriented) management practices in managed forests.

Accordingly, it cannot be taken for granted that policy objectives geared towards multifunctionality and the integration of biodiversity conservation in forest management are implemented in forest management practices on the ground. While financial incentives are important for a large share of the forest owners for participating in biodiversity programs, a large minority cannot be particularly motivated by compensation payments (Boon *et al.* 2010). Deuffic *et al.* (2018) report that the 228 forest owners interviewed in 10 countries (Bulgaria, France, Germany, Ireland, Italy, Lithuania, the Netherlands, Portugal, Slovakia, and Sweden) adopt more easily those forest and forest-relevant policies, which support or enable their own management objectives and practices, and tend to reshape or ignore the remaining rules, norms and incentives. They also diagnose a division among private forest owners in the countries under study: while about 40 % of them are opposed to EU and national policies for the conservation of forest habitats and species under the Natura 2000 network of protected areas, about 20 % trust in the success of integrating both timber production and biodiversity conservation. Although Maier and Winkel (2017), Sotirov *et al.* (2017) and Joa and Schraml (2020) find strong support for the more general idea of (integrated) biodiversity conservation amongst German public forest managers and non-state Forest Biodiversity respectively, they also establish that the corresponding conceptions can differ very much (compare also Cosyns *et al.* 2020) which can be an indication for challenges in implementation. For the diffusion of biodiversity conservation efforts, the local advisors (Korhonen *et al.* 2013) and local cooperative groups of forest owners (Herzele and Aarts, 2013) are supposed to be key, while scarce resources and wood production targets can be key obstacles (Maier and Winkel 2017).

Conclusion

This chapter has elaborated on the structure and integration of norms, rules, and practices regarding forest biodiversity conservation at different levels. fig. B 3.2 provides an overview over the legal provisions and policy instruments, implementation strategies and voluntary concepts that have been or usually are put forward at different levels of government within different contexts. While important impulses were given at the international, particularly the EU-level, by nature conservation policy (EU Birds and Habitats Directives/Natura 2000), there is also a history of integrative forest management concepts that have emerged more from within the forest sector, partially in response to external pressure (Borrass *et al.* 2017). Such concepts are growing in number and quality, and are increasingly based on a mix of instruments and implementation strategies. Whether the overall Forest Biodiversity strategy in a country relies on an integrated forest management approach or rather follows a more segregative approach very much depends on the particular interpretation of SFM in the country, which is again linked to factors such as the economic importance of the forest sector, forest policy priorities, and the forest ownership structure.

Of all the international rules and guidelines mentioned, the EU's nature directives have most prominently and effectively shaped forest biodiversity provisions in EU member states. They have either initiated new or fuelled already existing forest biodiversity strategies and concepts that are relevant also beyond Natura 2000 sites. Depending on the political system in which forest policy in a country is embedded, forest biodiversity strategies are developed either at the national or the sub-national level. They are often developed in cooperation with actors from the public forest and they vary with respect to the ambition of objectives they formulate for a selection of more integrative (such as habitat trees) as well as more segregative (such as nature forest reserves) management options, including historical management forms and 'sparse forest', for example. They also are likely to be more or less comprehensive, e.g. by emphasising the spatial distribution and network character of protected areas and objects.

Beyond the public forest, however, a key aspect of successful integration is – next to the general

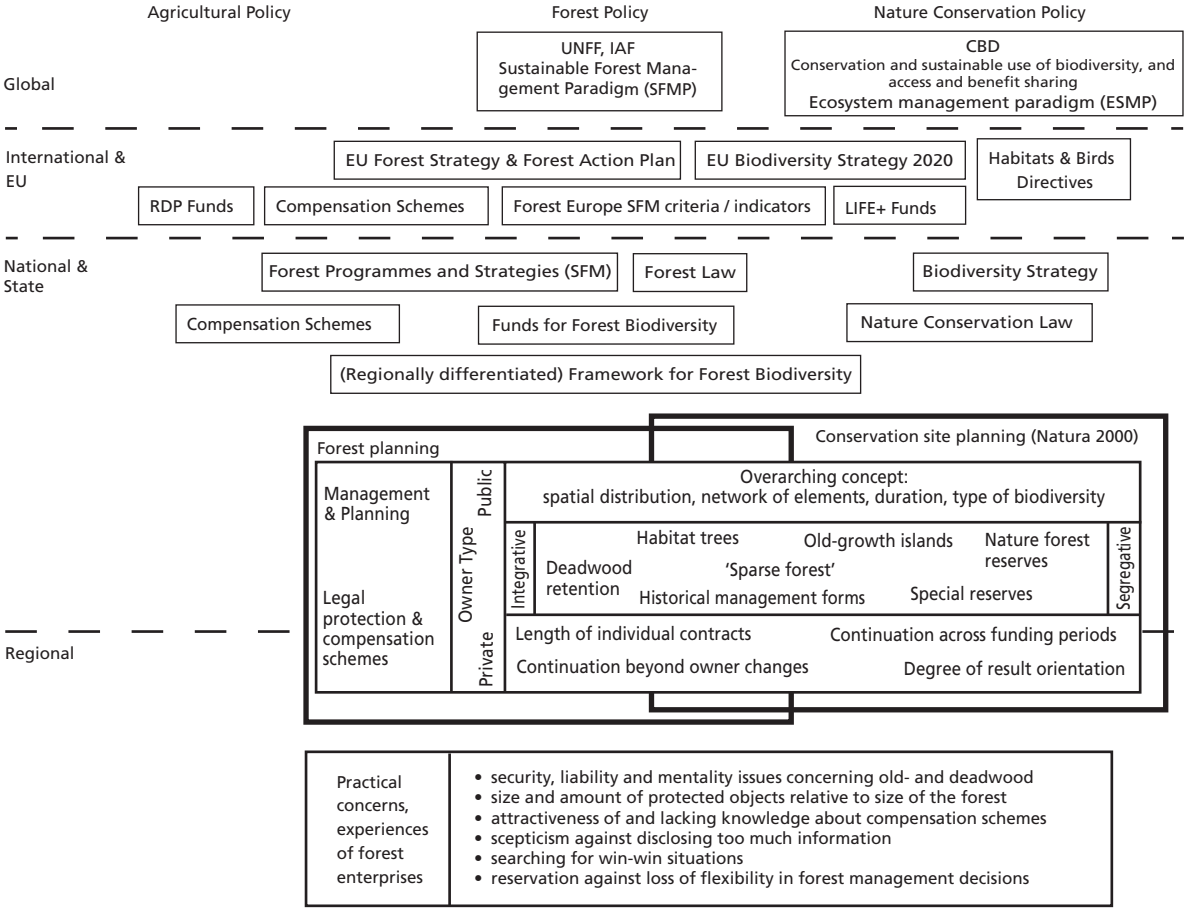

Fig. B 3.2. Regulation, strategies, and concepts supporting forest biodiversity at different levels by integrating agricultural, forest and nature conservation policies (ignoring further relevant policy fields, such as water, recreation, etc.).

interest and support by private landowners – the design of compensation schemes. Financial support under Natura 2000 is largely dependent on the availability and use of EU financial resources earmarked for support in agriculture and rural areas. This dependence can create competition and goal conflicts between agricultural, biodiversity, and forestry objectives resulting in a lack of, or non-use of funding opportunities for forest biodiversity. Economically motivated private forest owners are more likely to participate if, on the one hand, the duration of the contract is not too long and thus allows for periodic adaptations and if, on the other hand, the contracts can be expected to be extended in a possibly amended form as there exists a commitment to fund the general programme in the long term (Kownatzki *et al.* 2017). Particularly more segregative approaches need a longer time-horizon, and thus legal protection securing management restrictions beyond owner changes are essential in that realm. What could also increase acceptance among forest owners are more results-oriented compensation schemes, which are at least Strategy contingent on frequencies of species appearing in the forest after the implementation of a measure (Franz *et al.* 2018a). The standard approach is still to compensate for management restrictions implemented, though. In any case, however, sufficient capacities and favourable organisational structures at the sub-national level are usually supportive of a closer coordination between nature conservation and forest actors in designing innovative instruments that are better embraced by the addressees.

Nature conservation integrated into forest policy in federal states: Switzerland, Germany, and Austria compared (Tobias Schulz and Hannes Cosyns)

In federal states, the implementation of forest biodiversity conservation measures is usually subject to negotiations and interactions between different policy levels. While in Germany, the single states (and the state forest enterprises) are responsible for setting up their own forest biodiversity conservation policies, in Austria it is the federal level (as well as the federal forest enterprise) that decides about the forest biodiversity programme. In Switzerland, competences are shared between the cantons and the federal state. However, in all countries, forest biodiversity conservation policy has been accelerated at least partially by an impulse 'from above', and related responses from the subnational levels 'from below':

Germany

The German national forest policy is limited to a framework that grants much discretion with respect to forest biodiversity conservation to the German states. Since the 1980s, the states have gradually developed their own forest biodiversity rules (Borrass *et al.* 2017). Many of the German states own a large share of the forest area (from about 15 % to up to 50 %), and not least due to the legal 'common welfare' obligation of the state forest organisations (Rehbinder 2019), forest biodiversity concepts were developed for the state forest, often in connection to close-to-nature forestry concepts – the latter also have strong roots in private forestry in Germany. These concepts also became relevant for the implementation of EU biodiversity policy (Borrass *et al.* 2015; Sotirov and Arts 2018), and have in response to legal, policy, and public pressure – and progress in research – developed further in the last decade (Petereit *et al.* 2019; Selzer 2018). While these state forest biodiversity concepts are binding, it turns out that district forester's personal priorities as well as temporal and financial restrictions can constrain implementation considerably (Maier and Winkel 2019). For the private and also for the so-called 'corporation forest' (forest owned by municipalities, churches etc.), the German federal states have initiated their own contractual nature conservation programs (Franz *et al.* 2018b) that often build on the existing rules for the state forest but have been adopted to better suit the private forest. The respective means are usually shared by funding from the EU regional development fund and a contribution of the sub-national level (Demant 2018; Franz *et al.* 2018b), although some states have decided to abstain from EU co-funding, inter alia as the rules for implementation and enforcement are not seen as being adapted to the peculiarities of the forest (de Buren *et al.* 2016).

Switzerland

Switzerland's forest policy has always been rather decentralised. Accordingly, programs to promote forest biodiversity had been developed quite early by some cantons. As private forests account for about 30 % of the forest surface and those owned by municipalities, corporations and, civic communities for about 60 %, policy design cannot rely on the expertise of large state forest enterprises as in Germany. With the integration of the national forest administration into the national nature conservation administration, the capacities for forest biodiversity conservation have been strengthened at that level. A large participatory process to elaborate the Swiss Forest Programme in 2004 had resulted in a first draft of close-to-nature forestry rules (Kaufmann *et al.* 2010) of which some elements are now part of the federal contractual forest nature conservation programme. Since 2008 the latter is co-financed through the national equalisation program (NFA), which gives the federal level more competences for forest biodiversity, as it requires the formulation of regionally differentiated objectives and implementation guidelines (Imesch *et al.* 2015) at the national level. The final policy design, however, is negotiated with the cantons in so-called 'programme agreements' (Walker and Roose 2016). Accordingly, the canton's degree of discretion in choosing their own mix of instruments (which may or may not be based on the canton's own forest biodiversity strategy) is relatively high.

Austria

In Austria, the single states (Länder) and even the municipalities do not own forest and virtually all public forest belongs to the federal forest enterprise (Österreichische Bundesforste, ÖBf), which is very active in forest biodiversity conservation and has elaborated its own guidelines (Fischer *et al.* 2017). However, as about 80 % of the forest area are privately owned, setting up a support scheme for forest biodiversity conservation is key. Forest policy is centrally organised in Austria, while nature conservation policy is vested with the states (Hogl and Nordbeck 2007). Hence, a federal support scheme existed since 2007 and was based on co-financing by the EU regional development fund. However, the implementation of Natura 2000 at the state level, apart from being highly conflictive (Geitzenauer *et al.* 2016), revealed incompatibilities between the requirements of the EU funding scheme and the needs of the implementing actors (Jaritz 2011). A strongly participative forest biodiversity conservation programme was thus started at the federal level that introduced innovations for the implementation and financial support in private forests (Heilingbrunner *et al.* 2013). The implementation of the programme remains challenging, though, and thus strongly dependent also on the collaboration between the state nature conservation and state forest administrations in order to coordinate respective financial support instruments (Fuchs 2017).

The future will show how biodiversity conservation in Europe's forests will develop given distinct incentives for forest management across the continent. Assuming that incentives for forest biomass use in support of the bioeconomy will not decline in the next decades, and, at the same time, societal preferences for nature conservation will likely rather increase than decrease, integrated approaches may be gaining ground across the continent and may also meet the expectations and preferences of more and more forest owners and managers. Yet, their definition and practise will, at least partially, remain bound to national and even local contexts, and importantly a substantially supportive policy framework will be needed to ensure that integrative forest policy goals do indeed transfer into integrative forest management practices.

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Implications of forest ownership changes for forest and biodiversity governance and management

B 4

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Changing forest ownership in Europe has implications for forest management and biodiversity. Drawing on the results of the European Cooperation in Science and Technology (COST) Action FP1201 FACESMAP (Forest Land Ownership Change in Europe: Significance for Management and Policy) we present the current ownership structures in four European countries: Austria, Germany, Sweden, and Switzerland. These countries were selected because the proportion of forested land is at least one-third of the total land area and because they differ in the proportion of forest that is in private ownership. We describe recent changes in ownership structures and discuss the implications that these changes could have on forest governance and management with a special focus on biodiversity.

Introduction

Multifunctional forests that provide biodiversity as well as diverse other services to society (such as water purification, CO_2 mitigation, recreation, and protection against natural hazards) have been placed at the core of forest policies of many European countries (Forest Europe 2015). In 2019, the European Commission stipulated through the European Green Deal (EC 2019) that forests need to improve both in quality and in quantity for the European Union to reach climate neutrality and a healthy environment (EC 2019, p. 13). The Green Deal also emphasised the importance of restoring biodiversity and ecosystem services. Through effective afforestation and forest preservation, as well as restoration in Europe, the European Commission aims to reach these goals (EC 2019, p. 13). These measures are also, in part, contingent on forest management, which in turn is dependent on forest ownership.

< Fig. B 4.1. The great variety of forest ownerships across Europe, from small-scale private to very large-scale professionally managed properties is a real challenge to develop common strategies in forest management. However, the effect that local people take responsibility and work in their forests contributes to a basic knowledge of society on forestry. The variety of small-scale management approaches leads to diverse structures that may promote nature conservation (Photo: Flurina Rigling, Hedingen).

In the last three decades, forest ownership has been changing across Europe (Živojinović *et al.* 2015) as a result of a variety of societal and political developments, such as structural changes in the agricultural sector, changes in lifestyles, privatisation, and restitution (Weiss *et al.* 2017). The flux in ownership has led to challenges for forest management and, consequently, the provision of forest services, and in particular biodiversity. On the one hand, there is a growing number of new forest owners, who mainly own small forest areas, live in urban areas, and lack agricultural or forestry knowledge (Živojinović *et al.* 2015; Weiss *et al.* 2017). These new forest owners often lack the motivation and/or knowledge necessary to actively manage their forests (Živojinović *et al.* 2015) or have objectives other than economic use of their forests, such as nature conservation, as is shown in Switzerland. This may have positive implications for biodiversity (Walker and Artho 2018). On the other hand, new private owners are emerging who are willing to manage the forests, bringing fresh interests, new management goals (e.g. non-income oriented),

attitudes (e.g. regarding forest functions), skills and capacities that have differing impacts on biodiversity (Weiss *et al.* 2017). In this chapter, we just address one question:

What are the implications of forest ownership changes for forest and biodiversity governance and management?

The interactions between changing ownership, governance and management approaches were investigated in the European Cooperation in Science and Technology (COST) Action FP1201 FACESMAP (Forest Land Ownership Change in Europe: Significance for Management and Policy (Živojinović *et al.* 2015)
(2012–2016). Drawing on the results of FACESMAP we present the current ownership structures in four European countries: Austria, Germany, Sweden, and Switzerland. These countries were chosen because the proportion of forested land is at least 30 % of the total land area, and because the proportion of private forest ownership in each of the countries is different. In this chapter, we describe the current ownership structures in the selected countries and the recent changes in ownership structures, and discuss the implications that these changes could have on forest governance and management with a special focus on biodiversity.

Ownership structures in Austria, Germany, Sweden, and Switzerland

To understand ownership changes in Europe, it is important to have an overview about the current ownership structures. Table B 4.1 shows a synopsis of the ownership structure in the selected four countries.

There is a striking difference between the countries with a high proportion of privately-owned forest and a low proportion of state-owned forest (Sweden, and especially Austria), and the countries with a lower proportion of privately-owned forest and a high proportion of state-owned forest (Germany and Switzerland). We also find that in Switzerland and Germany private forest owners own on average small forest areas (e.g. 2.5 ha in Germany and 1.4 ha in Switzerland), resulting in diverging management philosophies, including a lack of any management (BMLFUW 2015). In Austria, 40 % of the private forest owners own less than 3 ha (BMEL 2017). In Germany, the vast majority of private forest owners own less than 20 ha (Koch and Maier 2015). In Sweden, the average plot owned by private forest owners is 47 ha (Swedish Forest Agency 2018). A difference in the forest ownership in Switzerland is that around 2.5 % of the total forest area is under mixed ownership, meaning that public and private actors share ownership (Landolt *et al.* 2015).

Changes in ownership structures

Table B 4.2 shows the trends in forest ownership change, as identified by experts during the FACESMAP project. The main trends identified were: (i) restitution (the return or sale of state forest land to the original/rightful private owners); (ii) privatisation of previously state-owned companies); (iii) changes in forest ownership through transfer of land ownership; (iv) changes in forest ownership through change of land use; and (v) changes in forest ownership through changing lifestyles, motivations, and attitudes (Weiss *et al.* 2017).

Not all trends are equally important for all four countries selected (Table B 4.2). Only the 'changing lifestyles, motivations, and attitudes of forest owners' is a main trend of change across all four countries. This means that there is a trend towards increasingly urbanised owners that lack the technical skills and equipment, as well as time to manage their forests (Koch and Maier 2015). In Austria, there is a growing share of 'new' or 'non-agricultural forest owners' because of structural changes in the agricultural sector. Since 1960, the share of farm enterprises has decreased from 400 000 to 220 000 in 1999 (Weiss *et al.* 2015). Additionally, the ratio of two-thirds of Austrian farms being operated on a full-time basis and one-third being operated on a part-time basis has reversed (Weiss *et al.* 2015). Even though there are structural changes regarding ownership structures in Austria, the market for forest land is currently not active (Weiss *et al.* 2015). In Germany, privatisation or restitution of forest land was a main trend after the reunification of West and East Germany. This means that in East German states, state-owned forests were privatised, resulting in new private forest owners and more heterogeneous small-scale private forest ownership (Koch and Maier 2015). However, no further data on private ownership changes are available. In Sweden, in the last 20 years the total number of forest owners has decreased by 6 % (Swedish Forest Agency 2013). However, the main trend

identified in Sweden is in the increased use of contractors, meaning that private forest owners outsource forestry operations to reduce the need for large investments in expensive machinery. It is estimated that between 1993 and 2009, the number of forestry contractors has increased by 80 % and the number of employees working for contractors has increased by 157 % (Lidestav *et al.* 2015; Häggström *et al.* 2013). In Switzerland, between 1970 and 2017, the number of private forest owners has decreased from 260 000 to 245 720 (a decrease of 5.5 %), and the number of public forest owners decreased from 3900 to 3381 (a decrease of 13.3 %) (FOEN and FSO 2018).

Table B 4.1. Synopsis of current ownership structures in Austria, Germany, Sweden, and Switzerland. Source: Compiled by authors based on sources provided in the table.

	Austria	**Germany**	**Sweden**	**Switzerland**
Total area	8.4 million ha	35.7 million ha	41 million ha	4.1 million ha
Forest area	3.99 million ha	11.4 million ha	28 million ha	1.28 million ha
Forest share (%)	48 %	32 %	68 %	31 %
Growing stock	30.4 million m³	121.6 million m³	3.3 billion m³	10 million m³
Share in private ownership (incl. private companies)	80 %	48 %	72 %	27 %
Share owned by the state (incl. local, regional, and national governments, state-owned companies)	15 %	52 %	22 %	70 %
Share of other ownerships (e.g. foundations, mixed ownership)	5 %	0 %	6 %	3 %
Number of private owners	145 000	2 million	327 727	240 000
Average forest area per private forest owner	< 3 ha	< 20 ha	47 ha	1.4 ha
Sources	BMLFUW (2015)	BMEL (2017); Koch and Maier (2015)	Swedish Forest Agency (2018)	FOEN and FSO (2018)

Table B 4.2. Trends in forest ownership. 0 (not relevant); 1 (to some extent); 2 (rather important); 3 (highly important). *In the case of Sweden, forest owners outsource mechanised forestry operations to contractors to reduce costs. Source: Compiled based on information from Živojinović *et al.* (2015).

Trends in ownership change	**Austria**	**Germany**	**Sweden**	**Switzerland**
Privatisation, or restitution, of forest land	0	2 (in former East Germany) / 0 (in Western Germany)	1	0
Privatisation of public forest management	1	2	2	0
New private forest owners who have bought forests	1	1	1	0
New forest ownership through afforestation of formerly agricultural or waste lands	0	1	0	1
Changing lifestyle, motivations, and attitudes of forest owners	3	3	2	3
Other trends			3*	

Fig. B 4.2. Camping in the own forest. An alternative way to utilise private forests (Photo: Guillaume de Buren).

Forest governance and management

Forest governance shapes forest management. Governance can be understood as a means of steering and regulating societal behaviour – here specifically in relation to human access, use and impact on forests (Kooiman 2003). Key dimensions of governance include: the degree of state intervention; the actor's (e.g. forest owner, manager) role and responsibility in managing their forest; new approaches (such as novel tools of communication and collaboration); and types of forest policy instruments. The degree of state intervention refers to how much the state frames or influences forest management. Either the forest owner themself can assume responsibility for forest management or they can delegate it to someone else. The types of policy instruments are differentiated between regulatory, marked-based, or persuasive instruments. These instruments can strongly shape forest management and subsequently the fulfilment of forest functions. Table B 4.3 and Table B 4.4 provide an overview of the degree of state intervention, the responsibility of the actor, and the current policy instruments with regard to ownership changes and biodiversity promotion in the countries from the FACESMAP project. Each of the criteria is described based on a literature review of the sources referred to in Table B 4.3 and Table B 4.4. For this project, each country described forest ownership, forest management approaches, and the policies influencing ownership. In this context, it is important to mention that a weakness of both tables, from a comparative point of view, is that these reports have not been elaborated in a way that allows strict comparison of all aspects. The results of this comparison have to be carefully interpreted as not all policy instruments used are stated in the reports (e.g. subsidies from the EU). The approaches include private and public forest management initiatives such as forest owner associations and cooperations with private owners.

The degree of state intervention in Austria, Germany, Sweden, and Switzerland varies between public and private, as well as between large- and small-forest ownership categories. In Austria, state intervention in public forests is potentially large, although these forests are managed by a private law organisation (Österreichische Bundesforste AG; Austrian Federal Forests). Large holdings managing

Table B4.3. Degree of state intervention and responsibility for forest management for Austria, Germany, Sweden, and Switzerland. Sources: Compiled by authors based on the sources stated in the table.

Criteria	Austria	Germany	Sweden	Switzerland
Degree of state intervention in forest management	Low degree of state intervention (small < 20 ha) High degree of state intervention (large > 200 ha, public forests) Forest management plans are mandatory for larger holdings, not in private forests. Forest owners are obliged to be a member of the Chamber of Agriculture (Landwirtschaftskammer Österreich). Large forest holdings need to have a trained and state approved forester.	Low degree of state intervention (private) High degree of state intervention (public) The defined forest management requirements by the Federal Forest Act are not as demanding for private forests as the requirements related to public forests. Public forests: (i) mandatory management plan for a period of 10 to 20 years; (ii) a forest inventory assessment is needed to provide the basis for harvesting, thinning, and regeneration measures; (iii) monitoring systems, ownership responsibility, and high training standards of forest professionals make sure that forests stay in good condition.	Low degree of state intervention No mandatory forest management plans; however, many forest owners have a management plan (often made by the Swedish Forest Agency, forest owner associations, or other forest consultants). The plan is done externally and forest owners pay for the service.	Low degree of state intervention (small < 2 ha, mainly private) High degree of state intervention (large > 2 ha, mainly public) Forest management plans are mandatory. Owners of very small plots (< 2ha) are exempted from the requirement to produce a management plan. Cantonal forest authority approves the plan.
Responsibility for public forest management	3 categories: communal or municipal (local governments), provinces, and national. National level forests are managed by the Austrian Federal Forests (Österreichische Bundesforste AG) Municipal or province level the community or province assumes the management of the forests.	State-owned companies or forest administrations are entrusted with the management of state forests. Forest professionals manage the forests.	Municipal executive board takes decisions for municipal forests.	Public forests are managed by professional foresters employed by the owners.
Responsibility for private forest management	Owners manage the forests. Owners of small-scale forests do the planning and operations by themselves. Larger holdings employ a professional forester. Forestry operations are outsourced.	Owners manage the forests independently and on their own, or the forests are not managed at all. Increasing trend to outsource forestry operations.	Owners manage the forests. Forestry operations are outsourced to large-scale companies, contractors, or timber merchants. Forest owner associations manage the forests, look after economic interest of forest owners, consider environmental issues, transport timber to the Swedish forest industry, offer service advice and training.	Owners manage the forests on their own, let someone else manage their forests, or the forests are not managed at all.
Sources	Weiss *et al.* (2015)	Koch and Maier (2015)	Lidestav *et al.* (2015)	Landolt *et al.* (2015); Imesch *et al.* (2015)

Table B4.4. Management approaches and policy instruments for Austria, Germany, Sweden, and Switzerland. Sources: Compiled by authors based on the sources stated in the table.

Criteria	Austria	Germany	Sweden	Switzerland
Management approaches for new forest owners	Increase the available information on the forest resources and the communication of this information primarily in order to increase wood mobilisation.	No data available.	No data available.	Private forest owner associations & cooperations (e.g. for efficient forest management). Collaborations within municipalities (e.g. for joint management to reduce fixed costs).
Types of policy instruments used (with regard to ownership changes, forest management, and state intervention)	**Regulatory instruments** (hinder fragmentation) **Marked-oriented instruments** (subsidies at EU level to: promote afforestation, support management planning and forest associations) **Persuasive instruments** (advisory service of Chamber of Agriculture)	**Regulatory instruments** (in agriculture and rural development to slow down socio-economic processes affecting ownership change; administrative permit (> 1 ha) is needed for selling land) **Marked-oriented instruments** (the state of Bavaria subsidises forest associations) **Persuasive instruments** (to advise new forest owners about how to manage the forest)	**Regulatory instruments** (hinder fragmentation of forest holdings) **Market-oriented instruments** (between 2007 and 2013 the state paid subsidies to improve competitiveness in forestry; promote merging of holdings into larger units) **Persuasive instruments** (the state offers advice to new forest owners in how to manage the forest)	**Regulatory instruments** (permit to fell trees, prohibition for clear cuttings, prohibition of measures that harm forest functions) **Market-oriented instruments** (subsidies for different measures concerning the maintenance of the functions of forests) **Persuasive instruments** (information and education via seminars about proper management measures)
Policy instruments for forest biodiversity (all forest owner types)	Natura 2000[1] Biodiversity Strategy EU[2] Biodiversity Strategy Austria 2020+[3]	Natura 2000 Biodiversity Strategy EU Forest Strategy 2020[4]	Natura 2000 Biodiversity Strategy EU Forests and Forestry in Sweden 2015[5]	Swiss Biodiversity Strategy and Action Plan[6] Forest law[7]
Examples of other activities promoting biodiversity (e.g. NGO's or foundations creating nature reserves)	Naturschutzbund Österreich (Nature conservation organisation) – e.g. acquire and manage forest land for conservation purposes[8]. Pro Silva Austria- e.g. pursue conservation of biological diversity in forests[9].	NABU (Nature conservation organisation) – e.g. acquire and manage forest land for conservation purposes (NABU Waldschutzfonds) Bundes Bürger Initiative WaldSchutz – e.g. propose new forest reserves[10].	Swedish Society for Nature Conservation – e.g. goal of increasing the proportion of protected forest in Sweden to 10 %. Private forestry companies (e.g. Bergvik Skog) – e.g. allocate a certain amount of voluntary set-asides for conservation measures.	ProNatura (Nature conservation organisation) – e.g. looks for forest owners who would give up part of their forests for forest reserves[11]. BirdLife Schweiz – e.g. campaign to promote diversity in the forest (several projects)[12].
Sources	Weiss *et al.* (2015)	Koch and Maier (2015)	Lidestav *et al.* (2015)	Landolt *et al.* (2015); Imesch *et al.* (2015)

public forest areas larger than 200 ha need to have a management plan. For public forest areas smaller than 20 ha and for private forest owners, this is not compulsory. For forest areas between 20 to 200 ha the degree of state intervention is unclear. However, all forest owners are obliged to be a member of the Chamber of Agriculture (Landwirtschaftskammer Österreich).

In Germany, the degree of state intervention is large in public forest areas. Managers need to apply pre-defined measures for forest management. For example, they need to have a management plan for the upcoming 10 to 20 years, which is approved by the local forest authority. Additionally, they have to carry out a forest inventory to provide the basis for harvesting, thinning, and regeneration measures. These pre-defined measures do not apply to private forests.

In Switzerland, in public forest areas larger than 2 ha, a high degree of state intervention is found. In these areas, a mandatory forest management plan is needed that is approved by the cantonal forest authority. The degree of state intervention in private forests is low (e.g. no mandatory management plan is needed).

In comparison to Austria, Germany, and Switzerland, there is a low degree of state intervention in any type of forest ownership in Sweden. In the Swedish forest policy it is stated "freedom under responsibility", which means that most things are advised but not compulsory.

In Austria, public forests at the national level are managed by the Austrian Federal Forests SC. At the municipal or province level the community or province assumes the management. In Germany, public forests are managed by state owned companies or forest administrations. These state owned companies or forest administrations entrust forest professionals with the management of their forests. In Sweden, a municipal executive board takes decisions for municipal forests. In Switzerland, professional foresters employed by the owner (e.g. canton, municipality) manage public forests. Private forest owners in all countries, on the contrary, have different strategies. Some private forest owners manage their forests on their own (e.g. Austria, Germany, Sweden, and Switzerland), others pay third-party providers or the forest administration (e.g. farmers, public foresters, private companies) to manage their forests and do the work (e.g. Austria, Switzerland, and Sweden) and some do not

[1] Natura 2000 – e.g. create a network of ecological protective areas in all of Europe, inhibit the degradation of these protective areas, introduce strong protection system for endangered species.

[2] Biodiversity Strategy EU – e.g. mandatory forest management plan including strategies for biodiversity, afforestation towards biodiversity, regulations concerning invasive species, subsidies for providing public goods and for ecosystem services in multifunctional forests, trade agreements including biodiversity goals, promotion of networks between forests and farmers to preserve landscape features and biodiversity.

[3] Biodiversity Strategy Austria 2020+ – e.g. Austrian Forest ecology programme, subsidies for the creation of old forested islands, transformation of non-natural forests to natural forests, creation of forest reserves.

[4] Forest strategy 2020 – examples of measures: promotion of areas without intervention, augmentation of deadwood proportion, creation of forest reserves, improvement of the network of Natura 2000, subsidies for voluntary agreement for forest reserves, subsidies for ecosystem services.

[5] Forests and Forestry in Sweden 2015 – examples of measures: equal importance to production goals and environmental goals, subsidies for measurements that increase the environmental value, designation of strictly protected forest areas, forest certification schemes, conservation consideration in all forest management, special programmes to preserve habitats for endangered species.

[6] Swiss Biodiversity Strategy and Action Plan – segregation (e.g. creation of forest reserves where biodiversity is the primary goal), integration in forest management (e.g. designation of old forested islands, optimise regeneration in terms of genetic diversity), specific measures for priority species and habitats in and around forest reserves or edge of forest (e.g. preserve habitat trees, improve and cultivate the edge of forest, restore and cultivate 'light' forests), other measures (e.g. promote knowledge, exchange/strengthen research concerning forest biodiversity).

[7] Forest Law: creation of forest reserves (10 % of total forest area), the cantons define the areas and the confederation provides financial aid for the establishment and maintenance of the reserves.

[8] https://naturschutzbund.at/weitere-projekte-die-wir-mit-spendengeldern-realisieren/articles/naturfreikauf-unterstuetzen-3216.html

[9] https://www.prosilvaaustria.at/naturnahe-waldwirtschaft/grundsaetze/4-erhaltung-der-biologischen-vielfalt-von-waldoekosystemen/

[10] https://www.bundesbuergerinitiative-waldschutz.de/unsere-positionen/waldmanifest/

[11] https://www.pronatura.ch/de/wald

[12] https://www.birdlife.ch/de/content/wald

manage their forest at all (e.g. Germany, Switzerland). Others choose to join forest owner associations (e.g. Germany, Sweden, and Switzerland) or are obliged to join by law (e.g. Austria). These associations provide a wide range of forest management services.

Consequences for forest management and forest biodiversity

As known, forests with a high biodiversity are resilient against natural hazards (Thompson *et al.* 2009). In this context, the degree of state intervention and the management approach used influences biodiversity and the resilience of forests. While a high degree of state intervention promotes the management of forests allowing a more diverse biodiversity, a low level of state interventions gives the possibility to prioritise other management goals (e.g. biodiversity conservation) than wood production. In the cases investigated, two types of forest management approaches are used: clearcut (the dominant approach in Sweden) and close-to-nature management (Austria, Germany, and Switzerland). While clearcuts can have a positive effect on biodiversity (increased number of plants and insects) and the diversity of species (quantitative increase) in the short term, close-to-nature management has a positive impact on biodiversity in the long term (qualitative increase).

Several measures are being used to promote biodiversity at the EU level (e.g. Austria, Germany, and Sweden) through the following non-legally binding guidelines and strategies: Natura 2000 and Biodiversity Strategy EU. Natura 2000 is enshrined in the national law of Austria and Germany. Subsequently, it is legally binding for both countries. Additionally, all countries investigated have their own national biodiversity strategy. The measures stated in these strategies vary from creation of forest reserves to designation of old forested islands. However, none of these strategies specifically address private forest owners. Additionally, to the national measures, there are private initiatives promoting nature conservation in the countries investigated. The measures vary from acquisition of forest land for nature conservation purposes to campaigns to promote biodiversity in forests. However, these private initiatives do not specify which type of forest ownership is addressed. In general, it is often public forest owners who shoulder the responsibility for applying biodiversity measures, as these forests are mainly managed according to societal demands.

The number of private forest owners is growing. These owners and their changing lifestyle, motivations, and attitudes have implications for forest management, and consequently for forest biodiversity (Živojinović *et al.* 2015). As shown, private forest owners of mainly small forested areas often have limited interest and time, and often lack the capacity to manage their forests (Landolt *et al.* 2015; Weiss *et al.* 2017), as they come from an urban environment bringing little or no agricultural or forestry knowledge (Živojinović *et al.* 2015). Consequently, forests are often not managed and the wood from the forests is underutilised. The underutilisation of wood affects its industrial use with implications for the timber and paper industry, as well as for production of wood energy (Weiss *et al.* 2015). The lack of management also places fulfilment of other forest functions at risk (e.g. CO_2 sequestration) and the possibility to adapt forest stands to the effects of climate change (Weiss *et al.* 2017; Koch and Maier 2015). Both aspects directly influence biodiversity. The lack of management has direct consequences on the variation in tree size, which is an important characteristic for preservation of biodiversity and habitat (Filyushkina *et al.* 2018). At least in the short term, the lack of management leads to darker and more dense forests with reduced variation in the size of trees. On the other hand, unmanaged forests often contain more deadwood, creating valuable habitat for species that depend on deadwood. Private forest owners consider biodiversity as important (Lidestav *et al.* 2015; Walker and Artho 2018). However, the way they promote biodiversity varies. In Sweden, for example, private forest owners assign greater value to preservation of 'virgin' forests (Lidestav *et al.* 2015). Thus, they are willing to stop harvesting operations in such areas or create nature reserves. In contrast, in Switzerland private forest owners have a high intrinsic motivation to manage their forests for biodiversity (Walker and Artho 2018). In all countries, having objectives other than wood production presents challenges to current forestry practices (Živojinović *et al.* 2015; Walker and Artho 2018).

The implications of the changing patterns of forest ownership, at least for Switzerland, are positive for other forest functions such as biodiversity,

groundwater filtration and wood energy, as the majority of private forest owners prioritise these goals (Walker and Artho 2018). This does not mean that the provision of biodiversity from forests is guaranteed, and it could be that, if private forest owners stop managing their forests, that these functions will not be fulfilled in the future. This development is seen also in other European countries participating in the COST Action (Živojinović *et al.* 2015). These findings are in line with previous studies showing that many of the new owners of small-scale private forest prioritise forest functions related to the protection of air, water and soil, biodiversity, and landscape more than income from timber and non-timber goods and services (Wiersum *et al.* 2005). However, the outcome of this prioritisation of functions has still to be investigated.

Conclusion and outlook

Forest ownership is changing in Europe and the changes are influencing the capacity of forests to provide forest functions (such as biodiversity). The growing diversity of forest owner types imply a need for revisions of forest governance and the resulting management approaches (e.g. forest owner associations, and the support and management services offered to owners) (Weiss *et al.* 2017). Additionally, with new management goals of the new owners (e.g. non-income oriented or environmental goals), new attitudes, other skills, and alternative capacities arise (Weiss *et al.* 2017; Walker and Artho 2018; Lidestav *et al.* 2015). Consequently, new forest governance and management approaches are required, which can include, for instance, new types of organisational forms (Weiss *et al.* 2017; Landolt *et al.* 2015). Based on the results presented, we see a challenge, but also an opportunity with the new goals and attitudes that can bring innovation for the future: the diversity of owner types has an impact on forest management and subsequently on the fulfilment of policy goals (Weiss *et al.* 2017). For instance, owners of small-scale private forest have an intrinsic motivation for nature preservation and biodiversity. Yet what this actually means for biodiversity on the ground may differ between the countries. For instance, in Sweden new owners of small private forest plots might be more likely to take forest out of utilisation than in Switzerland. However, forest ownership structures have so far not been intensively investigated in relation to forest governance and related management approaches and the 'real' effects on forests (impact) especially considering forest biodiversity. Thus, understanding ownership structures, the logic behind and its effects will help to address current challenges (Weiss *et al.* 2017).

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Fig. B 4.3. There are many small-scale private forests that have been inherited; the owners of such forests often use semi-professional equipment. Such activities on small scales are important for the society to keep knowledge and dedication on trees and forests alive. Especially children can experience valuable tacit knowledge (Photo: Ulrich Wasem).

JLG LIFT

Bioeconomy – potentials for innovation and sustainability regarding wood utilisation and forest management

B 5

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After revisiting the meaning of bioeconomy, this perspective paper explores the options of the forest and wood sector to contribute to the bioeconomy through traditional and innovative wood use. Novel applications such as engineered wood products have a large potential to substitute fossil-energy intensive materials. In this context, environmental assessment methods, and in particular life cycle assessment combined with material flow analysis, are crucial tools to increase resource efficiency and optimise cascading use and circularity of wood products. However, sustainability also implies input-related impacts caused by the wood sourcing in the forest. Wood production and harvesting can cause impacts on forest structure and function, and on other ecosystem services; these need to be addressed through good silvicultural practice. We conclude that sustainable timber production has a large potential to contribute to the circular bioeconomy when it combines sustainable forest management with sustainable wood conversion and use.

Definition and interpretation of the concept 'Bioeconomy'

Objectives and challenges of the political strategies for wood

The 'Political Strategy Bioeconomy' developed by the European Union in 2012 (EC 2018) aims at supporting the transformation to a renewable, bio-based, and resource efficient economy, which uses less or no fossil resources (Box B 5.1). The approach is to meet future social and economic challenges by decoupling employment and income from resource use, by managing the industrial structural changes

Box B 5.1. Definition of 'Bioeconomy' by the European Commission (EC 2018, p. 4).

Sustainable and Circular: Bioeconomy the European way

The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services.[1] To be successful, the European bioeconomy needs to have sustainability and circularity at its heart. This will drive the renewal of our industries, the modernisation of our primary production systems, the protection of the environment and will enhance biodiversity.

[1] Biomedicines and health biotechnology are excluded.

< Metropol Parasol in Sevilla, Spain. Currently the biggest wooden building of the world. This landmark of Sevilla, also called "Las Setas" (mushrooms) consists of 3500 m³ of veneerwood from Norway spruce and 700 m³ of steel. The building is 150 m long, has a width of 70 m and a height of 28 m (Photo: Holzforschung München, Ralf Diebold).

Table B 5.1. Classification of bioeconomy visions and key characteristics based on scientific research worldwide (adapted from Bugge *et al.* 2016, table 7, p.10).

	Bio-Technology Vision	Bio-Resource Vision	Bio-Ecology Vision
Aims and objectives	Economic growth and job creation	Economic growth and sustainability	Sustainability, biodiversity and conservation of ecosystems
Value creation	Application and commercialisation of biotechnology (molecular oriented	Conversion and upgrading of bio-resources (process oriented)	Development of integrated production systems with high quality products (system oriented)
Drivers and mediators of innovation	Research councils and funders (Science push, linear production mode)	Availability of bio-resources, waste management (Interactive production mode)	Favourable organic agro-ecological practices, transdisciplinary sustainability (Circular and self-sustained production mode)
Spatial focus	Global clusters/ central regions	Rural/peripheral regions	Rural/peripheral regions
Conceptual focus	Technical progress solves resource scarcity	Cascading as concept for maximisation of the resource efficiency	Integration of 'fair trade', participation in discussion and decision processes

in a socially acceptable manner, and by creating new development potentials in rural areas.

Wood as a renewable and sustainable resource for the bioeconomy plays a central role within this strategy (BMEL 2014; Bioökonomierat 2016; EC 2018). One important goal of the bioeconomy is mitigation of climate change. The transformation from fossil-based resources to the utilisation of wood can contribute a lot to this goal. While the sectors of agriculture and food are large sources of greenhouse gas (GHG) emissions, a sustainable forest management and wood sector has a large potential to mitigate GHG emissions by material and energy substitution and by sequestration and storage of carbon in forests and wood products (WBAE/WBW 2016; Nabuurs *et al.* 2018).

However, Mantau *et al.* (2010) predicted an increasing demand for wood in Europe, which will exceed wood supply for the 2020 and 2030 scenarios, and this could lead to unsustainable use, and hence, net CO_2 release. The main driver of the increased wood demand in recent years has been the renewable energy directive (RED; Directive 2009/28/EC), which mandated the increased use of renewable energy in the EU for the period 2009 to 2021, enhancing generally the wood use for energy services. In their National Renewable Energy Action Plans (NREAPs) of 2010, many EU member states counted on woody biomass for more than 50 % of their renewable energy targets (Muys *et al.* 2013). This was motivated on the one hand by the large standing stocks of wood built up in Europe since World War II, and on the other hand, by the high investment costs required for other types of renewable energy, such as solar and wind. At that time, energy planners paid insufficient attention to the fact that it is not standing stock but increment that is the basic indicator of the sustainable use potential of the forest; this resulted in downscaling of bioenergy expectations from the forest (Muys *et al.* 2014). As a consequence, the peak of energy use by wood seems to have been reached, and the subsidies for wood energy production will disappear soon because of the recast RED, while the material use will increase in the future because of increasing demands for wood to substitute for fossil-based and mineral-based products (Mantau *et al.* 2018). Therefore, research and development is needed to: (i) identify for which innovative purposes wood can be made usable in parallel to the traditional uses; and (ii) investigate how the quantity and quality of wood can be extended in a sustainable way with respect to competitiveness aspects and other forest ecosystem services. In the following text, we discuss strategies with a particular focus on Europe and Germany, but also considering worldwide trends and visions in some cases.

Worldwide bioeconomy visions

There have been wide-ranging and extensive discussions about what concepts and measures should be implemented for a successful bioeconomy. Based

on an analysis of peer-reviewed papers, Bugge *et al.* (2016) distinguished three 'visions' of the bioeconomy in relation to economic system types (Table B 5.1).

For the 'biotechnology vision' the most important goal is economic growth, and new products are developed using molecular-oriented production methods. In this vision, the focus is on solving the resource scarcity, whereby the bioeconomy development is driven by clusters of 'globally-acting' big businesses in a limited number of regions. The 'bio-resource vision' is also focused on economic growth. However, according to this vision, the process-oriented value chains for the development of new bio-based products do not only run linearly, but are also integrated, cooperating with other sectors like waste management. Therefore, the conceptual focus is on strategies, such as cascading, to maximise resource efficiency. New opportunities that can be implemented in rural areas are considered. Whereas both the 'biotechnology' and 'bio-resource' visions are focused on the '-economy' aspect of 'bioeconomy', the third vision is focused on the 'bio-' aspect of the term with conservation of ecosystems as its main objective. The basis of the 'bio-ecology vision' is a system integrated ecological management for biodiversity conservation and provision of multiple ecosystem services, which can stimulate economic development in rural areas.

Bioeconomy strategy of the wood sector

The interpretation of bioeconomy in the forest and wood sector is quite specific, and combines the above-mentioned visions. In Germany, for example, the German Bioeconomy Council (Bioökonomierat 2016) has picked up the topic in the memo 'Wood in the Bioeconomy – Opportunities and Limits'. The 'Charter for Wood' (BMEL 2018) has developed a special action area 'Potentials of Wood in the Bioeconomy', which addresses product and process innovations, both in traditional fields and new application areas. Additionally, the Charter presents further action areas for the forest and wood sector, regarding, for example, construction with wood, material and energy efficiency, forest and wood in the society, and research and development. Similar issues, but under other terms, have

Box B 5.2. The 'Wooden Age' from the Middle Ages to the nineteenth century (Hasel 1985, p. 180) (Photos: Holzforschung München. Gabriele Weber-Blaschke, Ralf Rosin).

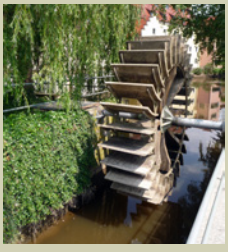
From the Middle Ages to the nineteenth century, wood was a vital resource; thus this time can be termed the 'Wooden Age'. Wood provided the raw material for the carpenters and coopers (i.e. the people who make barrels and casks) and was used in many aspects of everyday life: e.g. for construction of buildings like log houses or half-timbered houses, for engineering like water pipelines, windmills and watermills, wells, bridges, sawmills, forges, fencing, and agricultural tools.

Forge

Water pipelines

Sawmill

Half-timbered house



Watermill

also been discussed at the European level (Hetemäki *et al.* 2017; Winkel 2017a).

Thus, the term 'bioeconomy' is used on the one hand for specific innovation potentials, and on the other hand for discussing all implications related to bioeconomy. Therefore, the next sections of this chapter focus firstly on wood utilisation driven by the bioeconomy, followed by its effects on forest ecosystems and forestry.

Traditional and innovative wood utilisation

Traditional wood utilisation and wood resources

In fact, the 'Bioeconomy' is not a new idea. Forests and their wood have been used for material applications and energy purposes since the early stages of humankind. In particular, the period between the Middle Ages and the nineteenth century has been called the 'Wooden Age' (Hasel 1985). During those times, the use of wood developed in often innovative ways (Box B 5.2). However, since the Industrial Revolution, the use of wood has been replaced to an increasing extent by fossil resources as a material and especially as energy.

Traditional wood utilisation can be classified into four groups according to the lifespan of the wood products: (i) long-lived products of the construction sector with a lifespan of around 80 years or more; (ii) products of the furniture sector with a lifespan of around 15 years; (iii) short-lived products such as paper and packaging with a lifespan of around three years; and (iv) energy wood with a lifespan of around one year (fig. B 5.2).

The longer the product lifespan is, the longer the carbon is stored without release of CO_2 into the atmosphere. However, for the climate mitigation effect of wood products, it is not the storage itself that is important, but rather the increase of this storage in wood products, and therefore the increase of their carbon stocks. Currently, in Bavaria, Germany, 75 % of all carbon bound in wood products is stored in wooden buildings (Klein and Schulz 2012, fig. B 5.2). This fact demonstrates the important role of wood products for this sector not only today, but also in the future. In Europe, 113.6 million m³ wood is used annually in long-lived prod-

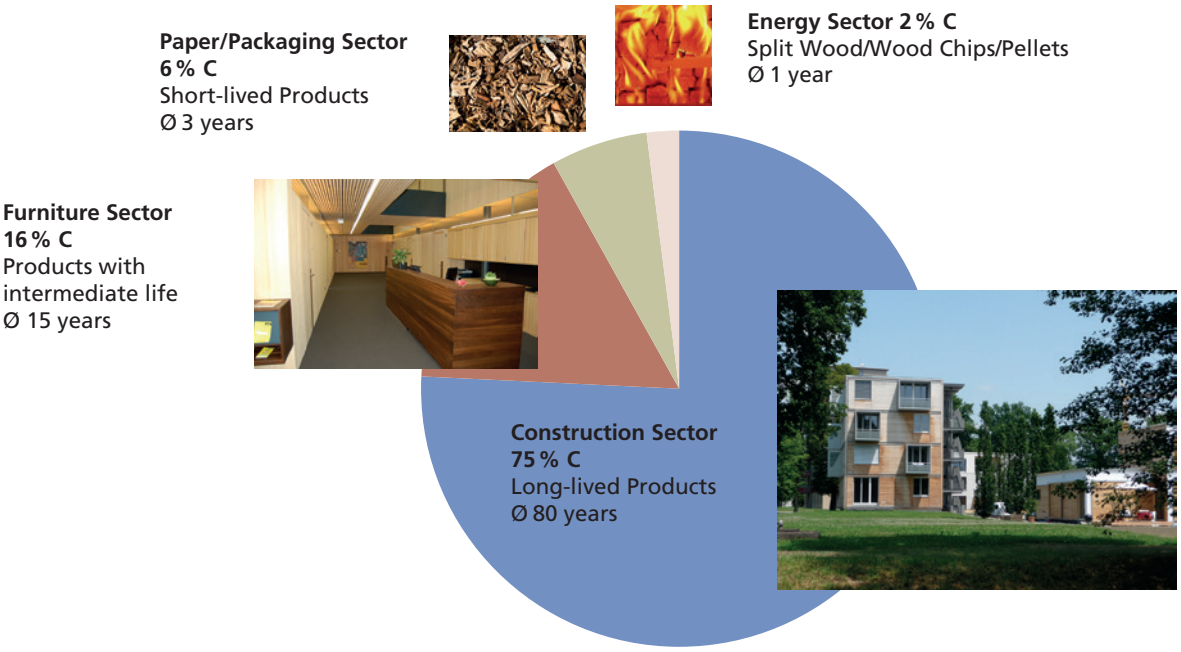


Fig. B 5.2. Carbon stocks in Bavaria in traditional wood products classified according to their lifespan. Data from Klein and Schulz 2012 (Photos: Holzforschung München. Ralf. Rosin, Gabriele Weber-Blaschke).

ucts (fig. B 5.3; EASAC 2017 based on Mantau 2012). Brunet-Navarro *et al.* (2017) estimated that the total carbon stock in European (EU-28) wood products was 0.819 Gt C in 2000 and this had already increased to 1.055 Gt C in 2016. This stock is expected to increase to 1.257 Gt C by 2030. In 2016 the stock was distributed between 62 % in sawnwood products, 31 % in wood-based panels, and 7 % in paper and paperboard.

Several European countries have explicit targets for increasing domestic wood production with the objectives of meeting the increasing demand in

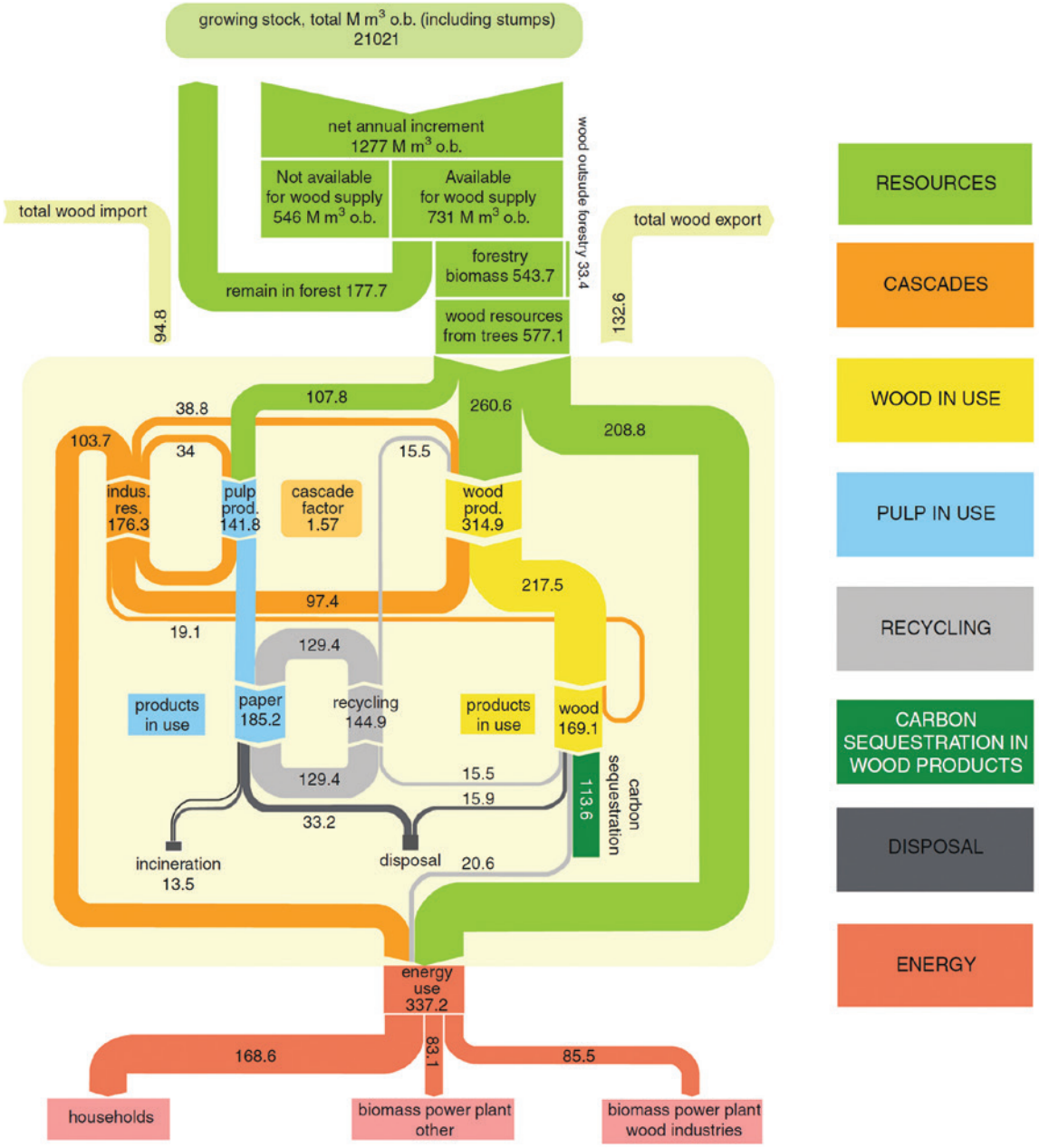


Fig. B 5.3. Wood use in the European Union in million m³ over bark (o.b.) per year (from EASAC 2017, p.8, redrawn from Mantau 2012).

Table B 5.2. Amounts of wood from the forests in Germany (without bark and residues) as well as percentages of wood from coniferous and broadleaved species, classified according to the type of utilisation and processing industry. (Data from DHWR 2016, p. 14).

		Amount (million m³)	Coniferous Wood (%)	Broadleaved Wood (%)
Total utilisation		**76 (100 %)**	71	29
Material utilisation	Sawmill industry (Building material)	35	96	4
	Engineered wood industry	9	81	19
	Pulp and paper industry	6	88	12
	Total	**50 (66 %)**	Coniferous dominated	
Utilisation for energy services	Commercial energy wood	6	49	51
	Energy wood for private households	20	43	57
	Total	**26 (34 %)**	Broadleaved dominated	

both material and energy use (e.g. Finland, Germany) and reducing the trade deficit (e.g. France) (Forest Europe 2015). However, the situation varies across Europe and can be categorised in five geographical regions (North Europe, Central-West Europe, Central-East Europe, South-West Europe, South-East Europe). The structure of the market is dependent on the wood supply (species, amount) and on the demand, which is traditionally oriented towards local resource availability and accessibility. The Central-East and Central-West European regions have the highest growing stock densities, and the North European region and Austria have the highest wood consumption. The countries in North Europe and Austria have the highest coniferous percentage and are the biggest exporters of coniferous sawnwood, whereas the other countries are mainly importing nations. The market for pellets has grown, not only with respect to domestic production, but also with respect to imports from outside Europe (particularly from North America) (FAO 2017). The utilisation type differs greatly by country: e.g. in Germany, Austria, and Italy pellets are used for residential heating, whereas in the United Kingdom, Denmark, Belgium, and the Netherlands, the pellets are instead used for combined heat and power production, mostly by co-firing.

In general, wood from coniferous trees is mainly used for material utilisation, whereas wood from broadleaved trees is mainly taken for energy production, because it is considered to have lower quality (see case study Germany; table B 5.2). Whereas long-lived wood products contribute to climate mitigation by carbon storage during a certain period, the carbon in the wood used for energy is directly released as CO_2 when the wood is burned.

The characteristics of the timber stock is the basis for possible utilisation patterns. In Germany, for example, the timber stock by tree species groups changed from 2002 to 2012. Especially the stock of beech *(Fagus sylvatica)* and oak (*Quercus* spp.) has increased, whereas the stock of spruce *(Picea abies)* has decreased (BMEL 2015). Because Germany has set 'sustainable mixed forests' and 'adaption to climate change' as goals, the silvicultural management has changed and the proportion of broadleaved trees, especially beech, is increasing, and the supply of wood from broadleaved species will increase in the future. Thus, the development of processes and products regarding their material utilisation instead of its use for energy is necessary. On a European level, the growing stock of broadleaved species has also accumulated at a higher rate on average than the growing stock of coniferous species (Forest Europe 2015).

In addition to the wood supply from forests, secondary wood resources are provided every year by the processing wood industries (sawmill and industrial residues), paper industry (black liquor), and the waste sector (recovered wood), which are currently mainly used for energy production (fig. B 5.3). Overall, European wood is used in almost equal proportions for energy (40 %) and products (40 %). The remaining 20 % is used for pulp (EASAC 2017). According to Mantau *et al.* (2018), the secondary resources provide around 30 % of the wood supply every year in Germany (data for 2016), whereas about 50 % of the wood supply comes directly from forests. The remaining 20 % of wood supply are mostly bark, forest, and

landscape residues, and pellet imports, all used for energy purposes.

To improve efficiency, greater use of secondary wood resources as a material rather than as energy should be achieved. For this goal, the applications of secondary resources would need to be upgraded. The innovative processing of forest wood is focused on beech as a building material (e.g. laminated beech wood) and on engineered wood products. The innovative concepts for secondary resources are re-use (as product) and recycling (as material); this is implemented through cascading by breaking wood products down to recover particles and fibres, and by dissolving wood for use in biorefineries to separate the various component substances contained in wood (cellulose, hemicellulose, lignin, and extractives).

Changing trade flows

The twenty-first century has seen big changes in the global market for forest products. The global forest products market was severely affected by the global financial crisis of 2008–2009, but the market had been recovering and the production of all major products (industrial roundwood, sawnwood, wood-based panels, pulp and paper) increased from 2015 to 2016. The recovery from the economic downturn of 2008–2009 was further continuing (FAO 2017). However, as seen with the current situation of the global COVID-19 pandemic, the economic recovery is fragile. It has been reported from stakeholders of the forest-wood-chain, that the trade of raw wood and wood products and their production process have been negatively affected with respect to the special regional situation of the pandemic (e.g. missing workers, missing resources, missing customers).

The last years have seen the emergence of Asia, especially China, as the biggest consumer and producer of many forest products, especially of wood-based panels and paper. China is also the world's largest importer of industrial roundwood, sawnwood, and fibre furnish (pulp and recovered paper), and the largest exporter of wood-based panels (FAO 2017; Hetemäki and Hurmekoski 2014). The consumption and production of wood-based products is increasingly shifting from the previously leading forest industry regions of North America, Western Europe, and Japan, to the rapidly growing large economies of China, Brazil, and India (Jonsson *et al.* 2017). The production of wood pellets has increased dramatically in recent years, mainly owing to demand generated from renewable energy targets set by the European Commission. Europe and North America accounted for almost all global production (58 % and 32 %, respectively) and consumption (81 % and 8 %, respectively); especially the United Kingdom increased its imports

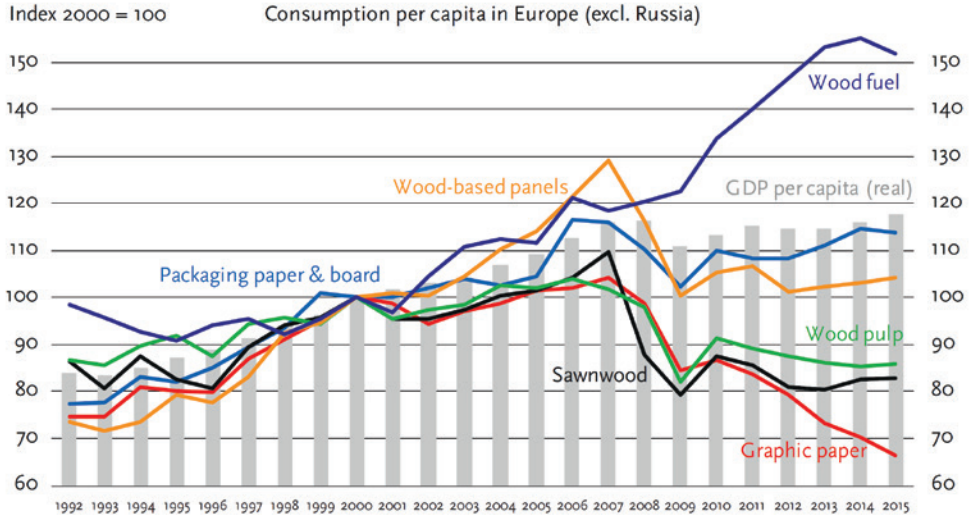


Fig. B 5.4. Consumption per capita of forest-based products and Gross Domestic Product (GDP) growth in Europe (excluding Russia) (Data: FAOSTAT, World Bank) (from Jonsson *et al.* 2017, fig. 15, p. 128).

and consumption (FAO 2017). The consumption of graphic paper has declined in most OECD countries, also in Europe (fig. B 5.4) and increasingly also in non-OECD countries, such as China, owing to the increasing use of electronic media (Jonsson *et al.* 2017). Besides, the global and European forest-based industries are undergoing major structural changes. New bio-based products, such as biofuels and bio-plastics, are emerging, and this will blur the boundaries with other sectors, such as the energy, chemical, and textile industries.

New processes and new products

Figure B 5.5 illustrates an example of an emerging innovative value chain including biorefinery processes (Box B 5.3). As the main product line, roundwood is processed first for sawnwood or veneer, and then for building materials and (prefabricated)

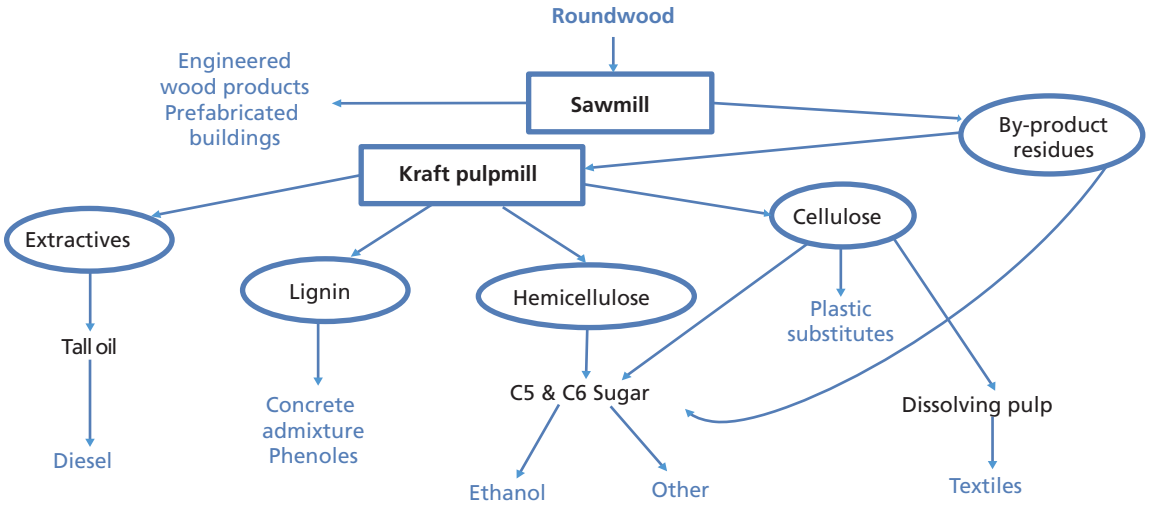


Fig. B 5.5. Illustration of a wood-based value chain exemplified by roundwood (modified from Hurmekoski *et al.* 2018, fig. 2, p. 1422).

Box B 5.3. (Forest) Biorefinery (EASAC 2017, Box 3, p. 9; Näyhä *et al.* 2014, p. 44)

Biorefining is defined by the International Energy Agency as the sustainable processing of biomass into a range of bio-based products (food, feed, chemicals, and materials) and bioenergy (biofuels, power and/or heat). The purpose is to use the raw material in the wood as a chemical feedstock to produce high value chemicals (e.g. fine chemicals, pharmaceuticals, polymers) and secondary energy carriers (transport fuels such as bioethanol, biogas). Outputs are thus considerably higher up the value chain than just using the biomass for generating heat and/or electricity (EASAC 2017, p. 9).

The forest biorefinery can use multiple feedstocks, including pulpwood, harvesting residues, extracts from effluents, fractions of pulping liquors, as well as recycled paper and industrial wastes (Näyhä *et al.* 2014, p. 44).

Major chemical components of woody biomass include lignin and sugars, and a range of biological, chemical, physical, and thermal processes can be applied to produce biochemicals and fuels. Typical processes include fermentation, biocatalysis, gasification, and pyrolysis. Major product streams depend on the chosen biorefining platform and the respective technologies, but may include bioethanol, biogas (methane), biochemicals, bioplastics, and foodstuffs. Potential industries to which biorefinery products can contribute include the food, electronic, medical, and clothing industries. In general, both energy-driven and product-driven biorefineries can be distinguished (EASAC 2017, p. 9).

It can be a large-scale industrial facility, integrated into a pulp and paper mill, or a medium- or small-scale facility integrated into a sawmill or plywood mill (most of the discussions have focused on the former) (Näyhä *et al.* 2014, p. 44).

The concept of the biorefinery is still in early stages and has attracted government support for innovation in some countries (EASAC 2017, p. 9).

A key requirement for any biorefinery development is a large supply of biomass from nearby areas to supply the necessary feedstock, which can conflict with other objectives (e.g. biodiversity or carbon storage targets) (EASAC 2017, p. 9).

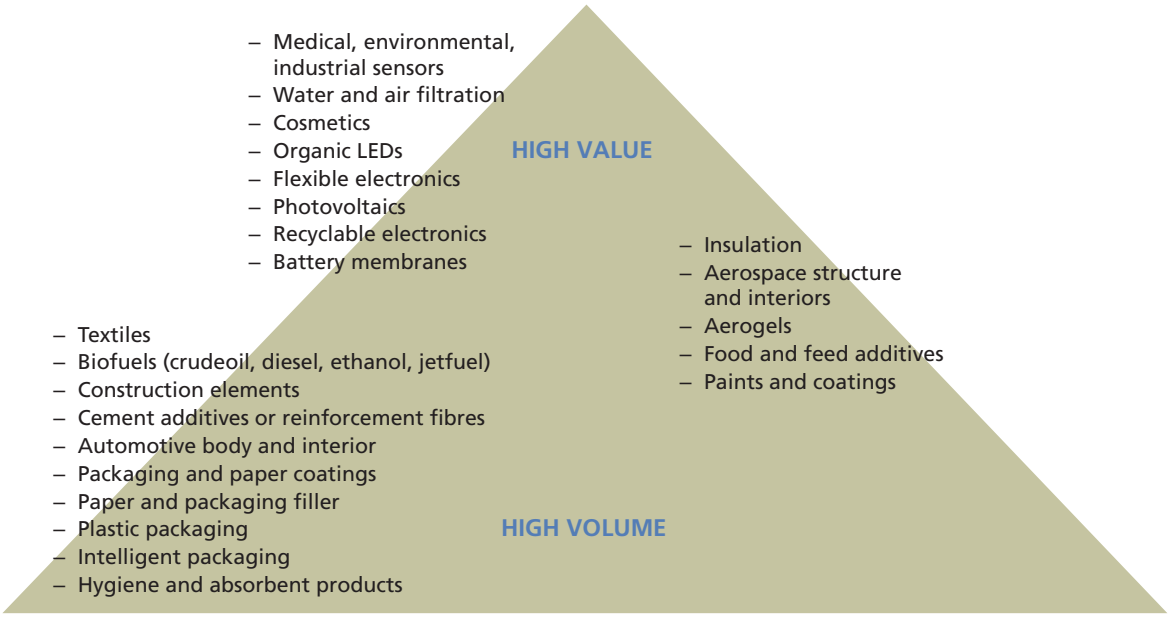


Fig. B 5.6. Innovative wood products (modified from Jonsson *et al.* 2017, p. 129, based on Cowie *et al.* 2014, Pöyry 2016 cited in Jonsson *et al.* 2017).

building elements. The co-product sawmill residues can also be used for material applications before being used for production of energy. Instead of producing graphic paper, for which the consumption has declined worldwide, the production capacity of pulp and paper mills could be converted to biorefineries for the production of cellulose, hemicellulose, lignin, and extractives (Box B 5.3). These substances in pure form can be used in various ways as fuel, concrete admixture, phenol, ethanol, and other platform chemicals. The fibres can substitute for plastic products or be processed into textiles. Besides sawmill residues, also other residues and recovered wood could be used (Hurmekoski *et al.* 2018).

The technical new engineered wood products from various wood species and the prefabricated building elements are an innovative product line with high value. The advantage of engineered products like laminated timber is that larger and stronger construction elements can be fabricated from smaller and poorer quality wood. Thereby, timber that was previously of limited use can be converted into upgraded products. This is an important development for the use of wood in areas, where the trees often do not grow with tall and straight stems, such as the Mediterranean region. Another major advantage of building with timber is the potential for quick construction. For example, a Bavarian timber construction award in 2018 was granted to a residential building for asylum seekers; the building used solid wood construction and was constructed in only six weeks (StMELF 2019).

The potential of innovative processes and products based on wood are expected to be very promising in Europe and globally (Jonsson *et al.* 2017, Hurmekoski *et al.* 2018). According to an analysis of the development until 2030 for the four major forest industry countries (i.e. USA, Canada, Finland, and Sweden), the biggest part of increases in primary wood consumption is predicted in the construction sector (saw logs) and in the textile sector (pulpwood). In the biochemicals and bio-plastics sectors, a very high increase of wood use, mainly of by-products from the sawmilling and pulping industries, is also predicted. These sectors will produce lower volumes of wood products but with higher value added (Hurmekoski *et al.* 2018). Thus, in terms of market growth, there is a different picture when looking only at large volumes of traditional products (sawnwood, wood-based panels, pulp and paper) compared to one that considers also new or emerging wood-based bioproducts (Jonsson *et al.* 2017; fig. B 5.6).

Building construction from laminated beechwood

Bavarian State Institute of Forestry
Freising

Textiles from Beech Cellulose

T-Shirt of the forest students at the Technical University of Munich
Freising

Fig. B 5.7. Potentials of the material utilisation of wood from broadleaved species like beech (modified from Weber-Blaschke 2019) (Photos: Holzforschung München. Ralf Rosin, Gabriele Weber-Blaschke).

Thermoformable wood and wood plastic composites in the automotive technology (e.g. in the Biofore Concept Car, UPM Biofore 2014), veneer layers for wood-based lightweight pipes of bicycle frames, and composites from sawmill residues for toys are examples for upgraded material utilisation of small-dimension wood, low-quality wood, and wood waste and wood residues. Examples of the innovative use of wood from broadleaved species include: the annex building of the Bavarian State Institute of Forestry on the Research Campus Freising-Weihenstephan near Munich constructed using laminated beech wood; and the T-Shirts of the forest students at the Technical University of Munich processed from beech cellulose (fig. B 5.7).

Environmental assessment and resource efficiency

Whether the emerging innovative processes and products are in fact environmentally friendly and sustainable has to be evaluated on a case-by-case basis. One method to do this is the 'Life Cycle Assessment' (LCA), in which the whole life cycle of a product is assessed (ISO 14040 2006a; ISO 14044 2006b). For example, the life cycle of a wood building product ranges from the raw material provision from the forest up to the construction of a building and the material or energy use of the recovered wood after the end of life of the product (CEN EN 15804 2018).

By comparing wood products with the respective non-wood products, the substitution and displacement effects can be evaluated. Thereby, environmental impact categories, complemented by economic and social aspects, can be evaluated with respect to all sustainability issues, which is called 'Life Cycle Sustainability Assessment' (Guinée 2016). On the input side, resource efficiency and land-use impact are indicators for resource and land consumption. On the output side, impacts on environment and human health can be assessed using indicators related to GHG emissions, as well as indicators related to various pollutants (acidifying and eutrophicating substances, particulate matter, and other pollutants).

An important indicator related to climate change is the environmental impact category 'Global Warming Potential'. In most cases, use of wood products results in reductions in GHG emissions compared to use of non-wood products, while the material utilisation of the traditional wood products have more reduction potential than the wood utilisation for energy services (Knauf *et al.* 2015; Wolf *et al.* 2015; Leskinen *et al.* 2018). However, also values of these substitution factors show ranges with additional burdens depending on how the wood product was produced and with which non-wood product it was compared. LCA studies are still missing for emerging innovative products (Leskinen *et al.* 2018).

In addition, the issue of resource efficiency is becoming more and more important since the demand for wood is expected to increase along

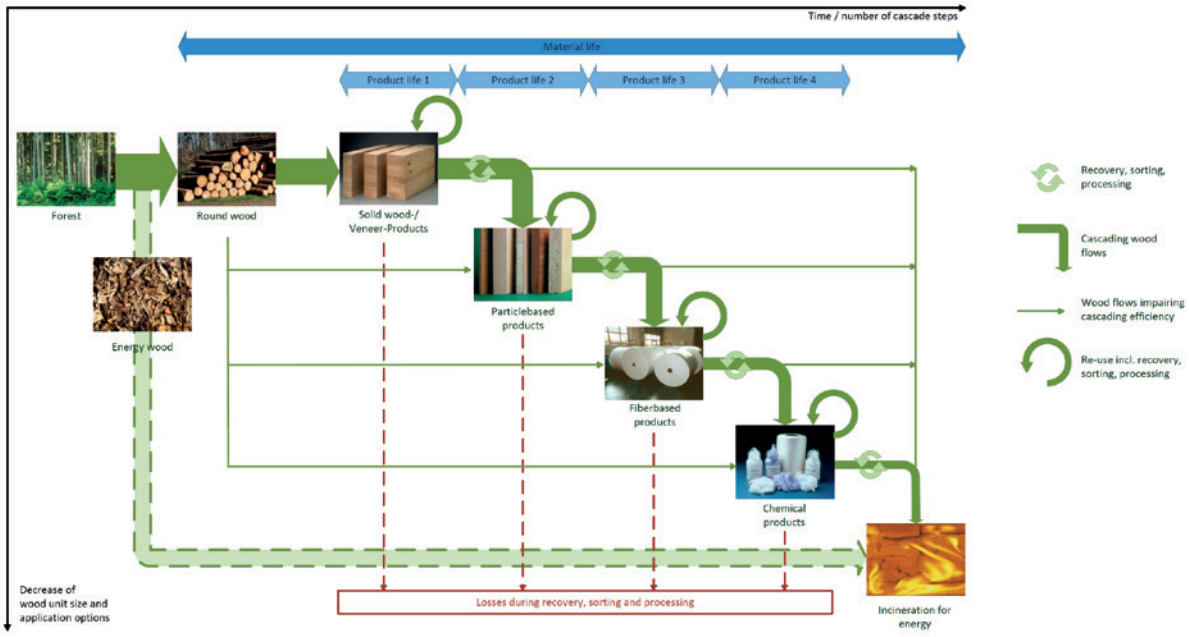


Fig. B 5.8. Illustration of wood cascading as a concept of the circular economy (modified from Höglmeier *et al.* 2016, fig. 22.1, p. 336) (Photos: Holzforschung München. Ralf Rosin).

with the bioeconomy transformation. Therefore, a circular economy is required (EC 2018, Box A 5.4). In relation to wood, the 'circular economy' refers to the renewable character of wood when harvested from sustainably managed forests, but it also refers to its cascading use (Hetemäki *et al.* 2017). The idea of cascading is to recycle a high-grade material through as many stages as possible; only at the final stage should the wood be used for energy production (fig. B 5.8) (Höglmeier *et al.* 2016; Brunet-Navarro *et al.* 2018). Thereby, the circular economy should not only consider recycling, which is mostly only a down-cycling by reprocessing the material, but also integrate re-use, which is the high quality use of the product itself for the same or for other purposes (Höglmeier *et al.* 2017; Mair and Stern 2017). The implementation of this is challenging, and requires a shift from linear thinking to thinking in terms of cycles. This concept requires that the products have already been designed at the beginning of their life to be reusable and recyclable at the end, which is currently not the case in practice (Risse *et al.* 2019).

However, it is not sufficient to only analyse single product lines by LCA. The new processing and utilisation ways of the wood raw materials and residues will shift the flows of the wood as well as of the non-wood materials and products at the regional level. This can be analysed by the method 'Material Flow Analysis' (MFA) (Brunner and Rechberger 2016). Thereby, raw wood, wood products as well as further relevant material and product flows are analysed within a region, including imports and exports. Combining LCA and MFA is necessary to investigate consequential effects of changing utilisation patterns. Appropriate indicators are needed for assessing environmental impacts (e.g. global warming potential, particular matter, acidification, human toxicity, biodiversity), economic impacts (e.g. value added, income, wealth), and social impacts (e.g. employment, equality, life quality).

Figure B 5.9 shows an example for several product lines, which are linked at the regional level (further developed from Höglmeier *et al.* 2015). A given demand in a region is covered either by wood products, or by non-wood products. The more wood products are used, the less non-wood products are necessary, and the impact balance will change.

Based on that LCA approach combined with MFA, Weber-Blaschke and Friedrich (2015) and Friedrich *et al.* (2016) demonstrated for a case study in

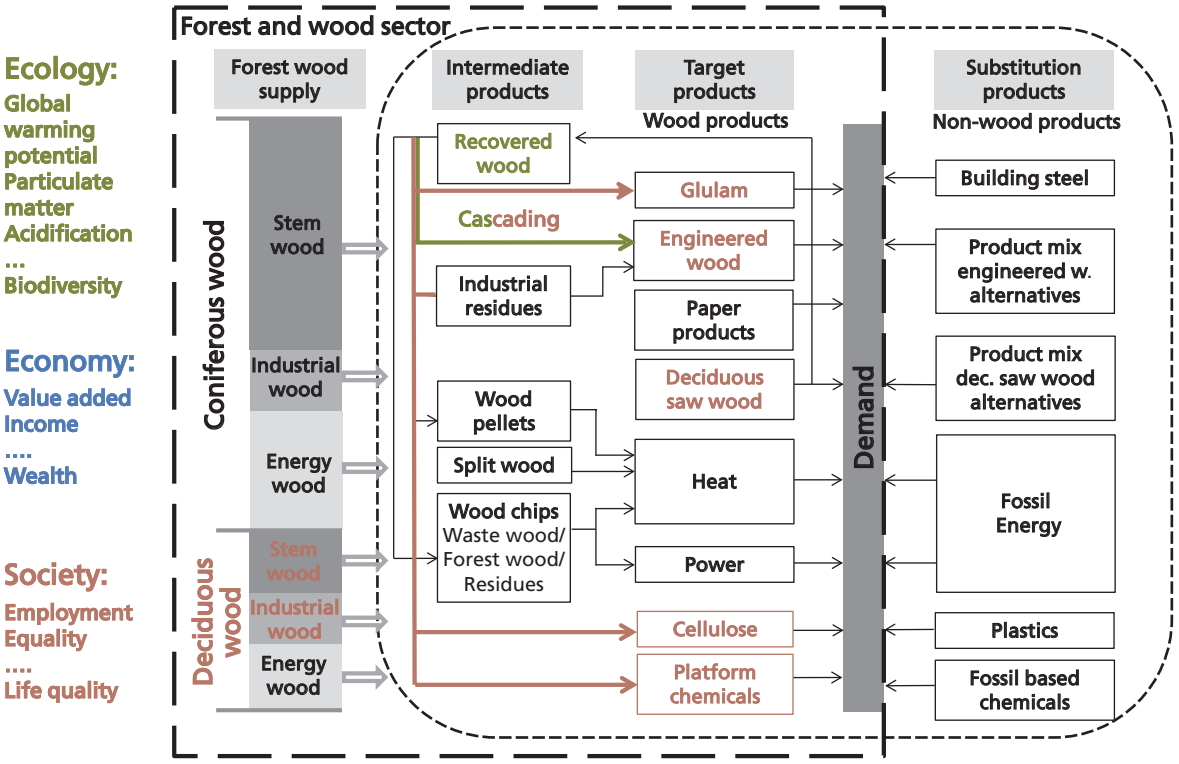


Fig. B 5.9. Life cycle (sustainability) assessment in combination with wood flow analysis: green flows–wood cascading; red flows–innovative product lines based on wood from broadleaved species and wood residues (modified from Höglmeier *et al.* 2015, fig. 1, p. 160; Weber-Blaschke and Friedrich 2015; Friedrich *et al.* 2016; Weber-Blaschke 2019).

Bavaria that the shift from the material to the energy utilisation of wood (substituting fossil energy) results in higher GHG emissions, in less value added, and in lower employment. In this scenario, the production of wood products for material applications is lower and fewer workers are necessary in the wood processing industry, because non-wood products are used to fulfil regional demands.

Recovered wood in cascading use can in fact reduce GHG emissions, but perhaps less than expected (Höglmeier *et al.* 2014, 2015; Risse *et al.* 2017). Virgin wood processing from the forest is in itself environmentally friendly with a low carbon footprint compared to the processing of recovered wood, and recovered wood is currently used only for particle board production and not for higher quality products (re-use), as a consequence of technological challenges and legal restrictions.

Comparison of the innovative wood-based product lines from broadleaved species with traditional non-wood product lines in terms of their environmental impact at the regional level (including import and export flows) is a topic that is currently under research. The options regarding biorefineries should also be integrated in such studies.

Box B 5.4. Circular Economy (Kirchherr *et al.* 2017, p. 225).

A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation, and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.

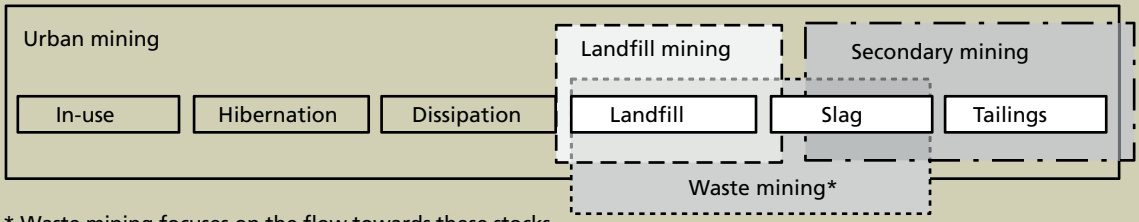
Box B 5.5. Urban Mining (Johansson *et al.* 2013, p. 38, 39, Fig. 3 p. 39).

Urban mining has been defined in the scientific community as the recovery of secondary resources from technospheric stocks …, as illustrated in Figure [3].

Technospheric mining seems to be a suitable term to describe extraction and recovery of mineral stocks within the technosphere in contrast to traditional virgin mining, since it brings all human- generated stocks into consideration. Technospheric stocks, however, are more or less ubiquitous since secondary metals are present in numerous forms (molecules of copper in air emissions as well as large steel constructions in-use), and are limited only by human ingenuity. Their location may furthermore be deep below the earth in terms of copper cables, in attics as obsolete mobile phones, or in space in the form of satellites. This implies that accessibility, suitable extraction methods, research needs, and the current level of implementation for extraction of metals in the technosphere can change substantially. The umbrella is therefore split into different subtypes correlating to stocks situated in the technosphere, suggesting six different subgroups within the umbrella of technospheric mining, …

Technospheric mining: (1) In-use mining; (2) Hibernation mining; (3) Dissipation mining; (4) Landfill mining; (5) Slag mining; (6) Tailing mining.

Existing mining concepts and their connection with different stocks in the technosphere:



* Waste mining focuses on the flow towards these stocks

Prerequisite: Sustainable wood utilisation

The production and utilisation of wood products have to be more sustainable than ever, despite and because of an increasing wood demand, which is expected because of the transition away from fossil resources, of the increasing population, and the efforts to improve living standards at a global level. Therefore, the expansion of wood product supply requires a sustainable management of the wood industry and the wood economy as a whole. Options include, for example, technological, logistic, and process innovations in the domains of wood industry 4.0, biotechnology, biorefinery, cascading, circular economy (Box B 5.4), urban mining (Box B 5.5), and design for re-use/recycling (Bioökonomierat 2016). To identify strategies towards a sustainable transition from a fossil-based to a wood-based based economy ensuring a sustainable wood economy and to estimate their system-wide impacts, the substitution potentials have to be assessed combining LCA and MFA as mentioned above. This approach represents an effective way to provide decision support in view of trade-offs between different environmental and sustainability objectives and increasingly complex networks of resource utilisation (Laner and Rechberger 2016; Cao *et al.* 2019).

Effects of bioeconomy on forest ecosystems and their management

Options to increase wood supply

The expected increase in wood demand will also affect forest management. The European saw timber industry depends heavily on coniferous forest resources, because of the high yields and reliable quality of coniferous timber. However, climate change makes monoculture conifer forests increasingly vulnerable to drought, and pests and diseases, e.g. see the reports of recent bark beetle attacks on spruce in Central Europe (Biedermann *et al.* 2019; Hlásny *et al.* 2019). This means that silvicultural interventions that increase the resilience of the for-

est, should be prioritised. Increasing the tree species mixture to take advantage of the insurance effect of biodiversity has proved to be a very promising silvicultural strategy to increase forest resilience (Jactel *et al.* 2017; Silva Pedro *et al.* 2015). Such changes to the species composition of forests will mean that the wood industry will need to be more flexible with respect to the timber species and grades that it uses. This change can be a driver of technological innovation.

In Germany, the options to increase wood supply include: utilisation of undervalued potentials of wood from broadleaved species, afforestation, short-rotation coppices, agroforestry, change of tree species (e.g. from spruce to Douglas fir *(Pseudotsuga menziesii),* shortening of the rotation period, integration of plant and forest protection, forest tree breeding, utilisation of residual wood from forestry, and increased mobilisation of wood sources from privately owned forests (BMEL 2018). In the various European countries, greater local production may be achieved by increasing the utilisation rate to the maximum possible level, which is defined in relation to the respective total increment. In the 2015 State of Europe's Forests report, different countries highlighted different strategies to increase the supply of wood: increasing mobilisation (Finland, France), increasing productivity (Sweden), increasing the forest area (Ireland), and increasing the area of managed forests (Hungary) (Forest Europe 2015). There is a huge potential for increased mobilisation of timber resources, especially in southern and eastern Europe.

Conflicts with other ecosystem services

Although provision of wood is a very important ecosystem service provided by forests, there are several other relevant ecosystem services provided by forests, including additional provisioning services (e.g. berries, mushrooms, honey, medicinal plants), regulating services (e.g. soil, water, and climate protection, and nature conservation), and cultural services (e.g. recreation). To provide ecosystem services to society, the ecosystem prerequisites

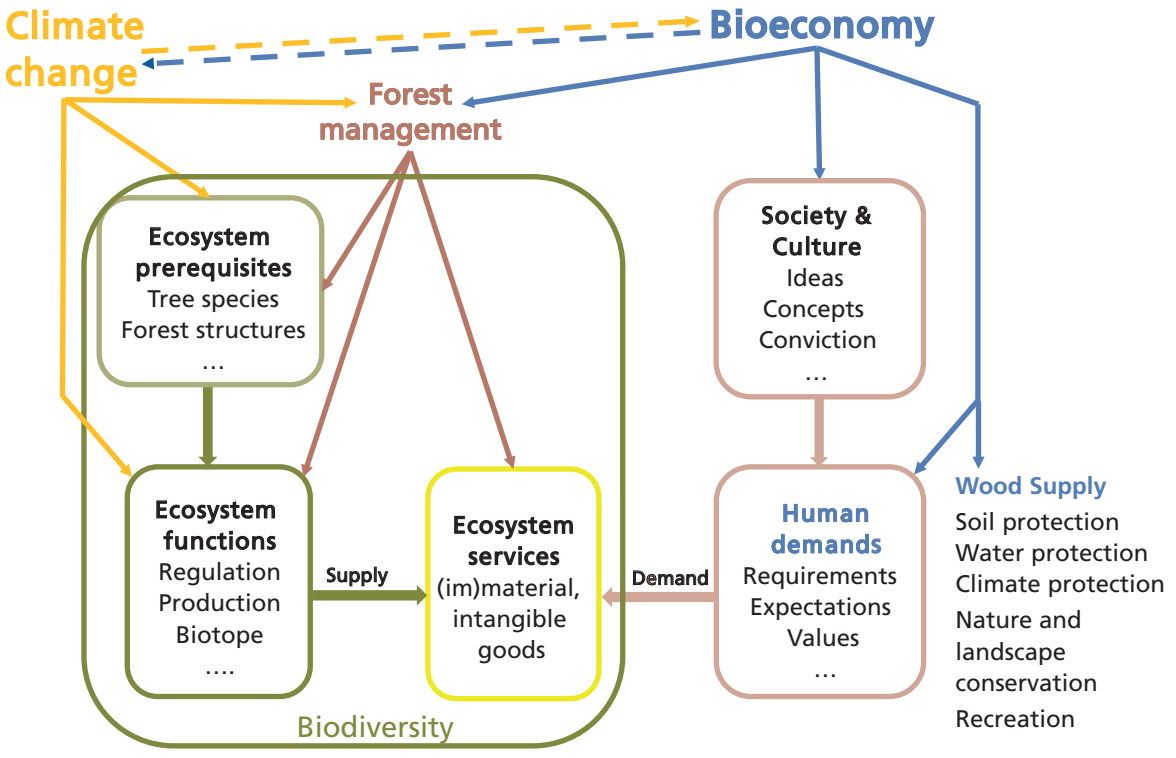


Fig. B 5.10. Illustration of the relationships between the ecosystem services provided by the forest and demanded by the human beings and the impacts of bioeconomy and climate change (modified from Bürger-Arndt 2012).

(amongst others in terms of tree species composition and forest structure) and the subsequent ecosystem functions have to be sustained in the long term (fig. B 5.10; Bürger-Arndt 2012). To continue providing ecosystem services at the current levels, measures should be taken to preserve forest ecosystems, and especially the biodiversity, which forms the basis of the delivery of many ecosystem services. In order to sustain the other ecosystem services at acceptable levels may mean that a greater percentage of the forest area should be set aside for zero management or dedicated to provision of ecosystem services other than provision of timber (Hetemäki *et al.* 2017). In addition, ecosystems have intrinsic value, and therefore the bioeconomy as valorisation of nature is also an ethical challenge (MEA 2003).

Prerequisite: Sustainable forest management

To fulfil the requirements of more wood supply (see options mentioned above), as well as the supply of other ecosystem services and of preserving the forest ecosystem all at the same time, a sustainable, integrated, multifunctional, close-to-nature forest management will be needed. In this kind of management, consideration of local and landscape related site conditions, and maintenance of biodiversity and ecosystem functions are the basis for management decisions. Elements of stand stability, including tree species mixture (e.g. underutilised broadleaved species), uneven-agedness and sufficient rotation lengths allowing natural regeneration, must be discussed. When considering utilisation of forest residues (e.g. small branches, needles and leaves, stump extraction, total tree utilisation), the sustainability of these measures has to be thoroughly evaluated. Besides forest protection measures (e.g. measures taken to control bark beetles and other insect pests), issues concerning conservation of biodiversity and maintenance of site fertility must also be taken into account for different sites.

Species diversity and forest ecosystem dynamics differ considerably throughout Europe. This is represented by the broad range of forest types, from boreal forests in northern Europe to broadleaved evergreen forests in the Mediterranean region. These forest types are differentiated by unique key factors related to structural, compositional (including tree species composition), and functional forest ecosystem components (such as biotic and abiotic disturbance factors and forest management) (Forest Europe 2015). In very broad terms, for boreal forests, decreased impact management strategies are recommended such as continuous-cover silviculture, integrated with increasing tree species diversity and landscape heterogeneity (EASAC 2017). Temperate forests need further transformation from single-species, even-aged cover into mixed uneven-aged forests by a continuous-cover (close-to-nature) forestry system to increase the resilience against natural disturbances and climate change impacts. Silvicultural measures such as reductions in rotation times to decrease storm and insect damage will have trade-offs related to biodiversity and carbon storage and have to be considered carefully on a site-by-site basis, and may be compensated by zero intervention areas. In the Mediterranean forests, the focus lies on fire, pest, and drought management; more intensive and more frequent thinning could be a useful strategy to increase water-use efficiency and decrease vulnerability (Gracia *et al.* 2011; EASAC 2017).

Concluding remarks

The bioeconomy is basically defined as the transformation of the fossil-based to a bio-based economy. Within this transition, the forest and wood sector plays a crucial role, given their climate mitigation potential through carbon sequestration and substitution of fossil-energy intensive materials. Currently, many stakeholders associate the forest and wood-based bioeconomy with the innovative development of products based on wood residues like textiles, micro-fibres, bio-plastics, cosmetics, and platform chemicals. The objective is to use the renewable, but limited, wood resource efficiently and sustainably. This can be done by integrating the concepts of the 'circular economy' and 'cascading' into the bioeconomy concept, and in this way strengthening the mitigation potential of the forest and wood sector through carbon sequestration in wood products and substitution of fossil-energy intensive materials. By assessing ecological, economic, and social impacts over the full life cycle of products, sustainable product lines can be identified. Additionally, by connecting these outcomes with material flow analysis, the sustainability can be assessed of the demands of society at local, regional, and global levels not only in terms of the consumer behaviour, but also in terms of the work-

ing and living conditions. It is also essential to integrate the traditional use of wood into the overall bio-economical assessment.

Forests and other ecosystems are the starting point of bio-based value chains. Without sustainable forest management there can be no sustainable wood-based bioeconomy. The development of a bioeconomy could have a strong effect on forest management by the increased demand for wood. In turn, forest management influences the ecosystem structure (composition and diversity) and function, e.g. through choice of tree species and rotation lengths. Additionally, climate change affects the forests, implying that the silvicultural operations also have to be oriented to climate adaption.

If 'bioeconomy' is not only seen as progress in terms of technological innovation or as a concept of economic systems using 'biotechnology vision', 'bio-resource vision' or 'bio-ecology vision', but also as a societal concept, the next step is, according to Winkel (2017b), the 'bio-society vision'. Humans are not only consumers of the wood products provided by forests, but are also direct and indirect users and agents of all the other ecosystem services and of the biodiversity as their foundation. Therefore, the forest-based bioeconomy has to be realised in a way that contributes to the development of sustainable societies.

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Fig. B 5.11. Wooden building, the so-called 'Magician's Hat' in Rapperswil (Switzerland), designed and built by a very innovative Swiss wood processing company, used by the Knie Circus. The Brunner-Lehmann group uses Swiss timber and is active across the globe with a very specific constructive approach (Photo: Blumer-Lehmann AG).

Forest management as an insurance against natural hazards – a case study of protection forests in Switzerland

B 6

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Forests in mountainous regions provide crucial protection against natural hazards. This regulatory ecosystem service has historically often been provided as by-product of traditional forest management. During the past decades, economic development, land-use change, and climate change have put pressure on forest owners and the ecosystem itself. In Switzerland, a system of subsidies and guidance for practitioners has therefore been implemented to ensure that ecosystem services are provided at desirable levels. Increasing forest resilience against disturbances is one of the key concepts in this system, as resilient forests can better fulfil their role as a natural insurance. Over time, protection forest research has provided practitioners and decision-makers with a growing toolbox for identifying especially hazard-exposed areas and prioritising management accordingly, and for providing sustainable protection against natural hazards. Using a case study from the Canton of Graubünden in eastern Switzerland, we show that innovative management approaches promoting forest resilience are often in line with the provision of biodiversity and other ecosystem services. Software for integration of forest ecosystem and hazard simulation has recently been developed. The software allows for quantitative risk assessment and cost–benefit analyses of different management strategies in different climate scenarios. Simulation results from this tool can support prioritisation of management measures and help decision-makers determine whether additional investments in proactive climate adaptation measures are worthwhile. In order to assess trade-offs and co-benefits of certain management strategies, it is also important to increasingly include quantitative indices for biodiversity and other ecosystem services, and to further develop and apply tailored management strategies meeting stakeholder preferences on different ecosystem services.

Introduction

Forests provide a multitude of ecosystem services (ES) for humans and society as a whole. Besides carbon sequestration, water purification or biodiversity, one of the primary services provided by forest ecosystems in mountainous regions is the protection against natural hazards, such as snow avalanches, rockfalls, shallow landslides, and debris flows (Brang *et al.* 2006; Moos *et al.* 2018). These are rapid, gravitationally driven currents that can inundate large areas, destroying infrastructure, disrupting important transportation lines, and causing injuries and fatalities. Establishing and maintaining healthy mountain forests provides valuable

< Fig. B 6.1. The protection of local people, tourists and infrastructure from natural hazards is a very important and obvious forest function, not only in mountain areas. Forest management has to set clear priorities but still needs to respect other important forest goods and services, including biodiversity. The economic value of these forests is, apart from timber, the significant substitution effects avoiding expensive technical protection measures – but who has to pay and who will profit is the central question (Photo: Ulrich Wasem).

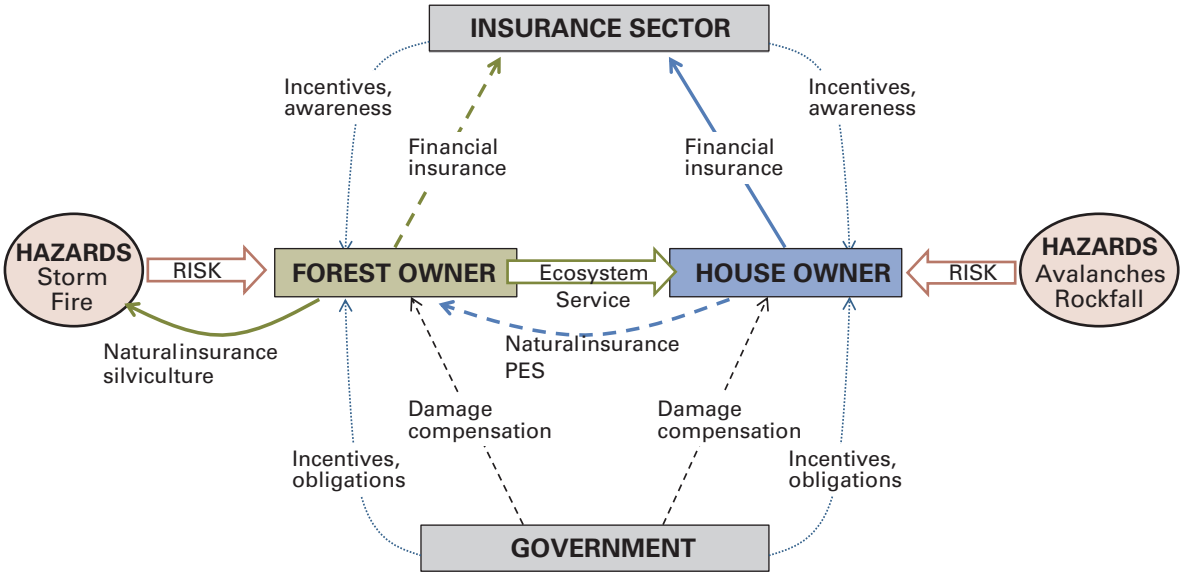

Fig. B6.2. Options for dealing with natural hazard risks. Natural hazards play a dual role as direct threats to human settlements and as important forest disturbances. By managing the forest in a sustainable way, forest owners reduce their own risk of economic losses; however, they also promote different ecosystem services such as biodiversity or protection against natural hazards. Direct payments for ecosystem services (PES) from house owners do currently not exist, possibly because protection has the character of a public good. As protection is the main forest function in hazard-exposed areas, specific management is incentivised by the government, and house owners buy financial insurance to cover the residual risk. Figure by R. Olschewski. WSL, 2017.

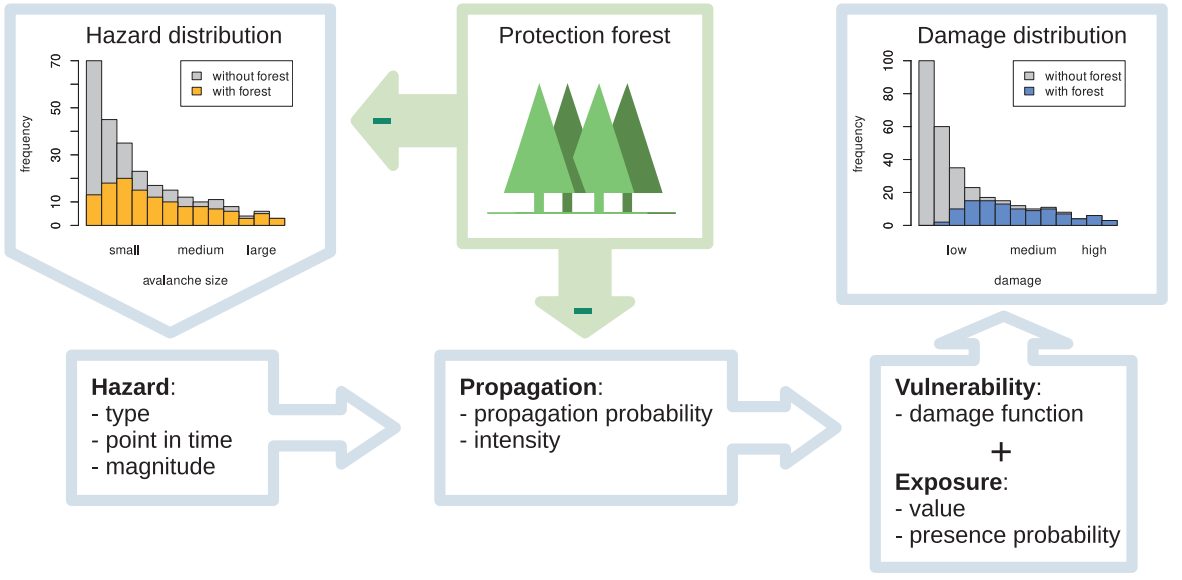

Fig. B6.3. Schematic representation of natural hazard risks and the mitigating role forests in mountain regions (see Moos *et al.* 2018).

protection and can be seen as investing in a 'natural insurance' against these hazards as damage will be smaller subsequently. As the protection capacity of forests is changing and may drastically be impaired by natural disturbances and other extreme events, there is increasing consensus that the resilience and thus sustainable protection in such forests should be maintained or enhanced (Bebi *et al.* 2016). While there are several studies quantifying the large economic value of protection forests in terms of avoided damage during past events (Teich and Bebi, 2009; Grêt-Regamey *et al.* 2013), the protection ES is typically not marketed to generate funding for forest management (Quaas and Baumgärtner 2008; Baumgärtner and Strunz 2014).

House owners living in hazard prone areas usually hedge their risk by buying financial insurance from an insurance company and do not directly pay forest owners for providing protection ES (fig. B 6.2). Partly, this may be because of the existing legal obligations (FINMA 2013), but more importantly it is a consequence of natural insurance having the character of a public good: once the insurance is in place, nobody can be excluded and there is no rivalry among neighbours in being protected. Furthermore, minimum protection levels have been required by forest laws for centuries.

The provision of protection has traditionally often been seen as a by-product of traditional and sustainable land use (Schuler 1996). While protection forests in Switzerland are highly appreciated and largely taken for granted, management of these forests has become less attractive owing to falling timber prices and rising management costs. The costs for protection forest management has thus, particularly in the Alps, increasingly been covered by public subsidies (Mannsberger 2017; Sandri *et al.* 2017), while management of forests on inaccessible slopes and/or without specific protection function against natural hazards has often been abandoned (Kulakowski *et al.* 2017).

In Switzerland, the economic development, the expansion of settlements and infrastructure, and increasing property prices have led to an increase of the value exposed to natural hazards (Moos *et al.* 2018). The existing hazard management system combines hazard zoning, avoidance measures, technical constructions, and dedicated forest management. Even if this works well and ensures a good level of protection, the optimisation of resources towards sustainable protection against natural hazards remains challenging. Particularly in protection forest management, the ongoing global change (Bebi *et al.* 2016; Sandri *et al.* 2017) and the provisioning of other ES (Mina *et al.* 2017) bring about new challenges. New options related to the interplay between financial and natural insurance may thus be relevant for the optimisation of future protection functions against natural hazards and of synergies with biodiversity and other ES.

Forests as a natural insurance against gravitational hazards.

When aiming to combine financial and natural insurance, it is crucial to understand how protection forests actually mitigate risks from gravitational natural hazards. According to a popular definition by the Intergovernmental Panel on Climate Change (IPCC 2012) and the United Nations Disaster Relief Organization (UNDRO 1980) (as cited by Moos *et al.* 2018), risk is the product of three factors: hazard, exposure, and vulnerability. While forests cannot influence the exposure and vulnerability of houses or infrastructure at the bottom of a slope, they have a large influence on the magnitude, onset probability, and propagation probability of the hazard itself.

For example, the snow retention in a protection forest could prevent avalanches from being released at all (onset probability), and snow detrainment (the extraction of avalanche snow mass) in the forest could reduce the magnitude of small- to medium-sized avalanches, resulting in smaller, less frequent damage (propagation probability). From an insurance point of view, the protection forest would change the magnitude–frequency distribution of a certain hazard, as well as the way in which this hazard distribution translates into a monetary loss-frequency-distribution (see fig. B 6.3).

Dynamics of mountain forests and implications for management and ecosystem services

Protection forests are dynamic ecosystems that change all the time, with interactions and feedback loops on different spatial and temporal levels. Abiotic and biotic disturbances are substantial driving forces of forest development and frequently reshape the landscape (Wohlgemuth *et al.* 2019). Interactions such as the coincidence of windthrow and warm weather favouring insect reproduction can multiply the effect of the original disturbance. Because of slow forest growth at higher altitudes

or high browsing pressure, legacies of both disturbances and management interventions may remain visible for several decades. Therefore, disturbance legacies and interactions between disturbances are such pivotal factors in mountain forests, that they need to be considered in both the assessment of protection ES and forest management.

Additional to natural disturbances, effects of historic land use and former forest exploitation often have an important effect on current structure and long-term provision of ES in mountain forests. After the maximum of forest exploitation in the nineteenth century, afforestations and abandonment of former pastures have often led to an increase in forest cover and density in many mountain chains of Europe (Kulakowski *et al.* 2017). These forests are now often characterised by dense, even-aged stands with strong competition between trees, short crowns, and no regeneration below the canopy. While dense and even-aged stands often provide good protection against rockfall and avalanches, their susceptibility to disturbances may be increased and the capacity to regenerate after disturbances and adapt to climate change is reduced compared to more structurally diverse forest stands (Bebi *et al.* 2017).

With increasing growing stocks and awareness of natural disturbances in mountain forests, the focus of protection forest management has shifted during the last decades from afforestations to interventions for enhanced resilience (Brang *et al.* 2006; Bebi *et al.* 2016). The concept of resilience can thus be seen as a useful guideline to protection forest management because it aligns very well with the aim to ensure the stable provision of desired ES even in a disturbed environment (Briner *et al.* 2013; Albrich *et al.* 2018).

The dynamic nature of forests including legacies of former land use, disturbances, climate, and feedback loops between different drivers makes it highly challenging to evaluate or even predict changes of ES and risks in mountain forests. It is thus necessary to move from indicator-based steady-state assessment methods to process-based representations of the (eco)system and temporally integrated measurements of risks and ES. Important steps in this direction have been undertaken during the last years (e.g. Briner *et al.* 2013; Maroschek *et al.* 2015; Albrich *et al.* 2018; Moos *et al.* 2018); these steps have specifically focused on ecosystem resilience as a prerequisite for a stable provision of ES even in a disturbed environment. In the second part of this chapter, we propose a new tool to expand their work: a dynamic, bidirectional link between forest development and natural hazard simulations that allows simulation of damage over time and calculation of the costs and benefits of different management scenarios.

Management for resilience in protection forests

Ecosystem resilience is commonly defined as the capacity of ecosystems to absorb disturbances while maintaining their basic structures, functions, and feedbacks (Walker *et al.* 2004; see also Chapter A9 Lindner *et al.* in this book). As such, resilience is an ecosystem property that "determines the persistence of relationships" within the system (Holling, 1973). Mäler and Li (2010) characterise resilience as *"a kind of insurance against reaching a non-desired state"*. The higher the level of resilience the lower the risk of facing losses of ES, income, or wealth. Following the definition by Mäler and Li (2010), resilience is thus a highly desirable quality of protection forests, determining how well forests can withstand and recover from disturbances in order to provide uninterrupted protection.

Resilience in protection forests can generally be improved by enhancing diversity in terms of tree species and forest structure. The most common management approach towards promoting increased resilience in protection forests are relatively small regeneration cuts (Frehner *et al.* 2005; Brang *et al.* 2013). These management interventions aim mainly at increasing light availability and improving growth conditions for new regeneration while maintaining protection against natural hazards at acceptable levels. In the longer term such regeneration cuts would thus increase the sustainable protection against natural hazards by reducing, for example, the time when there is limited protection against rockfall or avalanches after windthrow or other disturbance events by opening new windows of opportunity for a higher tree diversity and regeneration of climate-adapted tree species (Bebi *et al.* 2016).

Having said that, all the benefits brought about by managing forests for resilience come at a cost. As Albrich *et al.* (2018) conclude *"Achieving a temporally stable and maximum ES supply will often not be simultaneously possible in ecosystem management"*. In such frequently disturbed ecosys-

tems as mountain forests, though, accepting a lower baseline productivity and spending money on additional management measures might still pay off in the long run, if the disturbance damage is much smaller and the recovery of ES provisioning to pre-disturbance levels after an event is much faster.

Concepts for managing towards increasing resilience and a sustainable protection against natural hazards are already integrated in practical recommendations (e.g. Frehner *et al.* 2005; Mannsberger *et al.* 2017). For example, they are incorporated in the management guidelines NaiS (Sustainability and success monitoring in protection forest; Frehner *et al.* 2005); these guidelines are mandatory for all management interventions in protection forests of Switzerland and provide practical recommendations specific for forest types and natural hazard situations. Besides resilience as an overarching concept, these guidelines also consider several other aspects including the type of natural hazards, priorities according to the damage potential to be protected, or issues of pest control and climate adaptation (Sandri *et al.* 2017).

Case study: Co-benefits of protection forest management in Davos

In order to showcase how science-based approaches and increased resilience may contribute to an optimised protection forest management and how this may also help to promote biodiversity, we present a case study in the Canton of Graubünden in eastern Switzerland. In particular, we describe how a process-based simulation model may facilitate quantitative risk assessment, and we outline how forest management for resilience could be incentivised by quantifying regulatory and other ES provided.

Case study area Davos

Davos is situated at an elevation of about 1550 m a.s.l. in the central Swiss Alps. Forests of the 283 km² landscape around Davos (Landschaft Davos) are generally dominated by Norway spruce *(Picea abies)*. Additional tree species include Swiss stone pine *(Pinus cembra)* on drier sites near the treeline and European larch *(Larix decidua)* in frequently disturbed avalanche runout zones and towards the treeline. The area is famous for tourism in winter and summer, whereas farming activities have consistently been in decline since the end of the nineteenth century. The forest has gradually expanded, currently occupying an area of about 22 % of the total landscape and providing a variety of ES to residents and visitors (Grêt-Regamey 2013). About 50 % of the forests fulfil direct functions against natural hazards. Gravitational natural hazard processes such as snow avalanches, rockfall, and landslides are major hazards for people and infrastructure. In addition to rapid mass movements, mountain forests may also be disturbed by other abiotic disturbances such as storms and snow breakage, but also by biotic disturbances such as ungulate browsing and bark beetle outbreaks.

Main disturbances and natural hazards

The dual role of mass movements and the interactions between disturbances entail positive or negative feedback loops in the ecosystem: after a storm damaging parts of a protection forest, subsequent bark beetle outbreaks may further increase the damage (Seidl and Rammer 2017) and further reduce the protection against natural hazards; or after an avalanche cutting a new avalanche path into the forest, a follow-up avalanche may be more likely to reach the village below. On the other hand, avalanche tracks may serve as hotspots for biodiversity and as breaks for fire and bark beetle outbreaks, or lying deadwood left after a disturbance can become a germination bed for forest regeneration (Bebi *et al.* 2019).

Management system and ecosystem services

Forest management and forest ES have changed several times in the history of Davos. After settlement of the landscape around Davos in the thirteenth century, forests were heavily grazed, and trees were used for timber, firewood, and mining (Bebi *et al.* 2017). As a result, the forest structure was more open during former centuries. Towards the end of the nineteenth century, a firmer forest law and a strong decrease in the goat population caused an increase in forest cover and forest density. A further decrease of forest management in the mostly privately-owned forests has been related to the booming winter tourism since the 1950s and a decrease of wood prices relative to high management costs in the often steep and poorly accessible slopes (Bebi *et al.* 2012). Since the 1980s, forestry benefitted from new forest regulations and financial support for the management of protection

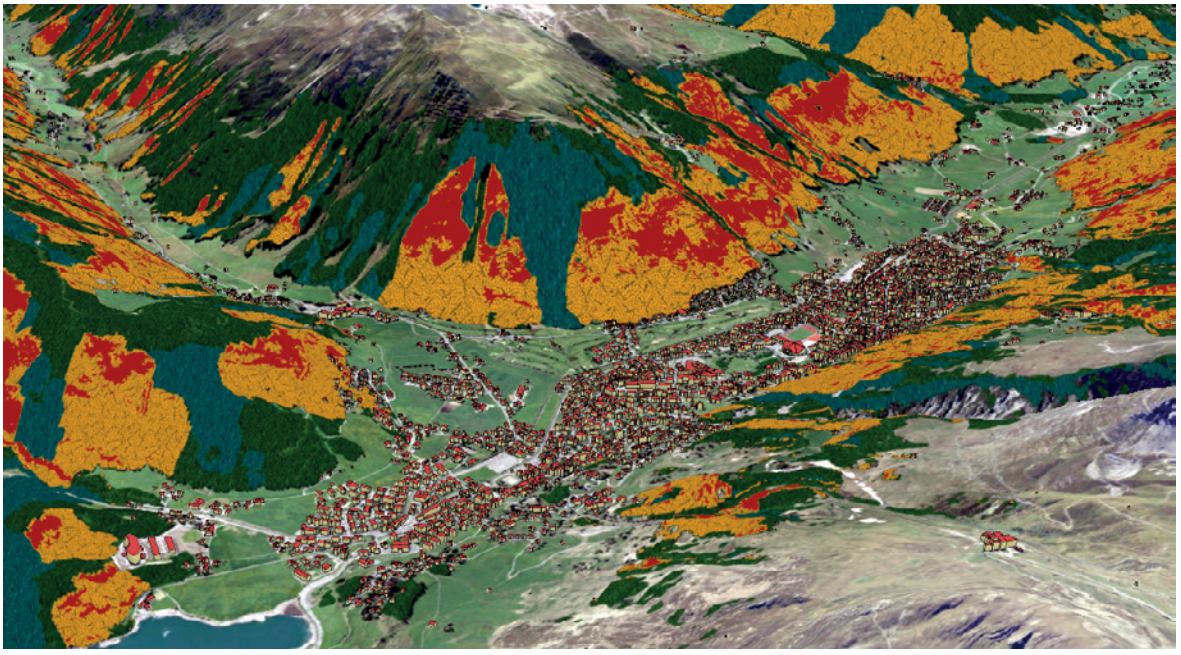

Fig. B 6.4. Example screenshot of an interactive map, showing how remote sensing data and avalanche models may be used to identify avalanche protection forests in Davos. Forests coloured in green have no direct effect on avalanches based on a comparison of RAMMS-scenarios with and without forest for a ca. 30-year avalanche event. Forests coloured in blue have an effect on avalanches, but have no direct protective effect for buildings. Forests coloured in red (≥ 35 ° steepness) and forests coloured in yellow (slope < 35 °) protect buildings against avalanches. The threshold of 35 ° in this example was chosen to highlight (in red) areas, where an appropriate forest structure is of particular high importance for the protection against avalanche releases (map created by Kevin Helzel, SLF).

forests from the Swiss Federation, the Canton of Graubüden, and the community of Davos (Sandri *et al.* 2017). Thanks to this support for protection forest management, the annual use of wood accounts on average for around 11 000 m^3, which corresponds to an average of about 70 % of the annual stand volume increment. As management operations without support for protection forest management is not economic, interventions are currently limited to protection forests and have to be carried out according to the NaiS-guidelines for a sustainable protection forest management (Frehner *et al.* 2005). The timber harvesting in the largely steep forests of Davos is carried mainly by cable yarding and to a smaller degree by skidding or helicopter.

Management approaches for improved protection and biodiversity

In the following paragraphs, we present five main fields of research and innovation in protection forest management that may play a key role in ensuring an optimal level of protection while also maintaining or enhancing biodiversity and other ES in the future. Some of them have already been implemented in Switzerland and may serve as inspiration for other regions, while others showcase methods still under development but possibly available to practitioners in the near future.

Managing where protection is necessary

An important requirement for an efficient management of protection forests is spatial information about the extent of forests with a risk reducing function. In Switzerland, such spatial information has been created and harmonised within the project SilvaProtect based on available data of damage potential and topography, and simulations of different natural hazards with and without forest cover (Losey and Wehrli, 2013). The relevant spatial extent of these forest patches with a relevant pro-

tection against natural hazard has been checked and consolidated by the cantons and serves today as basis for the distribution of financial support for measures in the protection forest. Within this perimeter, Swiss cantons have established multiple approaches to further prioritise measures for protection forest management. On the basis of improving data, modelling approaches, and knowledge about natural hazard processes in forested terrain, it is promising to periodically re-assess and, if necessary, improve these prioritising schemas in an operationally reasonable timeframe and to generate interactive maps of protection functions in relation to certain natural hazards. An example of how the identification of important avalanche protection forest can be supported based on interactive digital maps with newly available remote sensing data and models is shown in Figure B 6.4. Resulting interactive maps may support decision-making for prioritising forest intervention towards optimised natural hazard protection and for identifying other areas where biodiversity or other ES are more relevant. Depending on the site-specific requirements, even structurally diverse unmanaged forests with large deadwood pools can provide good protection against rockfall (Fuhr *et al.* 2015) and other regulatory ES (Seidl *et al.* 2019). This means that both biodiversity conservation and a high level of protection can be achieved by limiting management to areas where it is really necessary.

Increasing Resilience and climate change adaptation

Resilience in protection forests can mainly be improved by a diversification of age structure and species composition and by measures of climate adaptations (Bebi *et al.* 2016). Small intervention gaps according to Frehner *et al.* (2005) are the most important control instrument to increase the regeneration and thus the resilience in protection forest stands (Brang *et al.* 2006. In the sense of climate adaptation, regeneration cuts may additionally be used to adjust the tree species composition to the requirements of the future climate. In the mostly spruce-dominated and often relatively dense forests of Davos, it is thus important to foster advance regeneration and to promote additional tree species which are not affected by spruce bark beetles (mainly *Ips typographus*) and will be expected to tolerate warmer temperatures and drought. Beside other indigenous species like European larch and Swiss stone pine (which are only to a limited degree competitive in dense spruce forests), silver fir *(Abies alba)* and broadleaved species (e.g. *Acer pseudoplatanus* and *Fagus sylvatica*) may increasingly be introduced. In some parts of the study area, a diversification of tree species is only possible if wildlife management will be adapted in a way which allows the regeneration of these species (Didion *et al.* 2009). Management measures promoting forest resilience by increasing the structural and tree species diversity in even-aged spruce stands usually even foster biodiversity in other species groups.

Managing disturbances and the role of deadwood

In addition to regeneration cuts, natural disturbances offer the opportunity to adapt to climate change, whereby the pioneer vegetation can be specifically supplemented with additional (climate-adapted) plantings. After natural disturbances, it is also very important to exploit the positive effect of deadwood to increase surface roughness and protect against avalanches and rockfall (Fuhr *et al.* 2015) and to increase long-term resilience by fostering regeneration on deadwood (Brang *et al.* 2013). The positive effect of deadwood on the seedbed is well known, particularly in spruce-dominated forests with limited seedbed availability (Bače *et al.* 2012; Kalt *et al.* 2021; however, it should be noted that the time period until deadwood provides favourable conditions for regeneration in a relatively cold and dry region like Davos usually exceeds 30 years and a latent availability of deadwood in different stages may provide a more sustainable supply of seedbeds. Without additional treatment, leaving deadwood in the forest after a disturbance may increase the risk of bark beetle outbreaks. If bark beetle risk is mitigated (e.g. by peeling or stripping the bark from logs), then leaving deadwood is likely to be beneficial in multiple ways: for direct rockfall protection, for forest regeneration, and for biodiversity, in particular of saproxylic organisms (Thorn *et al.* 2018).

Timing of management interventions

The timing of management intervention is crucial for optimising the effects of the interventions on resilience and long-term protection (Frehner *et al.* 2005; Brang *et al.* 2016). Reducing the time between interventions and the harvested volume per management intervention may in some cases reduce

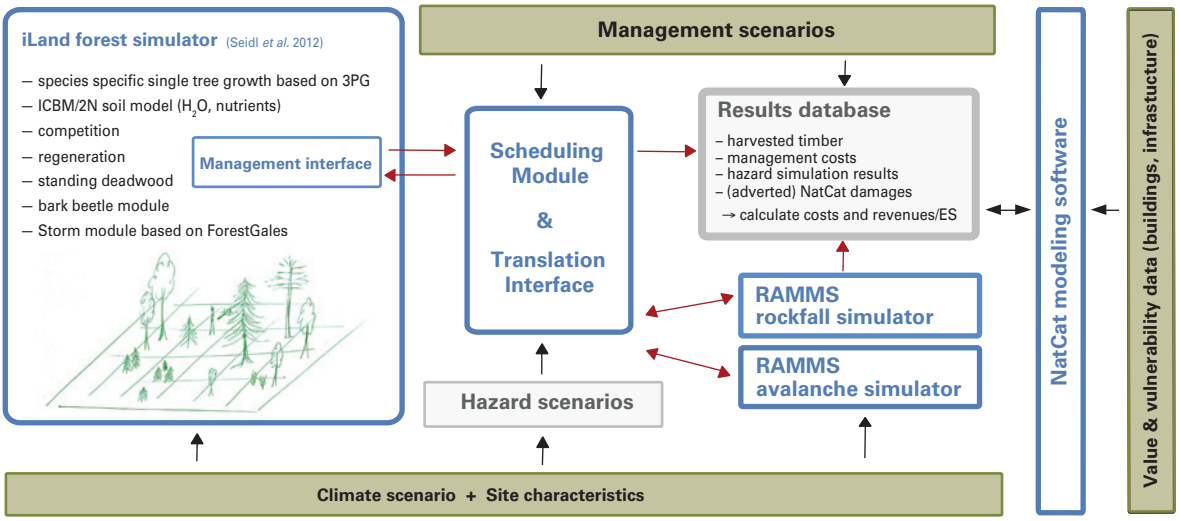

Fig. B 6.5. Simulation framework. Green boxes represent input data and scenarios, blue boxes represent the core parts of the simulation software.

windthrow risk (Brang *et al.* 2016). While early and repeated forest interventions are often particularly valuable in secondary spruce-dominated forests (regrown after agricultural abandonment or afforestation in the nineteenth or twentieth century), in order to avoid the development of even-aged and short crown forest structure with a low resilience (Bebi *et al.* 2017), the timing of management intervention seems to be less important if the timing for early intervention has been missed and a forest is already in an advanced self-thinning development stage (Guetg 2020). Time periods between management interventions may also be much longer in protection forest types with naturally higher resilience (e.g. in topographically complex terrain with clustered forests patches and suitable conditions for regeneration). In such cases with naturally longer time periods between management or with only passive management there is also a higher potential for synergies between biodiversity and optimised protection against natural hazards.

A simulation framework for quantitative risk assessment and cost–benefit analysis of forest management strategies

In times of climate change, it is particularly challenging for forest managers to shape forests that will keep providing essential ES even under rapidly changing environmental conditions. Unfortunately, hazard risk assessment tools often assume a steady forest state and do not take into account protection gaps resulting from interacting forest disturbances. An ongoing research project by the University of Freiburg and the Swiss Federal Institute for Forest, Snow and Landscape Research aims to overcome these limitations by dynamically linking hazard and forest simulation models. This might allow quantification of the hazard risk reduction and other ES over time and in various future climate and management scenarios.

Figure B 6.5 shows the methodological approach of the project. The forest landscape simulator iLand (Seidl *et al.* 2012) is linked to the process-based avalanche and rockfall model RAMMS (RApid Mass Movement Software; Christen *et al.* 2010, 2012) through a translation interface.

Input data for the models are climate scenarios, site characteristics, and starting conditions (tree species, diameter distributions, soil nutrient pools, seedbed, sapling cohorts, etc.) for the forest stands to be simulated. The landscape is separated into subdomains according to the spatial allocation of rockfall and avalanche release areas. Hazard release events are only simulated in the respective subdomain of the landscape, which given limited computing resources saves processing time.

Using the iLand management interface (Rammer and Seidl 2015) and a scheduling module, adaptive management strategies are defined, and disturbance events are dynamically integrated into

the simulation runs. To assess the costs and benefits resulting from different management strategies, realistic, site-specific stand treatment programmes are distributed in the landscape and coupled to realistic cost functions. For each combination of climate, disturbance, and management scenarios, multiple iterations are simulated. The results are transferred to a database including information about harvested timber, management costs, and hazard simulation results. Costs and revenues, as well as other ecosystems services (regulating services) are calculated per hazard domain. Using NatCat modelling software (e.g. CLIMADA, Aznar-Siguan and Bresch 2018), damage is calculated taking into account value and vulnerability data on buildings and infrastructure. The value of the protection ecosystem service can subsequently be calculated as the reduction of damage compared to a baseline scenario (no forest or no management).

To give an example, the benefits of funding additional, proactive climate adaptation measures on a critical slope could be calculated as follows: The value generated (ΔV) is the change in NatCat damage (D) compared to standard management (business as usual, BAU) minus the change in management costs (M) and the opportunity costs for all other marketable ES, in our case timber production, integrated over time.

$$\Delta V=(\Sigma D_{BAU}-\Sigma D_{add})-(\Sigma M_{add}-\Sigma M_{BAU})-(\Sigma ES_{BAU}-\Sigma ES_{add})$$

Of course, the last part of the equation subsuming other ES can be expanded as desired. Weights or utility functions according to stakeholder preferences can be added for single ES to facilitate decision-making. Hitherto, protection forest management has largely been guided by the aim of keeping hazard risks acceptably low and measures are subsequently prioritised to achieve this goal in the most economically efficient way. In a similar manner, biodiversity objectives or carbon sequestration goals could be incorporated into cost–benefit analyses of simulated management strategies and consequently play a larger role in forest planning.

Because of the stochasticity in disturbance and hazard events and the nonlinear feedback loops in the ecosystem, the outcomes of single simulation runs are not deterministic and must not be used to draw general conclusions. To account for stochasticity, we simulate several replicative runs for each combination of management and climate scenario, resulting in three-dimensional distributions of damage frequency curves, cumulative timber revenues, and management costs. To facilitate risk assessment and decision-making, these can be aggregated into cost–benefit distributions for each hazard simulation domain. This approach might in the future be extended towards a Bayesian optimisation of management strategies using expert recommendations as primers and then gradually varying management parameters.

Outlook and considerations for practical implementation

Many features of sustainably functioning protection forests, such as structural diversity, species diversity, and high volumes of lying deadwood also promote biodiversity. The case study of Davos shows how forest managers can shape co-benefits for biodiversity conservation and other ES while investing in resilient, climate-adapted protection forests.

New tools for quantitative analysis of ES and natural hazard risks facilitate prioritisation between multiple desired ES and balancing risks over space and time. Simulations of future forest development scenarios could show whether a proactive adaptation of forests to climate change is economically beneficial and which synergies between ES could be harnessed to reach multiple objectives at the same time.

The Swiss protection forest management has succeeded in balancing the interests of various stakeholder groups to maintain crucial ES when its traditional foundation came under pressure owing to changes in land use and economic structures. Despite generally being considered a success story, the Swiss protection forest management framework has some characteristics that might limit its transferability to other regions and it highlights some limitations of natural insurance schemes: because protection ES have the character of a common good, there are as yet no market mechanisms allocating funding for protection forest management; and because of the long-time scales in mountain forests, the scenario uncertainties and the stochasticity of disturbance events are unlikely to be reduced in the future. For these reasons, funding natural insurance schemes as proposed by Baumgärtner and Strunz (2014) with payments from private actors seems unlikely in mountain

regions. Nevertheless, protection forest management is generally deemed macroeconomically beneficial and desirable, as it helps protect large areas from natural hazards at a rather cheap price compared to technical solutions.

Switzerland has solved the structural challenge of privately-owned forests providing non-marketable but desirable ES for a larger public by establishing a legal and economic framework involving all levels of government. In particular, Swiss protection forest management has benefitted from specialised legislation (Swiss forest law, German: Waldgesetz, WaG 1991), science-based management guidelines (Frehner *et al.* 2005), a well-staffed forest administration, and the provision of public funds. It is, therefore, not easily transferable to other regions of the world where even the best ideas for forest management might fail owing to legal constraints or limited resources.

Finally, another very important aspect needs to be considered: acceptance. The Swiss protection forest management has gained the support of all relevant stakeholder groups – municipalities, local residents, forest owners, cantons, and the federal state – and carefully balances their interests. When applying natural insurance schemes elsewhere, possible improvements in the protection against natural hazards need to be balanced against other objectives and ES (see Paavola and Hubacek 2013 on trade-offs). Prioritisation of management measures exclusively based on economic criteria is problematic as it affects the spatial distribution of risk reduction measures: a protection forest management scheme that, for example, neglects sparsely populated side valleys and only protects village centres with a high density of properties would be economically efficient but would likely not find the acceptance of the local population. The public funding in Switzerland helps avoid this and even facilitates strengthening new objectives such as biodiversity conservation or carbon sequestration in protection forest management in the future. In fact, environmental policy research suggests that management of common goods is actually most effective if it involves all relevant stakeholder groups because their participation enhances the quality and implementation of environmental management decisions (Beierle 2002; Reed 2008). Natural insurance schemes should, therefore, go beyond a mere business model for single actors: if policy makers follow the guidelines by Farley and Costanza (2010) and consider temporal scales, local expert knowledge, and stakeholder participation, an implementation is more likely to succeed and find long-term acceptance and support among the population.

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Fig. B 6.6. Trees protect people and infrastructure from natural hazards. Hikers, for example, benefit from the protective service of forests in mountain areas, where trees prevent rockfall (Photo: Ulrich Wasem).

Integrative wildlife management based on the adaptive, collaborative management of social-ecological systems

B 7

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Introduction

Challenges in forest and wildlife management are increasing in Europe as a result of growing tensions between forest production, forest adaptation to climate change, biodiversity conservation, as well as other goals such as hunting, recreation, and tourism. These tensions also extend to issues concerning the provision of habitat for wildlife and damage caused to forest stands by specific species (in Europe mainly by even-toed ungulates) (Niemelä *et al.* 2005; Kolström *et al.* 2011; Redpath *et al.* 2013). Forest and wildlife management and biodiversity conservation are also linked to developments of land use, human demographics and livelihoods, wildlife populations, habitats, as well as climate on a global scale (Distefano 2005). Consequently, the activities of various stakeholders directly or indirectly influence wild animals and their habitats, as well as the tasks and actions of other stakeholders. Reconciling different demands often leads to conflicts between the various stakeholders and the various activities such as forestry, farming, hunting, tourism, and conservation (Redpath *et al.* 2015). These conflicts often have significant economic, social, and ecological impacts on both biodiversity and humans and their livelihoods (Young *et al.* 2010; Harich *et al.* 2013).

< Fig. B 7.1. While big predators are widely absent in Europe, the management of wildlife, in particular of ungulates, is an important part of managing forests and habitats. The sustainable provision of important forest goods and services directly depends on the availability of targeted tree regeneration which can be highly impacted by excessive populations of e.g. red deer, sika deer roe deer and mountain goat (picture) (Photo: Ulrich Wasem).

Adaptive collaborative management (ACM) of social-ecological systems (SES) has been promoted as a promising approach to address these challenges (see e.g., Allen and Garmestani 2015). It can also serve as a basis for the development of a working wildlife management concept (Butler *et al.* 2015). An analysis using the SES framework helps to gain a better understanding of processes in a wildlife management case (Williams and Tai 2016) and ACM helps to develop natural resource management strategies in light of the complexity, uncertainty, and change arising from the challenges mentioned above (Armitage *et al.* 2009). Political and social factors should be considered and combined with ecological aspects (Bennett *et al.* 2017).

An integration of knowledge by linking various fields of science (and practice as well) is crucial for the understanding of interlinked SES and the development of sustainable management solutions (Johansson *et al.* 2016). Such integrative wildlife management covers all areas of activity and measures affecting the occurrence, behaviour, and population development of wild animals and their habitats as well as the relationships and actions of stakeholders (Redpath *et al.* 2015). A comprehensive approach is needed in which all stakeholders are involved in the identification and implementation of solutions to the above-mentioned conflicts and to create pathways for shared responsibility and cooperation. In this regard, participation is a key element in the process, but there is no universal panacea. Instead, approaches must be tailored to deal with the complexity of the relevant SES, focusing both on the process and the outcome of participation (Reed 2008).

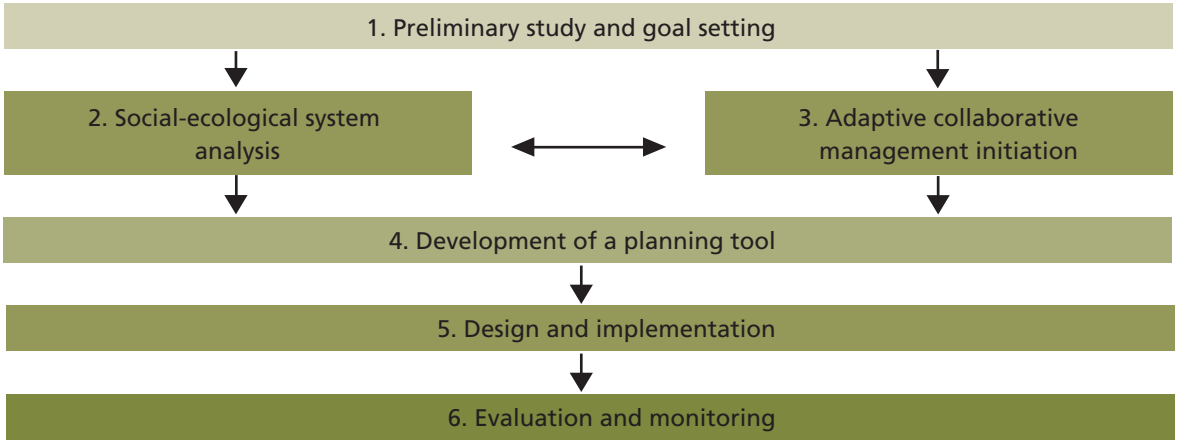

Fig. B 7.2. Approach for the development of an integrative wildlife management concept.

In the remainder of this chapter, we present an approach for the development of an integrative wildlife management concept that aims to improve the balance between biodiversity conservation and other forest management goals. It is based on the ACM of SES as well as on existing frameworks and success criteria of integrative wildlife management; the approach consists of six steps (fig. B 7.2).

We illustrate the approach with a case example concerning red deer *(Cervus elaphus)* management in the Northern Black Forest in Germany, and then discuss general insights that may be transferable to other contexts.

Case example

In the German federal state Baden-Württemberg, red deer populations have been restricted to five legally defined 'red deer areas' since 1958. These areas were implemented because of extensive damage caused by red deer, the risk of traffic accidents, and stakeholder demands. Inside red deer areas, red deer is controlled by an annual game harvest plan. Outside red deer areas, all red deer shall be shot. There is some exchange between populations of different areas, but adjacent residence, industry, agriculture, and traffic are barriers for animal movement. The largest red deer area is located in the Northern Black Forest (NBF, covering 105 000 ha). Owing to the high proportion of dense forest stands with little understorey vegetation and lack of alternative food sources in the NBF, red deer often browse on new shoots of trees and peel off the bark from larger trees. These impacts have led to discussions about forest management and biodiversity conservation, both in managed forests and in protected forests. Because of red deer's extended spatial use and complex social behaviour, its management is best coordinated across large areas. However, this has proven to be difficult because of the diverse landowner structure, the small size of hunting districts, the differing management strategies of the various stakeholders involved, and an increase of recreational activities in the NBF. In addition, the living conditions of red deer have changed as a result of large-scale windthrows and red deer population growth. Also, the Black Forest National Park was established in 2014 in the NBF, covering 10 062 ha of the NBF red deer area. The establishment of the national park has changed the conversational atmosphere, leading to tensions between stakeholders regarding wildlife and forest management, as well as associated questions of wood production, hunting, and biodiversity conservation. Therefore, an independent, interdisciplinary research team (including the authors of this chapter) has been assigned to develop a sustainable management concept for red deer management in the NBF[1]. The research team was responsible for the scientific studies, as well as the initiation and implementation of moderation and planning processes.

[1] Promoters of the project were the Ministry of Rural Affairs and Consumer Protection Baden-Württemberg and the Black Forest National Park.

Development of an integrative wildlife management concept

1. Preliminary study and goal setting

There are no clear boundaries around SES, and so the definition of a specific SES in a preliminary study is a necessary starting point to enable any planning process. This can be achieved with the support of the SES framework (Ostrom 2007, 2009; Ostrom and Cox 2010; McGinnis and Ostrom 2014) to analyse and structure natural resource management cases (Cox *et al.* 2010). The distinction of an SES is determined by social and ecological divides, such as management objectives, the distribution area for a species, or a protected area and its environment. In the NBF, the SES was predetermined by the boundaries of the red deer area. In a preliminary examination, basic SES elements were analysed by collecting data on forest structures and habitat characteristics, red deer population and distribution, land use, wildlife impacts on tree regeneration and vegetation, governance structures, and stakeholders. It is also important to define goals for the integrative wildlife management concept to be developed; these have to be coordinated between stakeholders, reconciling different forest and habitat functions, such as forest production and biodiversity conservation (Palomo *et al.* 2011). Therefore, preliminary conversations were conducted with stakeholders in the NBF, such as governmental and administrational actors, municipal and private landowners, foresters, hunters, national park administration, representatives of the tourism sector, and conservation organisations. Together with these stakeholders, the following goals were defined as desired outcomes of an integrative red deer management concept:

1. Restriction of wildlife damage caused by red deer damage to an extent that can be tolerated by landowners;
2. Continued provision of suitable habitat for a minimum viable population of red deer;
3. Locally differentiated adaptation (increase or reduction) of the red deer population following goals (1) and (2);
4. Creation of attractive hunting opportunities and hunting value;

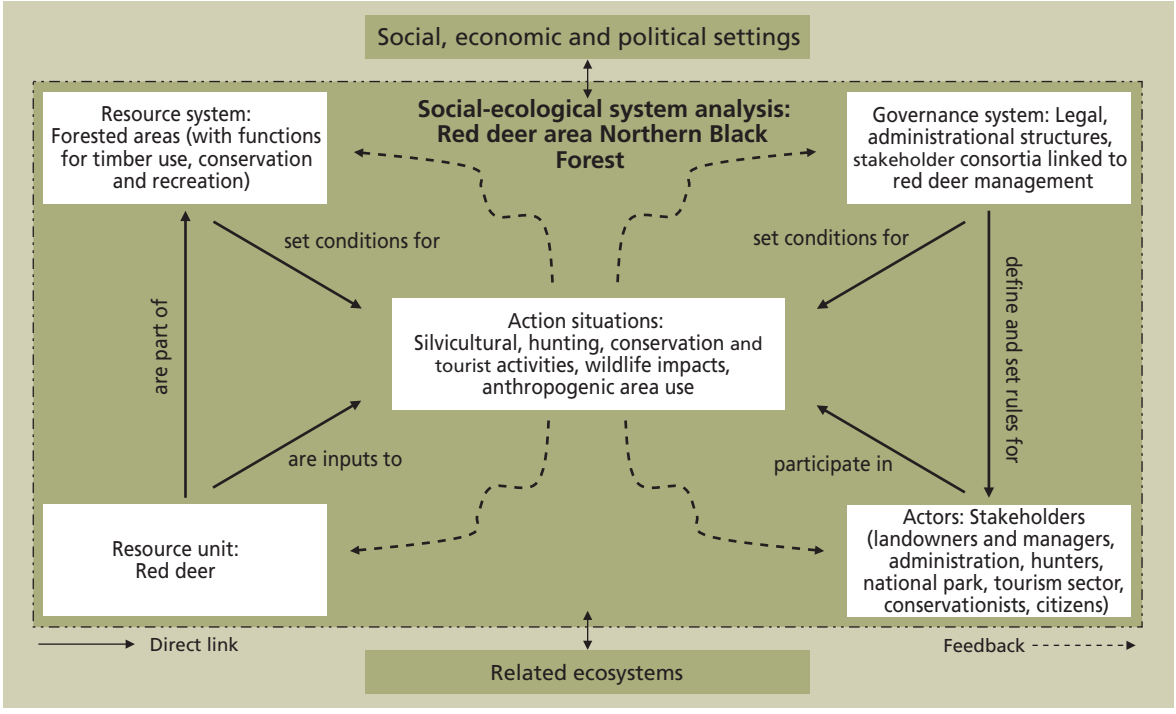

Fig. B 7.3. Social-ecological system framework of the red deer area in the Northern Black Forest (modified from McGinnis and Ostrom 2014).

5. Creation of a planning instrument for tourist development;
6. Establishment of permanent management structures;
7. Coordination of red deer management in the national park with the rest of the NBF.

2. Social-ecological system analysis

An SES encompasses four elements: resource systems, resource units, governance systems, and actors. These elements interact with each other in 'action situations'. In turn, these lead to different outcomes, which often provide feedback and lead to alteration of the elements (McGinnis and Ostrom 2014) (fig. B 7.3).

In the NBF, the resource system mainly consisted of forested areas with simultaneous management objectives of timber production, conservation, and recreation. These areas were analysed through an examination of forest types and tree composition as well as an assessment of how suitable the habitat is for red deer. Red deer was the resource unit in question. Composition, distribution, and behaviour of the red deer population in the NBF were surveyed by telemetry, genetic studies, and monitoring with camera traps. The relevant governance systems included legal and administrational structures as well as stakeholder consortia linked to red deer management. These were examined through discussion rounds and accompanying observation. Municipal and private landowners (including mayors and councillors), land managers (foresters, hunters), administrational stakeholders (e.g. state forest, administration, national park administration), hunting tenants, representatives of the tourism sector, conservation organisations, as well as citizens were identified as actors. Their frames were examined by in-depth interviews and their value orientations and attitudes were measured by surveys. Interactions between SES elements were examined through: (i) an inquiry of ownership distribution and management goals (silvicultural, hunting, conservation, and tourist); (ii) a standardised monitoring of wildlife impacts on tree regeneration and vegetation; (iii) an analysis of hunting quotas; and (iv) an examination of use of the area by the various stakeholders. Finally, important issues and actions were discussed in focus groups with stakeholders.

3. Adaptive, collaborative management initiation

There are 13 characteristics of successful ACM processes, which can be summed up under three categories: (i) political and legal context and rules, (ii) cooperative management and collaboration, and (iii) cooperative management and collaboration.

Box B 7.1. Characteristics of successful adaptive, collaborative management processes (summarised following Ehrhart and Schraml 2018)

- Political and legal context and rules
  - Well-defined user and resource context
  - Provision of auxiliaries and support
  - Reasonably clear appropriation and provision rules
  - Legitimacy
  - Accountability and responsibilities
  - Conflict resolution mechanisms and sanctions
- Cooperative management and collaboration
  - Bridging knowledge and transparency
  - Inclusiveness and fairness
  - Participation, interactions, and institutionalised cooperation
  - Management plans and measures
  - Coordination by key leaders or bridging organisations
- Adaptability
  - Adaptiveness, flexibility and learning
  - Assessment and collaborative monitoring

The development of an integrative wildlife management concept can be supported by an adaptation of these characteristics to the specific SES. For that purpose, an ACM process can be initiated (Ehrhart and Schraml 2018). ACM is a process in which networks and knowledge are examined and revised in a successive, dynamic, and self-organised way of learning through practice and science. Links between stakeholders are established with a focus on social learning. The process helps to increase trust and resolve conflicts. ACM has proved to be a suitable approach for the development of a resource management system, which is tailored to a specific SES and which is supported by, and works in conjunction with, various organisations (Armitage *et al.* 2007; Berkes 2009). In the NBF, an ACM process was initiated by the research team in two local forums, which were open for all citizens. In these forums, participants were randomly distributed in moderated groups which discussed and collected issues and questions regarding: communica-

tion and organisation, forestry, hunting, tourism, and conservation. On this basis, five topical working groups were established; the groups were open for anyone to participate. Individuals from all relevant stakeholders volunteered for participation in each of the working groups. A topical working group on communication and organisation acted as a panel that accompanied the ACM process, adjusted the 13 ACM characteristics to the NBF's conditions, and developed concepts for communication and governance (fig. B 7.4). Finally, regular meetings and workshops with and between stakeholders were established.

4. Development of a planning tool

Based on the information provided by the scientific results of SES analysis and the consideration of ACM characteristics, a planning tool can be developed. In order for the process to be successful, the stakeholders should take an active, responsible role (Palomo *et al.* 2011). This can be achieved through citizen task forces, where stakeholders identify and discuss important issues and develop solution approaches (Chase *et al.* 2000). For integrative wildlife management, it is important to consider different practical management dimensions such as forestry, hunting, conservation, and recreation, as well as communication. Based on this, it is possible to develop a planning tool, where goals and measures are defined on a local scale. These can then be aligned to superordinate processes and institutions, such as governance structures or monitoring systems. In the NBF, the other four topical working groups, which emerged through the ACM initiation, focused on forestry, hunting, tourism, and conservation. These groups used the information provided by the previous steps of the approach to develop a planning tool that included guidance for management actions and a zoning strategy. The planning tool included: (1) distribution zones of red deer, (2) core distribution zones of red deer, (3) zones for recreational and forest adventure activities, and (4) resting zones for wildlife. For each of these zones various priorities, criteria, and guidance for forestry, hunting, conservation, and tourism were defined (fig. B 7.5).

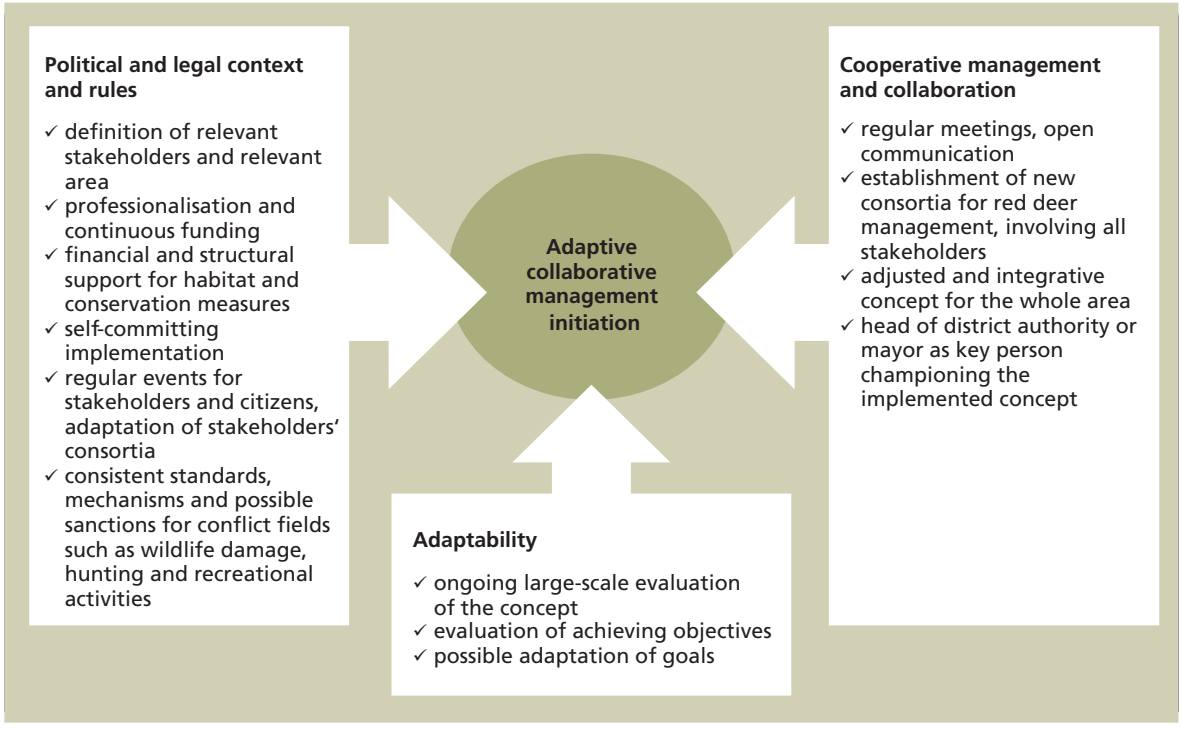

Fig. B 7.4. Adaptive collaborative management characteristics, adjusted to the red deer area in the Northern Black Forest by a topical working group of local stakeholders on communication and organisation.

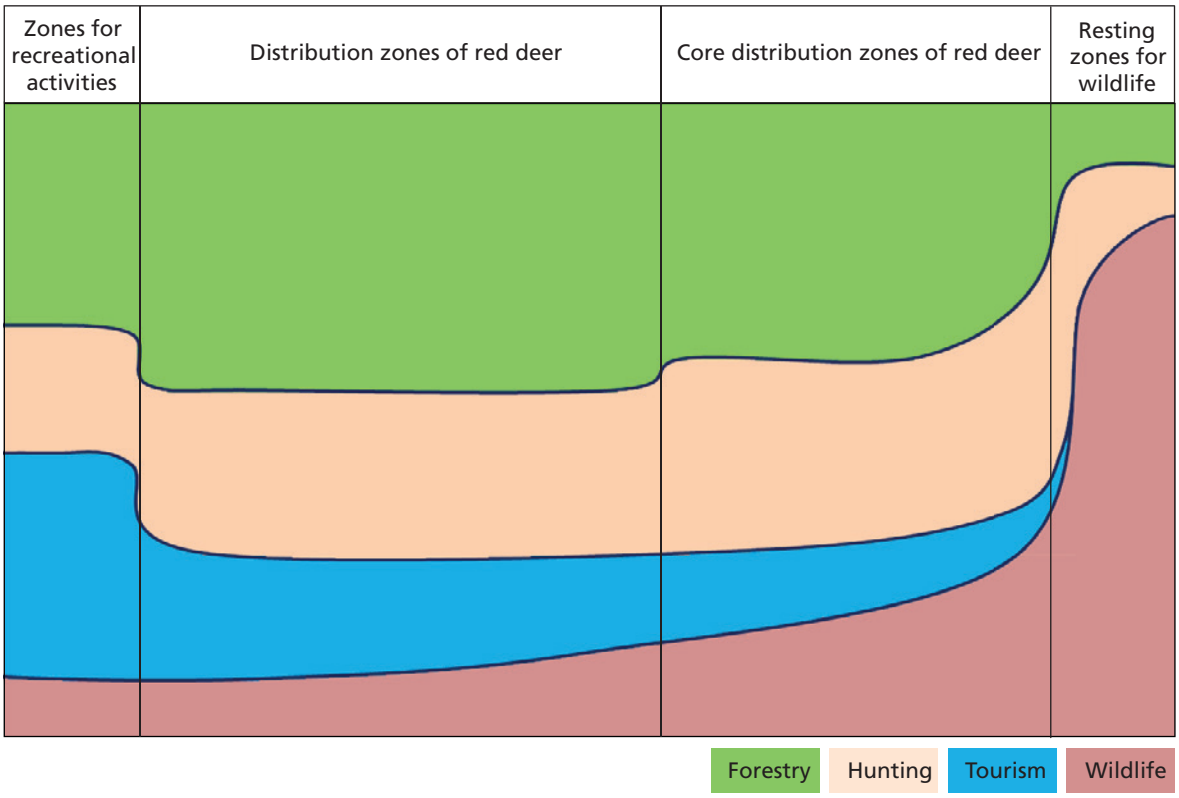

Fig. B 7.5. Zoning strategy for the red deer area in the Northern Black Forest, developed by four topical working groups of local stakeholders on forestry, hunting, tourism, and conservation.

5. Design and implementation

Through collaboration between stakeholders the planning tool can be used to design a locally adapted, specific management concept. The cooperation of science and practice is important to connect local knowledge and scientific insights of SES analysis (Clark and Slocombe 2011); this is possible if ACM characteristics are considered and if trust and cooperation have been established (Zurba *et al.* 2012). The challenge in the design and implementation phase is to reconcile the originally defined goals of the process and the results of the SES analysis with stakeholder demands. Thus, moderation and transfer of information about the SES are important to support development of trust and a common standard of knowledge. In the NBF, local stakeholders were asked if they were interested in participating in local task forces to establish local design processes. Initially, only landowners and the owners of the hunting rights (or the representatives of these groups) were included because of their importance with respect to this issue. After establishing communication, further relevant stakeholders were involved, such as foresters, hunting tenants, representatives from the tourism sector, and conservationists. Initially, it was difficult to get individual stakeholders to participate in the design process. Subsequently, the planning tool developed by the topical working groups was used as an instrument for the zoning of the areas (fig. B 7.6).

The results should now be implemented by local decision makers. Finally, the various local planning concepts should be merged into one overarching integrative wildlife management concept, again in cooperation with the project team and local stakeholders. Following the recommendations developed by the topical and local task forces, strategies for governance, forestry, hunting, conservation, tourism, and monitoring should also be adjusted.

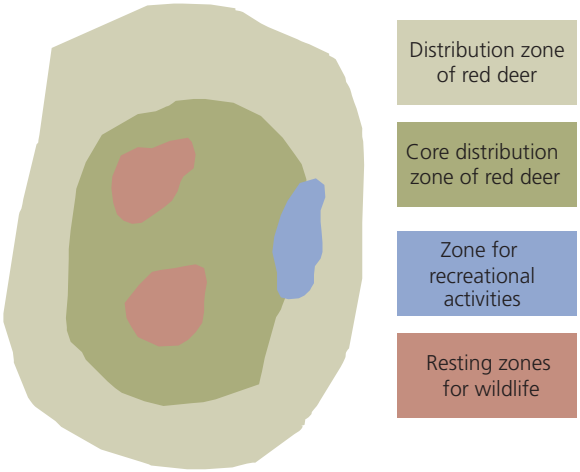

Fig. B 7.6. Illustration of a hypothetical zoned local area in the red deer area in the Northern Black Forest (in reality, zonings are much more complex and more detailed than shown here).

6. Evaluation and monitoring

Any SES is subject to change, and so evaluation and monitoring is an important part of any ACM process (Cundill and Fabricius 2010). To adapt the developed and implemented wildlife management concept over time, a participatory and scientific monitoring and evaluation of the SES elements and the management process itself should be implemented (Chapman *et al.* 2016). Thereby, the outcomes of the management process can be evaluated, and the concept can be adapted to new goals and changing conditions (Haydn *et al.* 2018). In the NBF, following the examination of SES elements, recommendations for long-term monitoring and evaluation were developed, such as approaches for regular monitoring of wildlife impacts, development of habitat and vegetation, red deer populations, and stakeholder opinions. Some of these monitoring measures should be executed through cooperation between practitioners and scientists.

Discussion

The presented approach proved helpful for the initiation of the development of an integrative wildlife management concept to improve the balance between the promotion of biodiversity and other forest management goals in light of the initially mentioned challenges in the NBF example. It helped to develop locally adapted management concepts in several areas inside the NBF with the cooperation of stakeholders. Currently, discussions with stakeholders are being conducted to adapt their management actions with regards to the goals and zones, which are part of the locally adapted management concepts. Initial results show that the system has had positive effects on both ecology and societal acceptance. However, as several stakeholders refrained from participation (such as some mayors or councilpersons of a municipality, or owners of a large privately-owned forest), and as there are no long-term monitoring data available at the moment, the long-term success of the process remains to be seen. Up to now, the whole research and planning process has taken five years; it is not finished yet.

A key point for the concept development was the willingness of stakeholders to participate throughout the process, from the original definition of ACM characteristics to the development of a planning tool through to designing local management concepts. Individual key stakeholders also played important roles by championing the process and providing a connection to other stakeholders. A successful implementation and continuation of the process depends on the dedication and participation of stakeholders (Sterling *et al.* 2017). Most steps and appointments had to be initiated by the responsible research team, which functioned as SES researchers and also as moderators during the process. Taking limited resources into account, this dual function will possibly apply to many other cases. Limited resources or limiting circumstances also require a compromise between an in-depth SES analysis and a pragmatic limitation of the scope of the SES to select and measure only the most important elements. Time is a resource needed in the process, with regards to research, administrational processes, and establishment of communication and trust with stakeholders. Hence, the development of a successful concept may take up to five to ten years (Butler *et al.* 2016a).

During this period, uncertainty and change of the SES and contextual factors often alter conditions of ACM (Clark and Slocombe 2011; Cundill and Fabricius 2010; Smedstad and Gosnell 2013); this could also be the case in the NBF example. In the NBF case, a single European grey wolf *(Canis lupus)* has moved into the area; this has resulted in

tensions and conflicts among stakeholders because of different beliefs and attitudes towards and issues with this species. As a consequence, controversies between stakeholders increase (e.g. between forest owners, who are also farmers, hunters, and conservationists), which can also have negative impacts on their discussion about red deer management. Additionally, forest management has been confronted with increasing problems caused by the European spruce bark beetle *(Ips typographus)*, resulting in additional pressure for forestry related to damage caused by wildlife. Likewise, disputes regarding the Black Forest National Park increased because of various political and administrational decisions. Furthermore, forest administration in Baden-Württemberg was reformed and restructured, which led to new responsibilities. As a consequence, there are new goals, individuals, and administrational structures which have to be considered.

These unforeseen obstacles and challenges show that the development of an integrative wildlife management concept is seldom a frictionless and straightforward process. It is important to understand the close linkage between forest management, biodiversity conservation, and wildlife, and incorporate these aspects into an integrative wildlife management concept. Also, adaptability has to be an inherent part of the planning process, based on monitoring and evaluation of both the SES and the ACM processes (Plummer *et al.* 2017). Political and legal circumstances have to be considered too. Regardless of how well thought out a regional concept may be, these circumstances are often crucial for failure or success and should be considered in the process (Butler *et al.* 2016b; Cosens *et al.* 2017). Despite the importance of participation and collaboration, top-down management decisions are still important, for example, with regards to existing hierarchies inside institutions, such as the forest administration.

Consequently, a functioning process must not be confused with a durable implementation of its outcome (Smedstad and Gosnell 2013). Comparable monitoring procedures in various SES can be used to observe change processes and to simplify the transfer and the development of integrative wildlife management concepts.

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Do we need squirrels everywhere? On the distinction between biodiversity and nature

B 8

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We observe an ongoing biodiversity decline and mitigating this biodiversity crisis is highly demanded by science, society, and politics. Therefore, multitrophic and evidence-based scientific approaches across multiple scales are needed. Biodiversity is affected by both natural disturbance and forest management at different temporal and spatial scales, with consequences for ecosystem functioning and human well-being. Accordingly, species diversity in forests is not evenly distributed, but dynamic across temporal and spatial scales. Stochastic processes of niche distribution are not only present in primeval forests but will also increasingly become important in managed landscapes due to climate change induced extreme events such as windthrow, fire, or drought. These build the basis for natural processes that beget biodiversity. The case of the Bavarian forest demonstrates that natural disturbances and subsequent successional pathways across large areas result in a dynamic occurrence of patches of low and high diversity. In naturally disturbed areas, as well as in managed landscapes, both rarity and commonness exist as consequence of species extinctions and biogeographic processes. The quality of naturally evolved biodiversity is, however, different from e.g. the maximised biodiversity fostered by biodiversity management. While we do not need every species everywhere, we do need strategies that guarantee the distribution of different successional stages at the landscape scale in a configuration that allows the coexistence of most species. This will be important to achieve resilient forest ecosystems and hence maintain ecosystem functions and services over a longer time-scale. We therefore advocate the need for large forest landscapes that eventually should be – against all odds – released from management in the future. Such large unmanaged landscapes not only will result in more dense populations of highly demanding species that also can spread out to managed landscapes, but will also serve as long-term references of natural forest processes and their benefits for biodiversity. One of the main challenges will be to develop strategies that aligns scientific evidence with the needs of society and policy makers.

On the rise of biodiversity

The industrial revolution of the eighteenth century with increasing exploitation of resources and urbanisation was followed by the growing societal awareness of the need to protect the nature that was being lost. During this time, many people such as Charles Darwin and Alexander von Humboldt were fascinated by the diversity of living organisms and their forms and functions and travelled all over the world collecting organisms and naming them. Over time there was a growing realisation that this biodiversity is vulnerable, e.g. by Rachel Carson in 'Silent Spring' (Carson 1962). The digital revolution beginning at the end of the twentieth century has subsequently led to the now broad awareness of the loss of biodiversity (Sala *et al.* 2000). In particu-

< Fig. B 8.1. The necessity to provide habitats for forest species, incl. such beautiful coral fungi (*Ramaria* spp.) is more than a moral commitment. The value of often unimpressive species for ecosystem functioning is usually little known among society but undisputed in the scientific community. However, it can be difficult to convince the broad society of the need to sustain biodiversity as a whole and not only spectacular flagship species (Photo: Ulrich Wasem).

lar, it made available to most people those things that had previously only been available to the privileged: diversity of food, knowledge and data, and forms of communication. Global markets and digital interconnection have made many of the demanded things more easily accessible, e.g. by reducing costs (food), or by increasing availability (free knowledge through the internet, or unlimited communication through digital networks). Population growth led to increased human demand for natural resources that caused overexploitation, with e.g. intensified agriculture being still a prevalent threat to biodiversity (Maxwell *et al.* 2016). The strong growth of world-wide resource exchanges has additionally caused the extinction of species (the so-called 'Holocene extinction' or 'Anthropocene extinction' or 'sixth mass extinction') (Ripple *et al.* 2017). The increasing loss of species has also been discussed as a threat to the future of humankind. This insight resulted in the inclusion of the term 'biological diversity' in the Convention on Biological Diversity (CBD), which was opened for signature at the Rio Earth Summit in 1992. The CBD defines biological diversity as:

> *… the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems. (UNEP 1994)*

The concept was further developed in the Millennium Ecosystem Assessment (Hassan *et al.* 2005) and the reports of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES 2019).

The digital revolution opened up new possibilities for data storage and data reproducibility. For example, data on species occurrences and distribution enabled us to quantify whether species are common or rare, the basis of nature conservation. Therefore, the importance of biodiversity has continuously grown and is increasingly being linked to the issue of most concern nowadays: climate change.

Changes in habitat quantity, quality, and diversity often correspond with the variation of individual species or species groups, in particular as a consequence of the species-area relationship and related fragmentation effects (e.g. Tscharntke *et al.* 2012). Beyond the evolutionary and biogeographic constraints that frame regional floras and faunas, both natural disturbance and forest management change the resource availability and diversity as well as microclimatic properties in multiple ways on temporal scales of years to centuries and in particular at smaller spatial scales. As a consequence, species diversity in forests is not evenly distributed but varies in time and space. On the one hand, many species are associated with undisturbed old-growth forest patches and some of these are generally low in abundance. On the other hand, there are old-growth forest species that only occur in open forest patches such as forest gaps and their abundance depend on the frequency and size of such disturbances; these species might partly occur also in more open and disturbed areas in managed landscapes as long as the required resources and habitats are available at sufficient temporal and spatial scales. Nowadays, primeval forests are mostly restricted to small patches, which are often too small to allow diverse natural gap dynamics. As a consequence, the richness of iconic species in old-growth forests, not disturbed by humans, is often low and transiently high in patches where disturbance has taken place. As a result, stochastic processes of niche distribution are not only present in primeval forests but will also increasingly become important in managed landscapes because of climate change induced extreme events (e.g. windthrow, fire, drought). These build the basis for natural processes that beget biodiversity.

Natural vs. biodiverse forests

Nature is the variety of life and of non-human landscape features and includes *"all the animals, plants, rocks, etc. in the world and all the features, forces, and processes that happen or exist independently of people, such as the weather, the sea, mountains, the production of young animals or plants, and growth"* (Cambridge Dictionary). Biodiversity can be thought of in a more neutral or more scientific way as the expression 'nature' (UNEP 1994; Thompson 2010). Thinking of 'nature' conjures up thoughts of 'virgin, pristine, or unmanaged land', 'wilderness', and 'unplanned' processes. In contrast, thinking about 'biodiversity' also means 'quantifying', 'measuring', and 'planning'. Unmanaged ecosystems underlie unplanned disturbances that shape natural processes. The absence of management

Fig. B 8.2. (a) European spruce bark beetle *(Ips typographus)* has generated large-scale disturbances in Norway spruce *(Picea abies)* forests in Europe. Because of its functional impact, creating habitats for many species, it is considered an ecosystem engineer (Lawton and Jones 1995; Müller *et al.* 2008) (Photo: Beat Wermelinger). (b) After the spruce bark beetle outbreak in the Bavarian Forest National Park, the high availability of spruce stumps colonised by, for instance, the polypore *Fomitopsis pinicola*, greatly increased the populations of the threatened flat bug *Aradus obtectus* (6.3–9.5 mm) (male-top, female-bottom; Photo: Martin Gossner), which sucks on hyphae of *F. pinicola. Aradus obtectus* is also quite abundant in the primeval forest of Scatlè (Grisons, Switzerland), where there is a large amount of suitable habitat.

does not mean an absence of dynamics, but rather the absence of planning, i.e. the absence of humans. This is the story of the forest in Bavaria, Germany. In the 1990s, this forest was affected by infestations of bark beetles and windthrows (fig. B 8.2) across large areas with widespread tree death in some stands; rather than taking steps to limit the extent of the infestation, the forest was allowed to develop and regenerate without human intervention. The area affected increased rapidly, reaching a maximum of >800 ha per year in 1996 and comprised a total area of 40 % in the older park of the national park (Müller *et al.* 2008, Lehnert *et al.* 2013). The unplanned processes have allowed millions of visitors to see nature 'striving' (Mayer 2014), and have resulted in increases in populations of species that used to be locally threatened (figs B 8.2, B 8.6; Thorn *et al.* 2017). Such processes contrast with most of the managed, and hence controlled, forests in Europe; by such processes, we can ask questions about the meaning of nature and biodiversity.

The case of the Bavarian forest nicely illustrates the relevance of dynamics in natural ecosystems for species variation over a longer time-scale. Biodiversity varies enormously over space and time leading to patches of low biodiversity as well as patches of high biodiversity at particular points in time; this also applies to unmanaged forests. Maximising biodiversity at the local scale is thus not necessarily related to a natural reference. This raises the question of whether increasing biodiversity should be an ultimate target irrespective of a natural reference (which is mostly not available in a cultural landscape like Central Europe) and irrespective of spatial and temporal dynamics (see also section "To protect as much as possible: scale matters"). However, the question 'Which biodiversity should be targeted in nature conservation?' is not only a matter of natural references such as any natural ecosystem; the question also requires consideration of our normative nature, i.e. our wish to 're-establish' or 'rescue' biodiversity to the extent that we think existed at some unspecified time, and in particular to when biodiversity presumably peaked; this is often referenced to a time 100–200 years ago (Landolt 1991; Korneck *et al.* 1998). All this has to be considered in conservation and management strategies. In any case, we need adaptive approaches as biodiversity and processes are generally dynamic.

Biodiversity is more than just species richness

Many recent studies have shown that biodiversity should not only be preserved because of its intrinsic value, but also because it is related to important ecosystem functions and services. There is growing evidence that greater biodiversity increases ecosys-

tem functioning (Isbell *et al.* 2011; Ratcliffe *et al.* 2017) and promotes the services that nature provides for humans, e.g. cultural services (BEF: Biodiversity-Ecosystem Functioning Relationships; van der Plas 2019). For example, in a global study Liang *et al.* (2016) found that there was a correlation between plant diversity in forests and forest productivity (in terms of tree volume), with less diverse forests having a lower productivity; the association was likely due to both a sampling effect (i.e. diverse forests more likely have a functionally important, e.g. productive, species in place than species-poor forests) and because there is a more complete resource use when there is a greater diversity of plants that occupy different parts of the functional trait space (Roscher *et al.* 2012). Functional traits are generally defined as morphological, physiological, and behavioural characteristics that affect species fitness (Violle *et al.* 2007). In the perspective of BEF relationships these are properties of species that are linked to a particular function. For example: (1) a variety of root systems among plant species allow for a more effective resource use and thus higher productivity (Forrester and Bauhus 2016); (2) a variability in the periods when foragers are active (e.g. daily, seasonal, active during sunshine or rain) and in morphological characteristics of mouth parts (e.g. trait matching between tongue length and flower morphology) of pollinators lead to more effective pollination (Blüthgen and Klein 2011); and (3) the variability in resource use by herbivores (e.g. feeding on different plant parts) intensifies nutrient cycling (Blüthgen and Klein 2011). In conclusion, beside species richness per se, also species functional characteristics and identity as well as the abundance of each species and thus the evenness of species (i.e. how equal the community is numerically in terms of individuals) might be crucial for the outcome of an ecosystem process or function (Wilsey and Potvin 2000; Hooper *et al.* 2005). Despite the general importance of BEF relationships, the correlation might be weak in cases were an ecosystem process is driven by a few abundant key species, as is the case for crop pollinating bees (Kleijn *et al.* 2015), but might be underestimated in more natural systems (Garibaldi *et al.* 2011; Garibaldi *et al.* 2013). There is a huge variation in pollination efficiency (Jauker *et al.* 2012; Eeraerts *et al.* 2020) among the >700 bee species in Switzerland (Westrich 1990; Michener 2007). While the domesticated honey bee *(Apis mellifera)* and a few other species might be sufficient to pollinate the vast majority of crops, we need many more bee species to ensure that we have diverse plant communities that provide ecosystem services of productivity, erosion control, resistance to environmental change, and not to forget diverse habitats for a diverse invertebrate community (Garibaldi *et al.* 2013). This becomes even more important in the context of ecosystem resistance and resilience (see also Chapter B 9, Lindner *et al.*, this book). Resistance is the ability for an ecosystem to remain unchanged when subjected to a disturbance. Resilience is the ability and rate of an ecosystem to recover from a disturbance and return to its pre-disturbed state (Ghazoul *et al.* 2015; Oliver *et al.* 2015). It is generally believed that more diverse systems have a higher resistance and resilience to environmental perturbations because there is more likely to be functional redundancy in a diverse ecosystem, i.e. if one species becomes extinct in a particular area after a disturbance, there are more likely to be other species that can fulfil the ecological roles previously played by the newly extinct species ('insurance hypothesis) (Mori *et al.* 2013; Pillar *et al.* 2013; Silva Pedro *et al.* 2015). Climate change will most likely further increase temperature and the frequency of extreme events, and this will further challenge ecosystem resistance and resilience. Maintaining a high functional diversity, which is currently under threat (Hallmann *et al.* 2017; Seibold *et al.* 2019; van Klink *et al.* 2020), is thus crucial for mitigating climate change effects.

To protect as much as possible: scale matters

To protect biodiversity requires an understanding of how biodiversity is organised in space and time; such understanding enables prediction of the impact of environmental change across different scales. Many recent studies have demonstrated that a focus on the biodiversity at the forest stand level (known as α-diversity) is not sufficient to predict biodiversity at larger spatial scales (landscape-scale diversity: γ-diversity; figs B 8.2 and B 8.3) because species turnover among forest stands and regions (β-diversity) might be even more important and driven by other factors (Müller and Gossner 2010; Gossner *et al.* 2013; Schall *et al.* 2018).

Ecological theory predicts that environmental heterogeneity generally promotes biodiversity

(Heterogeneity-Diversity Hypothesis; MacArthur and MacArthur 1961; Wilson 2000). However, the general validity of this relationship has been questioned recently as high heterogeneity might reduce the available area per species and, thus, population size to a degree where stochastic events can lead to local extinctions of species (Area-Heterogeneity Trade-off Hypothesis; Allouche *et al.* 2012). Species seem to show variable responses and a recent comprehensive study did not find consistent support for a generalisable mechanism determining patterns of heterogeneity–diversity relationships (Heidrich *et al.* 2020). From an applied perspective, it is not yet fully understood how scale and, thus, the spatial grain of management within one management system affects biodiversity at larger spatial scales, and how this is shaped by the composition and configuration of management systems.

Beech *(Fagus sylvatica)* forests are restricted to Europe and are one of the most important natural European forest types, covering an area of about 14–15 million ha (Brunet *et al.* 2010). Therefore, Europe has a responsibility to conserve forests dominated by this species (Knapp and Spangenberg 2007). Nature conservation policy and forest policy advocate fine-grained, so-called 'close-to-nature' management systems over traditional coarse-grained shelterwood systems in beech forests. This is driven by the idea that these management systems well mimic the prevailing natural disturbance regime characterised by small-scale gap dynamics (e.g. primeval beech forest remnants of eastern Central Europe, Hobi *et al.* 2015). Management systems emulating small-scale gap dynamics have also been promoted by forest policy and nature conservation in temperate forests of other parts of the world (Coates and Burton 1997; Ott and Juday 2002). While there are strong indications for the positive effects on biodiversity of selection cutting compared to large-scale clearcutting in boreal forests (Hjältén *et al.* 2017; Joelsson *et al.* 2018), there is little empirical evidence that uneven-aged (selection cutting) compared to even-aged (shelterwood system) management in beech forests actually increase biodiversity. Shelterwood systems in beech forests operate at much smaller scales than clearcutting systems in boreal forests. A recent study in European beech forests for instance has shown that even-aged forest management at a scale of 4–8 ha management units promotes a higher diversity of most taxonomic and trophic groups relative to uneven-aged fine-grain management. This was not only an effect of disturbance indicators or open land species as forest specialists were similarly affected (Schall *et al.* 2018). Moreover, mixing even-aged with uneven-aged and young unmanaged forests – in contrast to unmanaged beech forests in eastern Europe, the majority of unmanaged beech forests in Central Europe have been set aside relatively recently and largely lack old-growth features – in a landscape seems not to benefit biodiversity (Schall *et al.* 2020).

It underlines the importance of environmental heterogeneity at larger spatial scales for biodiversity levels, and the role of spatial grain (either management or disturbance) as a trigger to vary the abundance and diversity of specific species groups. On one hand, the spatial grain of management defines which species may establish viable populations given stochastic events that likely cause local extinction (Allouche *et al.* 2012). On the other hand, genetic exchange among populations is reduced by landscape fragmentation by roads and other built environments, but also by management units that are too large in even-aged management systems. To allow the survival of species requires continuous availability of suitable habitats at sufficiently close proximity to sustainably allow dispersal and establishment. Limited dispersal capacities in fragmented habitats mean that regional and internationally agreed measures to ensure survival of populations of threatened species are required, e.g. the establishment of corridors and stepping-stones. These measures have already been applied in biodiversity conservation strategies that aim to promote biodiversity such as the strategy implemented in the Steigerwald Forest in Germany where active deadwood enrichment is combined with the protection of habitat trees and protection of forest patches of different sizes (Bollmann and Braunisch 2013; Doerfler *et al.* 2017; Doerfler *et al.* 2018; Bürgi *et al.* Chapter B2 in this book).

Scale issues need to be addressed when considering management systems and related forest structural properties, i.e. the scale at which particular resources are altered in terms of amount and diversity. For example, whether habitat amount or habitat connectivity is more important is the subject of lively debate (Fahrig 2013), with an increasing number of studies supporting the habitat amount as being a more important factor (Seibold *et al.* 2017; Komonen and Müller 2018). Also, dispersal

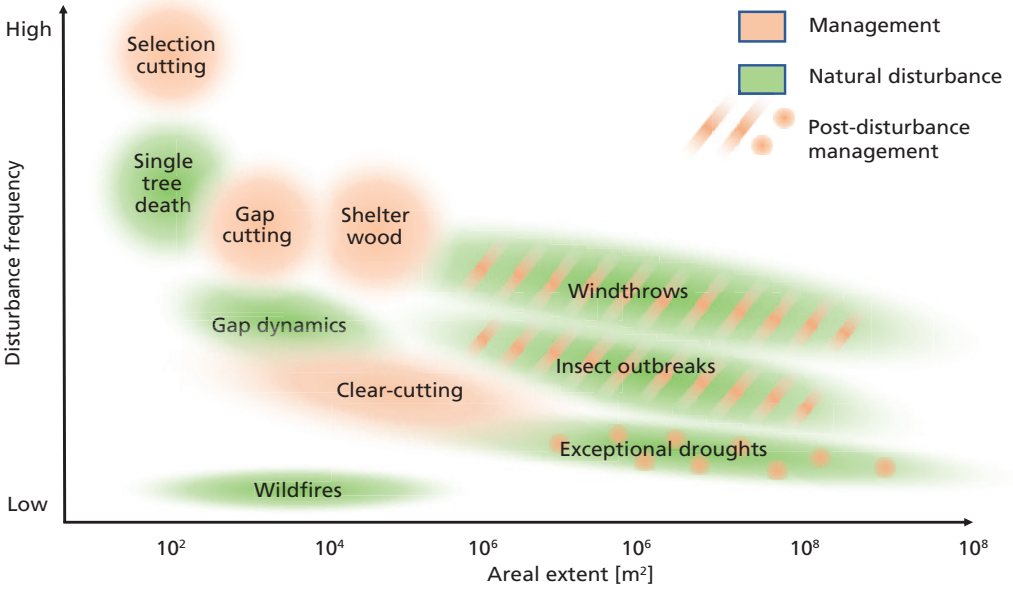

Fig. B 8.3. Comparison of disturbances to forests in space and time (based on Spies and Turner [1999]; Leverkus *et al.* [2018]). The post-disturbance management includes, in particular, 'salvage logging' that is often applied on a large scale after windthrows and insect outbreaks and that threatens biodiversity (Thorn *et al.* 2018) and 'sanitary fellings' that are applied after exceptional droughts that mostly cause scattered tree death.

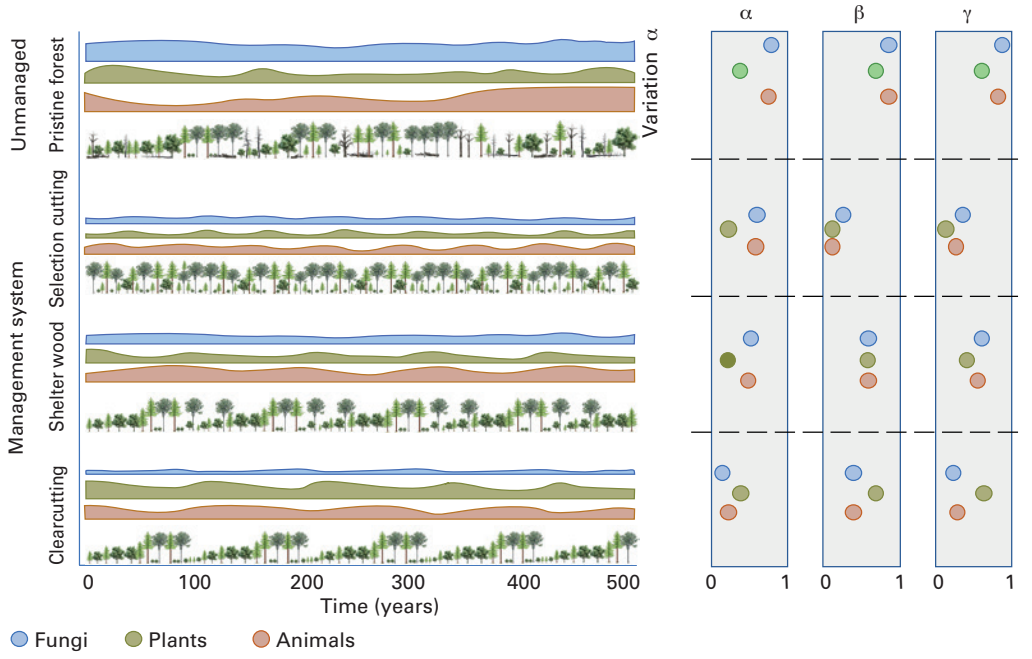

Fig. B 8.4. Comparison of managed and natural forest systems over several hundred years and with respect to local average (α), species turnover among sites (β), and landscape-scale (γ) diversity for fungi, plant, and animal species. The schema refers to beech and mixed broadleaved-coniferous forests in Central Europe. Left: α-diversity across time in relation to changes in forest structure, Right: diversities in unmanaged forests and different management systems across different successional or management stages. Based on Scherzinger (1996), Kuuluvainen (2009); Hilmers *et al.* (2018), and Schall *et al.* (2018).

Fig. B 8.5. Fruits of strawberry blite *(Blitum virgatum)* (a). The seeds can endure in soils for hundreds of years and germinate after soil perturbation or forest fire (Moser *et al.* 2006) (Photo: Barbara Moser). (b) So-called pyrophilous species such as the flat bug *Aradus lugubris* (4.5–6.6 mm), mostly black-coloured, can detect rapidly burned deadwood infested by a particular host fungus, i.e. *Daldinia loculata* for *A. lugubris* (Wikars 2001) after forest fires (Photo: Martin Gossner).

limitations seem be apparent in some species (Sverdrup-Thygeson *et al.* 2017).

In fact, both resource amount and resource diversity in combination with different environmental conditions might be important for many species, and consequently for forest resilience. This leads back to the great significance of natural disturbances which generates a stochastically evolved mosaic of conditions promoting biodiversity in a dynamic way. We should make use of the presumed increase in disturbances with climate change such as bark beetle outbreaks, storms, forest fire, and drought effects (Seidl *et al.* 2017) that contributes to the geomorphologically defined heterogeneity by creating additional structures on which many species depend (Müller *et al.* 2008; Thorn *et al.* 2019). The predicted changes in disturbances will likely differ in size and frequency, and this will promote heterogeneity (fig. B 8.3). In the frame of an adaptive forest management such areas could be taken out of management for a particular time (Bollmann and Braunisch 2013) to promote the first successional stages (fig. B 8.5) which are in particular important for biodiversity (Wermelinger *et al.* 2017; Hilmers *et al.* 2018).

However, in this context two aspects need to be considered. First, the increased frequency and intensity of disturbances destroys structures and environments that are only facilitated by less intense and less frequent disturbance. Many species are already facing too much disturbance of their habitat, and thus the application of novel disturbance regimes requires careful consideration of the implications (Felton *et al.* 2016). Second, a large number of species depend on later successional stages and large trees (Lindenmayer and Laurance 2016) as well as the long-term processes of growth and decay that allow for the development of the structures, resources, and habitats on which the species depend (fig. B 8.4). Thus, we need strategies that guarantee the distribution of different successional stages at the landscape scale in a configuration that allows the coexistence of most species.

Do we need a squirrel? Do we need a lynx? The rarity template

Commonness and rarity vs. endangerment

The Red Lists of flora and fauna around the globe give a similar picture: near threatened, vulnerable, endangered, and regionally extinct species usually make up 50 % to 75 % of all species of a regional flora or fauna (e.g. http://www.iucnredlist.org). However, it has been suggested that rarity type should not be used as a surrogate for extinction risk (Reed *et al.* 2020). Rabinowitz (1981) defined seven types of rarity based on the geographic range (large vs. small), habitat specificity (wide vs. narrow), and local population size (large, dominant in a particular location vs. small, non-dominant) of a species. Given any region, a list of species strongly

reflects the availability of their habitats in this region, with fewer widespread species representing the widespread habitats and the wide habitat specificity of many of these species (habitat generalists) and many rare species using the rare habitats and exhibiting mostly narrow habitat specificity (habitat specialists) of that region. Red Lists report mainly the rarity in the landscape in combination with human-induced drivers. The abundance of many of the currently rare species in a region has declined because of the recent habitat loss caused by land-use change. However, there are also species that are rare because they persist in a rare habitat, e.g. rocky outcrops, raised bogs or rare deadwood structures (fig. B 8.6). Conservation strategies should aim to reduce extinction risks for those threatened species for which a decline is due to definable human causes (human-caused rarity), but often include charismatic species that are rare but not threatened when using ecological criteria (natural rarity; Habel *et al.* 2020). If both land use and forest management have reduced or strongly homogenised natural habitats, and abundances of habitats are shifting, then species frequencies and abundances are also changing, resulting in, for example, longer Red Lists. Any conservation strategy will result in a shift of rarity and commonness. Managed and unmanaged regions differ in both the number and the type of disturbances, which, for some taxonomic groups such as vascular plants, corresponds to higher species diversity in regions with managed land in contrast to biodiversity in untouched natural systems (Paillet *et al.* 2010; Boch *et al.* 2013). Other taxonomic groups, such as mammals requiring large untouched habitats, are more frequent in unmanaged land.

Iconic species

There is no way to establish a complete inventory of all organisms of a region; however, we do know a lot about locally occurring iconic species. In forests, woodpeckers, squirrels (fig. B 8.7), deer, and wild boars are iconic animals. A sighting of such a species brings joy and excitement for the viewers, and so, the lack of such a species in a habitat, feels like a loss; more so than for losses of other less conspicuous species. The extinction of iconic species (or rather big species), has started thousands of years ago and can be viewed as the start of the sixth mass extinction. Obviously, nature adapts to the loss of such species, and so do humans. We know that we can live without certain species. For example: woolly mammoths (*Mammuthus primigenius;* once widespread across the tundra in Europe, Asia and North America, but now extinct); brown bears (*Ursos arctos;* once widespread across the whole of Europe but, in Europe, now restricted to a few fragmented populations); and northern bald ibis (*Geronticus eremita;* once widespread across Southern and Central Europe but which disappeared from these areas completely over 300 years ago). People adapt to nature or, more generally, to

Fig. B 8.6. Lemon-coloured Antrodiella *(Antrodiella citrinella)* (a) is a rare fungi inhabiting deadwood (Bässler and Müller 2010). It is considered an indicator of pristine forests and requires deadwood amounts of > 140 m^3/ha (Photo: Josef Hlasek). Other highly demanding species also only occur in large protected areas where suitable habitats are present in the long term. For instance, the saproxylic click beetle *Danosoma fasciata* (b; Photo: Simon Thorn) has survived in the Bavarian forest and its distribution is now expanding after the designation of the National Park in 1970. The saproxylic *Peltis grossa* (c; Photo: Jörg Müller) was considered extinct in the Bavarian forest for over a hundred years and was recently rediscovered.

Fig. B 8.7. The red squirrel *(Sciurus vulgaris)* is widespread in forests from Europe to Siberia (Photo: Andreas Rigling). In continental Europe, red squirrels are not threatened and forests do not depend on this species; however, people enjoy meeting this iconic species in forests, parks, and gardens.

change and not all species on earth are necessary to maintain the functioning of our ecosystems. However, anyone who has ever been in a pristine forest or, more likely, walked through an uncleared windthrow patch or an untreated burned forest, will experience the excitement of natural dynamics, will observe natural rarity and commonness, will find a source of interest and life that makes life worth living. This excitement does not only arise from seeing iconic species but also from experiencing the ecosystem consisting of so many species that coexist and interact (Thompson 2010). Nature and species diversity have an often underestimated positive effect on human health (Irvine *et al.* 2019).

Do we need squirrels everywhere? Do we need forest management everywhere?

Our society is characterised by its need to control everything. In Central Europe, we know the habitat requirements for many species and consequently can design, at least theoretically, how much biodiversity we want in any particular place. Therefore, in theory we could design our forests according to our desires; for instance, we could have more red squirrels, more capercaillie, or more light-demanding, or more deadwood-related species. Across Europe, there are thousands of people working to transform disturbed ecosystems into species rich ecosystems; the fields of restoration ecology and ecological restoration are flourishing. Eventually, society (or governments) defines, how much forest and what type of forest management we want, and how much of the forest should remain as untouched ecosystems by taking forest areas out of management and restricting access. (fig. B 87). Protection of species and biodiversity is now one of the important considerations that informs these policies and choices. Protecting biodiversity means investing in species, and in increasing or maintaining biodiversity in disturbed habitats ('cultural landscapes') such as open land that would otherwise be covered by forests. Red squirrels are not threatened, but are a highly attractive and typical element of forests. They feed on the seeds of coniferous and broadleaved forest trees, and thus occur in many forest types across Europe and northern Asia. The species is also found in parks and gardens. While squirrels depend on seed trees, forests do not necessarily depend on squirrels. In most forests on the Mediterranean islands, squirrels have been

absent since evolutionary times, and the niche has – at least on some islands – been occupied by crossbills (*Loxia* spp.) (Benkman and Parchman 2011).

In contrast to designing our environment, rescuing natural processes by non-intervention not only is less spectacular, but it is also less labour-intensive, although difficult to achieve in densely populated landscapes. There are, however, examples of initiatives of forests being released from management to let natural processes rule. Thanks to an initiative of a former city-forester of Zürich, management in the highly productive Sihl forest (German: Sihlwald) was stopped in 2000 (Kasper 2012). For 20 years, natural disturbances have been the only dynamics in the forest that now serves as a wilderness area open to the public.

Conclusions

Natural disturbance regimes in pristine or in old-growth forests are important study objects to evaluate natural processes in space and time; they serve as evidence of, and a blueprint for, optimum habitat requirements regarding biodiversity. Also, research in managed forests serve to demonstrate effects of increased frequency of natural disturbances as a consequence of climate change and disturbances by human interventions on biodiversity. Such information on a multitude of different disturbance regimes at different temporal and spatial scales can help to inform and optimise management strategies by integrating naturally occurring disturbances and targeted interventions into adaptive management systems. On the one hand, this allows us to promote species diversity in forests by providing sustainable habitat availability at the landscape scale. On the other hand, common efforts across municipality, state, and even national borders are needed to achieve sustainable biodiversity aims. This will be challenging owing to the complex organisation of forestry across Europe, but is needed to promote a high diversity given the high environmental heterogeneity and related species turnover (β-diversity). Importantly, additional socio-cultural aspects need to be considered, for instance the beauty of iconic species such as the red squirrels as part of cultural ecosystem services. We advocate the need for large forest landscapes that eventually should be – against all odds – released from management in the future. Such large unmanaged landscapes not only will result in more dense populations of highly demanding species that also can spread out to managed landscapes, but will also serve as long-term references of natural forest processes and their effects for biodiversity. Ecosystem functioning in the best interest of the societies in Europe can only be guaranteed, in the long term, by a combination of nature (i.e. large strict reserves) including natural processes and the promotion of biodiversity in managed land.

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Enhancing resilience to address challenges in forest management

B 9

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We present different definitions of forest resilience and discuss how this concept can be used to guide forest management under a changing climate. Forest resilience can be seen as an overarching concept of nested hierarchies, with engineering resilience being nested inside ecological resilience, which in turn is nested inside social-ecological resilience. Active land use and targeted pro-active management to increase forest resilience are crucial strategies to address increased disturbance risks. Indicator-based resilience assessments offer great potential in monitoring of forest vulnerability and steering forward-looking risk management strategies towards enhanced forest resilience. More experience needs to be gathered to identify good practice examples and recommend suitable metrics to operationally adopt the forest resilience concept for safeguarding future forest ecosystem services, including the conservation of biodiversity in a changing climate.

In the nineteenth and twentieth centuries, European forestry has put much effort into overcoming former large-scale deforestation and widespread forest degradation. The context has changed in recent decades, and halting biodiversity loss and responding to and mitigating climate change are the two largest current challenges to which European forests can contribute. Our current toolbox of management strategies seems no longer sufficient to cope with unprecedented extreme climatic events and disturbances affecting forest ecosystem service provisioning, and alternative concepts are being explored. One of these concepts is 'forest resilience'. As biodiversity (the main focus of most chapters in this book) is a crucial component of forest resilience, it is pertinent to ask in this chapter if the resilience concept can help forest management practices better cope with these major challenges. Resilience has received increasing attention in recent years, and is applied in many different contexts, particularly when it comes to dealing with uncertainty. A search for the term 'resilience' in Google Scholar yields more than 2.6 million results (search done in June 2020). Unfortunately, despite its increasingly widespread use, there is considerable confusion about the meaning of the concept of resilience. Furthermore, an operational definition remains lacking, which contributes to the rarity of the cases in which the concept has been applied to guide decision making in forestry.

< Fig. B 9.1. The Bavarian National Park was strongly affected by storm and large-scale bark beetle outbreaks and serves as one of the rare examples where the effects of large-scale disturbances on forest dynamics and the resilience of subsequently developing forests and the entire landscape can be studied (Photo: Ulrich Wasem).

The situation is remarkably similar to the ambiguity that exists for other popular concepts such as 'sustainability', which developed from a narrowly defined origin – sustainable timber yield as framed in the early eighteenth century (Carlowitz 1713) – to many different contexts, especially since the early 1990s, including the very broad application in

the context of the sustainable development goals (United Nations 2015). Developing an operational implementation of such ambiguous concepts takes time and effort (Linser *et al.* 2018; Päivinen *et al.* 2012). After 25 years of work on criteria and indicators for sustainable forest management, their role in monitoring, assessing, and reporting on forest conditions and trends is no longer questioned (Linser *et al.* 2018). Learning from this experience, it may not take quite as long to adopt the resilience concept into practice with transparent definitions and operational methods, but this will take considerable effort and close collaboration by scientists and practitioners.

Overview of selected interpretations of resilience

In forest science, three main resilience concepts have been used:

(i) Engineering resilience defined as "The time that it takes for variables to return towards their equilibrium following a disturbance" (Pimm 1984);

(ii) Ecological resilience refers to "The system's capacity to absorb disturbance without changing as well as the ability to self-organize and build adaptive capacity" (Holling 1973); and

(iii) Social-ecological resilience which is understood as "The capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions. It describes the degree to which the system is capable of self-organization, learning, and adaptation" (Resilience Alliance 2020).

In this chapter, we provide examples of how these alternative concepts have been applied in the forest science literature.

Engineering resilience: Engineering resilience starts from the assumption that an ecosystem will recover to its pre-disturbance state. If this is not the case, the concept cannot be used. A rather widespread application of engineering resilience is in the analysis of tree responses to drought by measuring pre-drought growth rates, growth during drought, and post-drought growth (Lloret *et al.*

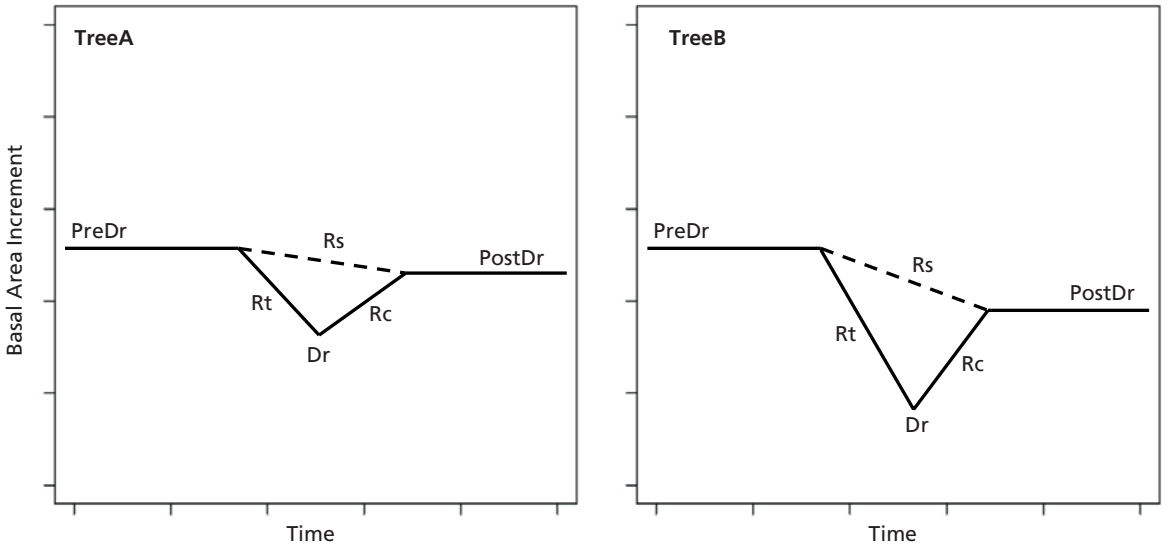

Fig. B 9.2. Analysis of tree growth responses during and following a period of drought as proposed by Lloret *et al.* 2011 (here adopted from Pretzsch *et al.* 2013; modified). Resilience (Rs) describes post-drought growth (PostDr) relative to pre-drought growth (PreDr); Resistance (Rt) measures how much the growth is depressed during the drought (Dr) relative to PreDr; Recovery (Rc) measures PostDr relative to Dr. Two different growth responses are shown: tree A is more resilient to drought than tree B, measured by comparing basal area increment of the trees.

2011, cf. fig. B 9.2). An example of this type of resilience assessment is the study on the resistance of the growth of European tree species to drought stress in mixed versus pure forests (Pretzsch *et al.* 2013). Drought resistance in pure stands increased from Norway spruce (*Picea abies*; lowest), to beech (*Fagus sylvatica*; intermediate), to sessile oak (*Quercus petraea*; highest). Interestingly, although 'drought resilience' and the 'speed of recovery following drought' were found to be species specific, they did not follow the same patterns as 'drought resistance': while oak and beech recovered only slowly from drought, spruce showed a faster recovery. The drought resilience of beech was significantly higher in mixed stands, particularly where the species occurred in mixtures with oak (Pretzsch *et al.* 2013).

Ecological resilience: Climate change may alter the disturbance regimes to an extent that recovery to a previous state may not be realistic or even desirable (Seidl *et al.* 2016). Studies of ecological resilience explore the ability of ecosystems to return to past ecosystem properties. Figure B 9.3 illustrates the 'past basin of attraction', which represents past states of the system (including its variability) and can be quantified by the historical range of variability of the system (Keane *et al.* 2009). Disturbances commonly push systems towards the edge of their basin of attraction (e.g. old-growth conditions for forests developing naturally), as they lead to the loss of live biomass. Following the disturbance, the forest develops again towards the basin of attraction (i.e. mature forest, including old-growth characteristics if the system is left to develop naturally, or the desired conditions by humans in managed forests). In case of an event of unprecedented disturbance severity, such as exceptionally intense wildfires exacerbated by climate change, the ecosystem may be pushed outside of its historical range of variability. From this state, the ecosystem may either return to the past basin of attraction (i.e. recover to a state that is similar to the one before the disturbance), but under certain conditions the system may also develop towards an alternative basin of attraction (e.g. to a forest composed of different tree species or even a steppe ecosystem).

Social-ecological resilience: The application of the social-ecological resilience concept can be exemplified with a study on community resilience and land degradation in forests and shrubland

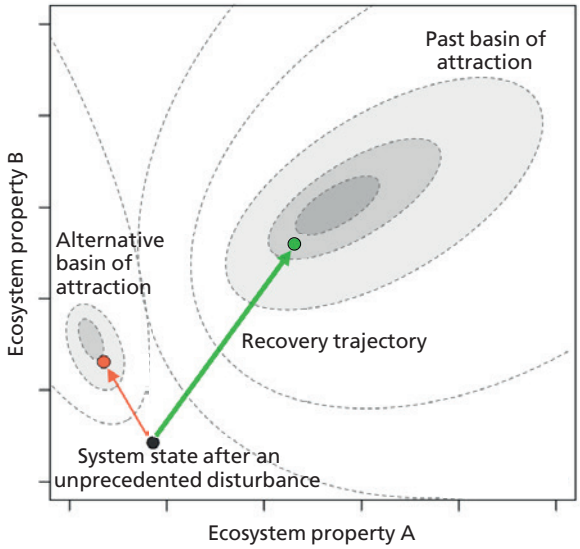

Fig. B 9.3. Schematic visualisation of the constituents characterising an ecosystem's resilience to novel disturbance regimes (from Seidl *et al.* 2016). Changes in the disturbance regime can push the forest system (black dot) outside of its past basin of attraction (indicated by the grey ovals). The resilience to such a change describes whether (ecological resilience) and how fast (engineering resilience) the system returns to the past basin of attraction (e.g. a closed forest; green trajectory), or whether the system shifts instead to a state within an alternative basin of attraction, such as a shrubland (red trajectory).

socio-ecological systems in Italy (Kelly *et al.* 2015). In the study region, forest productivity decline was driven by historic forest mismanagement and overgrazing as well as extreme climatic events, which led to land degradation that negatively affected the community. Stakeholder interviews revealed that community resilience was significantly affected by the lack of economic development (affected by poor road and communication infrastructures, rural depopulation, and land abandonment). However, the role of land abandonment in community resilience had mixed effects, as it may result in reduced soil erosion because of slope stabilisation following vegetation re-growth. On the other hand, it also increases wildfire risk with subsequent increased soil erosion risk. Declining local environmental knowledge and skills were pointed out as another critical threat to community resilience. This case study demonstrated the complex interplay between economic, institutional, social, cultural, and natural

domains in determining the resilience of socio-ecological systems at multiple scales (Kelly *et al.* 2015).

The above examples illustrate that the alternative resilience concepts have similarities, for example in the disturbances studied. However, they also document different perspectives: whereas engineering and ecological resilience focus on the capacity of a system to resist change and recover from disturbance, social-ecological resilience often stresses transformation and evolution of the system as a crucial part of resilient systems (Nikinmaa *et al.* 2020). The definitions of the three concepts further illustrate differences in complexity: engineering resilience focuses mainly on recovery of the system; ecological resilience includes aspects of both resistance and recovery of the system and acknowledges the possibility of multiple stable states; and social-ecological resilience includes resistance, recovery, adaptive capacity, and the ability to transform to new system states (Folke *et al.* 2010). Rather than stressing the differences between alternative resilience concepts, resilience can thus be understood as an overarching concept of nested hierarchies, with engineering resilience being nested inside ecological resilience, which in turn is nested inside social-ecological resilience. Moving from one concept to another either adds or removes dimensions from the system under study as the system boundaries change (Nikinmaa *et al.* 2020; cf. fig. B 9.4).

Resilience science is currently shifting from understanding resilience to active resilience building, with a growing emphasis on measuring and evaluating resilience (Moser *et al.* 2019). Researchers have identified many indicators for quantifying resilience in each of the resilience concepts described

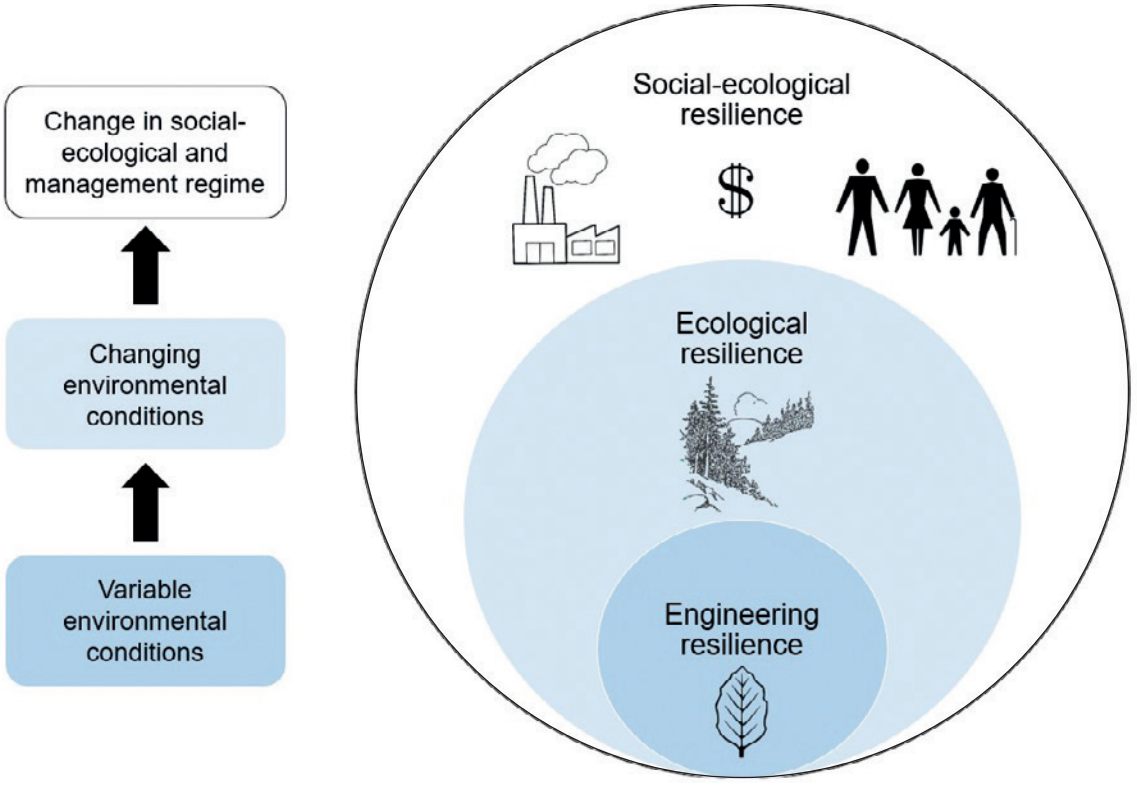

Fig. B 9.4. The hierarchy of resilience concepts and assumptions behind each concept (modified from Nikinmaa *et al.* 2020). The circles on the right show how the three main resilience concepts are related to one another. The boxes on the left indicate increasing complexity in the systems that are studied by the respective resilience concepts. Variable environmental conditions imply that conditions vary but remain in the historical range of variability, whereas under changing environmental conditions they leave the range of historical variability.

above (Nikinmaa *et al.* 2020). Engineering and ecological resilience share many of the same indicators. Typically, these indicators describe the state of the forest community or population. For example, vegetation cover and basal area increment are frequently used in studies assessing forest resilience to drought or fires. In contrast, studies applying the social-ecological resilience concept use a distinctively different set of indicators. These indicators describe the state and function of the social part of the social-ecological forest system in detail, while the state of the ecosystem is usually described in broader terms, for example by the level of biodiversity. Therefore, when choosing indicators to quantify resilience, the complexity of the system analysed, and the chosen resilience concept need to be taken into account. Furthermore, the selection of indicators should be carefully considered, as it has considerable influence on the degree to which a forest is resilient or not (Müller *et al.* 2016). Consequently, a comprehensive set of indicators should be used (ideally authorised through a consultation process with relevant stakeholders) to avoid a narrow perspective on resilience.

So how can we measure and evaluate resilience in practice to enhance forest ecosystem services delivery? The first step is to identify the system of interest (and its boundaries), and to assess whether it is likely to change in the future (Grimm and Wissel 1997; Nikinmaa *et al.* 2020). Is the main interest to assess the resilience of one important tree species, the ecosystem services provided by a forest landscape, or a regional supply chain of a wood products manufacturer? Are the social and environmental conditions changing and to what extent? The second step is to identify the perturbations

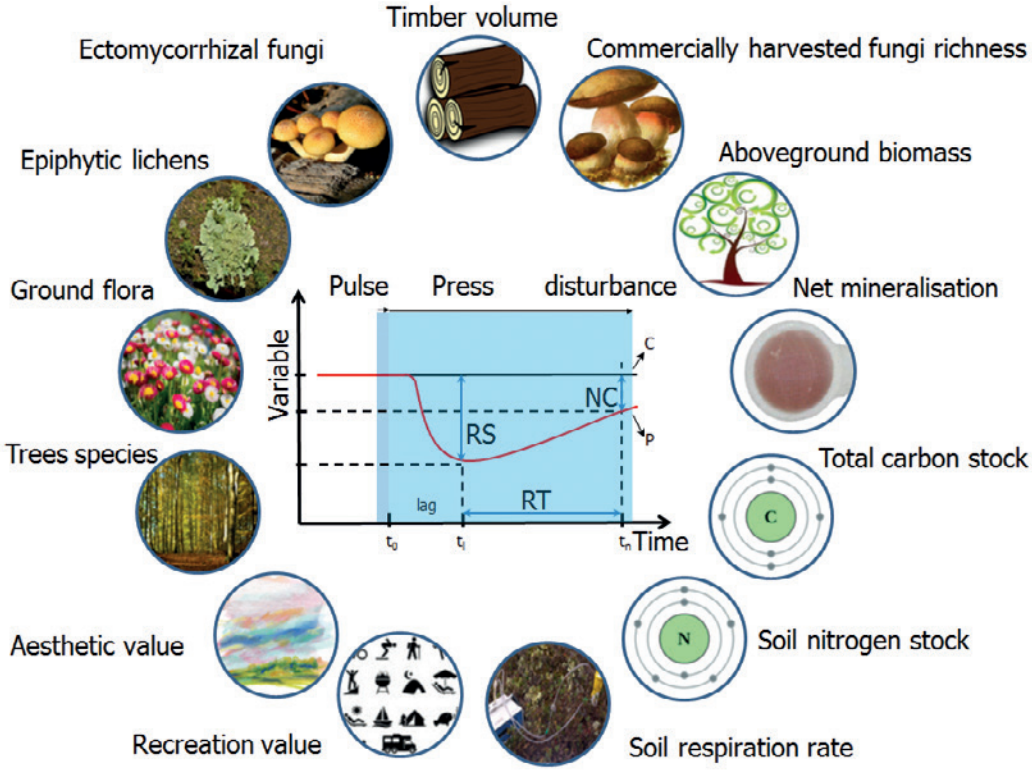

Fig. B 9.5. Selection of 13 indicators chosen to measure and quantify resilience of ecosystem services in a temperate forest landscape (Cantarello *et al.* 2017). The inside graph exemplifies the resistance (RS), recovery time (RT), and net change (NC) of a response variable (i.e. indicator) to a pulse and press disturbance. The black upper line represents the control variable (C) and the red line the perturbed variable (P).

that could potentially affect the system of interest. Is the disturbance of concern a single event (e.g. a storm; pulse disturbance), a continuous stressor (e.g. ungulate browsing; press disturbance), or a combination of both (e.g. climate change, with both a continuous increase in stress and more pronounced extreme events)? How are perturbations interacting (amplifying or dampening)? Engineering resilience can be used in situations where it is possible to go back to the pre-disturbance state, while ecological resilience is a powerful concept when several interacting disturbance types and the complex responses of ecosystems are in focus. Social-ecological resilience should be used if the system of interest also includes the social dimension, such as management responses, a whole forest wood chain, or changing societal demands for forest ecosystem services. The third step is to identify relevant time scales. Engineering resilience is a powerful concept best applied on a short timescale (a few years). For longer timescales, either ecological or social-ecological resilience are better suited, as focusing on short-term recovery might lead to the overlooking of important factors determining the long-term resilience of a system (e.g. to which state is the system recovering).

Recently, forest resilience has been investigated in several regional case studies as a basis for guiding management decision making. For example, the resilience of multiple ecosystem services including habitat services (biodiversity) was investigated using 13 indicators in a temperate forest landscape in the New Forest, a National Park in southern England made up of ancient broadleaved woodlands, lowland heathland, valley mire communities, and acid grassland (Cantarello *et al.* 2017). Three components of resilience, namely resistance, recovery, and net change of response variables were measured to explore the impacts and spatiotemporal patterns of different disturbance intensities on ecosystem service provisioning (fig. B 9.5). Key conclusions included that managers should adopt specific management actions to support each of the three components of resilience separately, as these may respond differently to disturbance. In addition, the consideration of both pulse and press disturbances was important in the selection of management interventions to prevent threshold responses to disturbances.

Risk management and resilience

The concept of resilience is particularly relevant in the context of risk management (e.g. Angeler *et al.* 2018). Disturbance risk management was dominated in the past by command-and-control type efforts to anticipate and contain disturbance impacts (Seidl 2014). Risk management has favoured suppression (e.g. removing wildfire from the landscape) and combating disturbance spread (e.g. by sending airplanes to fight fires across Europe, or by containing bark beetle outbreaks). In contrast, enhancing the ability of forests to recover from disturbances and forming more resilient forests with lower disturbance susceptibility has received considerably less attention, with the exception of forests protecting against gravitational hazards such as rockfall or snow avalanches (Brang 2001; Wohlgemuth *et al.* 2017). Climate change has already contributed to increased forest disturbance in Europe, and projections indicate further increases in the frequency and severity of disturbances (Seidl *et al.* 2017). Temperature extremes have substantially increased since 1950, and even more so than what was projected by climate models (Lorenz *et al.* 2019). Extended drought periods, heat waves, and other extremes are creating novel situations, as witnessed for example in the drought-induced mortality affecting beech and silver fir *(Abies alba)* in central Europe in 2018–2019 (c.f. Schuldt *et al.* 2020). In the case of extreme and/or novel disturbance, conventional disturbance management may fail to contain risks (e.g. Dobor *et al.* 2020). Extreme wildfires and recent large-scale bark beetle outbreaks underline that command-and-control approaches may become insufficient to deal with magnified disturbances under climate change (Castellnou *et al.* 2019; Hlásny *et al.* 2019).

Enhancing resilience as a guiding concept in forest management

Active land use and targeted pro-active management to enhance forest resilience are promising tools to address increased disturbance risks. For example, in the New Forest study in southern England, Cantarello *et al.* (2017) recommended protecting tree regeneration from herbivores and limiting the current practice of heathland burning as

management options to enhance forest resilience. In Mediterranean ecosystems, encouraging livestock grazing and promoting agroforestry are recognised as useful tools to mitigate wildfire risk (Damianidis *et al.* 2020). Furthermore, modifying landscape configuration and species composition via forest planning at scales larger than the stand level holds potential to increase forest resilience (Honkaniemi *et al.* 2020). However, it is important to note that disturbances are natural components of ecosystem dynamics; their role in ecosystems needs to be understood well in all efforts to enhance forest resilience (Hlásny *et al.* 2019). Therefore, while management cannot entirely prevent disturbances from happening, it can contribute to reduce the probability and severity of disturbances, foster the ability of forest ecosystems to recover quickly, and to continue to deliver ecosystem services.

One example of how resilience can be integrated in forest management is given by so-called protection forests on steep slopes (see Antkowiak *et al.,* chapter B 6 in this book). The management of these forests in Switzerland tries to balance the need for both permanent forest cover and high ecological resilience (Brang 2001), or even social-ecological resilience since criteria like feasibility and economic proportionality are also applied. Biological requirements include permanent cover, maximum gap size, and minimum basal area (Brang *et al.* 2006), all assuring delivery of the relevant ecosystem service, i.e. prevention or slowdown of mass movements. While very dense stands have the highest preventive effect, they are more prone to disturbance (in particular from wind and snowload) than more open stands, and do not allow for continuous patchy renewal of the overstorey, which is required for a long-term continuous protective effect (Schönenberger and Brang 2004). Moreover, vertically and horizontally structured stands with small openings allow for the establishment of regeneration in their understorey, which confers a stand with higher resilience in the case of disturbance, since it speeds up post-disturbance recovery (Brang 2001). All these requirements are formalised in the Swiss guidelines for protection forests which ensure managers follow a structured decision-making process by assessing a suite of indicators (Brang *et al.* 2006). These indicators and the associated target values are site- and hazard-specific and partly relate to the ecosystem service (e.g. protection against snow avalanches), and partly to resilience (i.e. by a visual assessment of the density, size, and composition of the regeneration, or of the proportion of microsites suitable for future seedling establishment). The decision-making process requires projection of stand development over 10 and 50 years for each indicator and thus allows early detection of unwanted developments. Currently, the guidelines are adapted by integrating tree species suitable for future climates, and by integrating altered disturbance regimes in the projections.

Similar approaches of practical guidance on enhancing forest resilience are needed for other forests to make resilience more than a buzzword for scientists. Recent advances in resilience science underline the large potential for the approach to address the pressing challenges in forest management under climate change. As European forest ecosystems are widely altered owing to changes in climate and societal demands, forest management guidance needs to consider adaptation to these changes both in the natural and the human system components, and therefore the wider social-ecological resilience concept should generally be adopted. An indicator-based resilience assessment will allow targets for critical indicators to be set and may also be used for monitoring of forest vulnerability and resilience. However, quantifying resilience in the field remains a challenging task. More experience needs to be gathered to identify good practice examples and recommend suitable metrics that cover the multiple dimensions involved, spanning both ecological and social-economic components of forest social-ecological systems, as well as short-term and long-term resilience dynamics. Nevertheless, there is reason to believe that forward-looking risk management strategies focusing on enhancing forest resilience offer an important contribution to safeguarding future forest ecosystem services, including the conservation of biodiversity in a changing climate.

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Forests under a changing climate: increasing adaptability and resilience through more diversity and heterogeneity

B 10

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Introduction

In the last two decades increasing attention has been paid to the links between biodiversity, forest ecosystem resilience, and climate change. However, while some authors claim that the resilience inherent to intact forest ecosystems – fully functional units of plants, animals, micro-organisms, and fungi – provides the best insurance against climate change and improves the prospects for ensuring that forests meet the needs of present and future generations (e.g. Thompson *et al.* 2009; Ibisch and Blumröder 2020), others doubt that forest ecosystems can cope with rapid climate change and advocate more active adaptation strategies (e.g. Messier *et al.* 2019).

The Ninth Conference of the Parties to the Convention on Biological Diversity (CBD) hosted by Germany in 2008 had put the biodiversity of forests at centre stage. In the run-up to the conference, Germany adopted a comprehensive and ambitious National Strategy of Biological Diversity (NBS) aiming at the implementation of the CBD's targets on the national level (BMU 2007). The NBS considers the European framework (e.g. Birds Directive, Habitats Directive, Natura 2000) as well as relevant obligations to international agreements and conventions. The NBS addresses not only public administrations on the federal, state, and community levels, but all relevant societal stakeholders.

The adaptation of forests to climate change is one of several specific targets of the NBS, but it is the one that is currently the subject of most controversy. The extreme summer droughts and heatwaves of 2018, 2019, and 2020, combined with storm events and large-scale bark beetle outbreaks, have led to severe damage in German forests and represent a historical challenge to German forestry. Currently, the area affected by forest dieback is estimated to amount to 285 000 ha, but this area might significantly increase in the coming years. Most damage occurs in coniferous forests (fig. B 10.1), but broadleaved trees are affected too, although to a minor degree.

Man-made climate change is considered to be the main cause for the recent increase of disturbances in forests. Thus, if the adaptation of forests to climate change is to succeed, greenhouse gas emissions must be reduced worldwide and other external stressors further amplifying the effects of climate change (e.g. atmospheric nitrogen inputs, groundwater lowering, and spread of alien invasive species or habitat fragmentation) must be effectively contained.

However, the current situation may also be seen as an opportunity to revisit current silvicultural management concepts, control instruments, and planning approaches so that they can more effectively meet the challenges of climate change. Sustainable management strategies must better take into account the dynamics and unpredictability of climate change and the complex responses of ecological systems to such changes.

According to Milad *et al.* (2012) the objective of forest management should be to develop diverse, resilient forests that can adapt or reorganise themselves in the face of climate change while maintaining their basic functions and ecological services (see also Puettmann *et al.* 2008; Filotas *et al.* 2014). This

< Fig. B 10.1. Medium-aged homogeneous spruce stand. Bigger parts of the forest were dying and removed because of drought and subsequent bark beetle infestation in Rhineland-Palatinate (Photo: Anke Höltermann).

implies that existing silvicultural management concepts and approaches which assume the predictability of ecosystem processes, and favour homogeneous planning, management units, and economic objectives should undergo a fundamental reorientation. That is to say, there is a need to move away from the traditional, anticipatory management paradigm in forestry towards a more process-oriented, incremental, and adaptative nature paradigm.

Management decisions following this approach should be guided by the following principles:

They should be as robust and flexible as possible, i.e. independent from a specific climate scenario as well as open and responsive to new information and stochastic events (Millar *et al.* 2007; Ogden and Innes 2009). According to the concept of adaptive management, goals and measures have to be evaluated repeatedly on the basis of model- or scenario-based planning processes and, if necessary, adjusted (Bolte *et al.* 2009; Filotas *et al.* 2014; Lawler *et al.* 2010; Wintle and Lindenmayer 2008). A comprehensive forest ecosystem monitoring that goes beyond the existing production-oriented monitoring programmes and puts more emphasis on the functionality of the forest ecosystem, including its biodiversity, is critical for this purpose. It should provide feedback to forest practitioners on a regular basis.

Furthermore, management strategies should focus more on promoting diversity and heterogeneity at various levels. The improvement and conservation of biodiversity – including genetic, species, and habitat diversity – forms the basis to maintain the self-regulating capacity of forest ecosystems and for providing diverse ecosystem services (Chapin III *et al.* 2000; Folke *et al.* 2004; Hooper *et al.* 2005; Naeem *et al.* 2016; IPBES 2019). This overall objective should be supported by a variety of management approaches, as these provide opportunities for facilitating learning and adaptation processes that strengthen the resilience of the 'human-environment system' in the long term (Milad *et al.* 2012; Puettmann *et al.* 2008). In this sense, different ownership structures and diverse management forms, ranging from more production-oriented forests to no-action, and from experimental forms of forestry in private forest enterprises to the stronger integration of citizens' interests in public forests, provide the basis for a wide range of silvicultural systems, conservation approaches, and forest types.

Based on these principles, in autumn 2019, the Federal Agency for Nature Conservation (German: Bundesamt für Naturschutz, BfN) published a position paper on 'Forests and Climate Change' (German: Wälder im Klimawandel) (BfN 2019). The position paper presented recommendations for a forest management focussing on the adaptation of forests to changing environments and social needs and provides proposals for their implementation. The position paper addressed four issues: (I) How to reforest disturbed forest areas? (II) Which trees to choose? (III) Forest conversion; and (IV) Forest management accounting for the functionality and integrity of forests. The key aspects of the paper are summarised in this chapter.

Enhancing the adaptability and resilience of forests through increased diversity and heterogeneity – key actions

I. Increased use of natural reforestation as adaptation mechanisms

Large areas affected by forest dieback have to be reforested in the coming years. As emergency relief to private forest owners, the German Federal Government and the states of Germany announced to provide a large-scale funding programme of € 800 million in total (BMEL 12. 12. 2019) for clear-up and reforestation of the damaged areas. The objective is to reforest the areas as fast as possible.Environmental organisations and scientists have criticised this approach as it is likely to recreate extensive, homogeneous forest stands that are vulnerable to the impacts of future climate change (open letter to the Federal Minister of Food and Agriculture Julia Klöckner of 10 August 2019).

BfN also postulates that not all dead trees should be removed from affected forest stands, unless this is unavoidable owing to concerns about pest management and public safety. Clearing and driving heavy equipment across large areas can cause serious damage to soil structures (Hildebrand *et al.* 2000; Schäffer 2002) and limit the chances of successful reforestation (WBW 2018). In contrast, remaining deadwood in its various forms will ensure diverse structures as well as gradients of light, temperature, and moisture, and thus increase habitat diversity in the following stand (Beudert *et al.* 2015; Kulakowski *et al.* 2017). In general, natural succession enables the establishment of better adapted

Fig. B 10.2. Protected by lying and standing deadwood, a diverse new tree generation establishes after bark beetle infestation in the Harz National Park (Photo: Harz National Park).

trees and supports a higher genetic diversity compared to artificial regeneration (Lässig 2000; Cavers and Cottrell 2015; Roloff and Grundmann 2008). It should be preferred whenever possible (fig. B 10.2).

However, in situations when the existing tree species or provenances are no longer adapted – e.g. when Norway spruce *(Picea abies)* is regenerating in former Norway spruce stands, artificial regeneration might be the only viable alternative to regenerate the forest. Even then, natural forest development should be permitted at least on parts of the area to monitor the self-organised adaptation processes of the ecosystem.

II. Choice of tree species

The overall aim of reforestation should be to establish diverse, resilient forests that are as close as possible to the structure and functionality of our native forest ecosystems, as this is expected to provide the best insurance against climate change. Deciduous broadleaved forest is the prevailing natural potential vegetation in most of Germany. Therefore, coniferous species such as Scots pine *(Pinus sylvestris)* and Norway spruce *(Picea abies)* should no longer be cultivated in monoculture on large areas, but mixed in groups with indigenous broadleaved tree species. This also reduces the risk of forest fires (FNR 2019) and improves nutrient flows (Emmer *et al.* 1998). Exceptions are those few sites on which conifers grow in pure stands even under natural conditions (e.g. *Picea abies/Abies alba/Larix decidua* stands on high-montane to sub-alpine sites or *Pinus sylvestris* stands on subcontinental sites of sand/silicate rock).

Light-demanding species such as oak (*Quercus robur, Q. petraea, Q. pubescens* etc.) and accompanying tree species like wild service tree *(Sorbus torminalis),* service tree *(Sorbus domestica),* field maple *(Acer campestre)* or Montpellier maple *(Acer monspessulanum)* could be promoted on temporarily open, unstocked areas following disturbances.

Non-native tree species, i.e. species that have been introduced into an area outside their natural range as a result of direct or indirect human involvement, should only be cultivated in a very restricted manner. Uncontrolled introduction in the sense of 'experimenting with new forest types' may increase the number of usable species in the short term. In the long term, however, this can lead to a decline in biodiversity because of the disruption of established species and habitat relationships (Roloff and

Grundmann 2008). Their cultivation may even trigger irreversible processes that eventually lead to a restriction of ecosystem services and future management options. The severe impairments to forestry and nature conservation resulting from the introduction of the late-flowering black cherry *(Prunus serotina)* to Germany (fig. B 10.3), and the fact that a further eight alien tree species *(Acer negundo, Ailanthus altissima, Fraxinus pennsylvanica, Pinus strobus, Populus canadensis, Pseudotsuga menziesii, Quercus rubra, Robinia pseudoacacia)* were found to be invasive in Germany (Nehring *et al.* 2013; Vor *et al.* 2016) should serve as a warning.

For these reasons and in accordance with the precautionary principle, indigenous tree species (and preferably regional provenances) should always be given priority over non-native tree species unless there is scientific evidence that indigenous tree species can no longer maintain important ecological services. BfN is not principally opposed to the use of non-native trees but demands that these are only cultivated, if: (1) their cultivation is based on a thorough ecological risk assessment and long-term ecological monitoring; (2) measures for prevention, early detection, and response are in place to minimise negative effects of alien tree species becoming invasive (e.g. control and surveillance of stands, regulations for cultivation, prohibition of use in certain areas, removal, etc.); and (3) the nature conservation goals at the specific site are not affected.

Fig. B 10.3. Late-flowering black cherry *(Prunus serotina)* invades pine forests on the lower terraces of the Rhine near Schwetzingen and prevents the regeneration of native tree species (Photo: ILN Brühl).

The introduction of non-native tree species into protected areas, especially nature conservation areas, Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), should in general be avoided.

III. Accelerate ecological forest conversion

Structurally rich, mixed forests, displaying a broad ecological amplitude have a higher resilience and adaptability to climate change induced disturbances when compared to single tree species stands (Jenssen *et al.* 2007; Pretzsch *et al.* 2013; Schelhaas *et al.* 2003). This is nothing new. In the last three decades, public forests and some privately owned forests have increasingly focused their activities on the principles of close-to-nature forest management. However, still more than half of the forest cover in Germany continues to be dominated by non-site-adapted coniferous forests (BWI 2012), of which about 3 million ha are pure stands. Therefore, efforts for ecological forest conversion need to be intensified. Each year until 2017, approximately 22 000 ha of forest were converted to more natural stands (UBA 2019). At this rate, the conversion of all pure coniferous stands would take at least another 100 years.

Preference should be given to site-specific regeneration methods over long periods of time as these will contribute to the preservation of genetic diversity and allow better adaptation to climate change through natural selection processes (Bonfils and Bollinger 2003; Kätzel 2009; Milad *et al.* 2012). Indigenous tree species should always be prioritised (see Choice of species section). Nevertheless, as in the case of reforestation, when site conditions are expected to change rapidly and non-site-adapted, high-risk tree species spontaneously regenerate, then active removal and planting of more suitable species (including non-native species, particularly from European regions and which have undergone a certain coevolution) might be the only solution (Milad *et al.* 2012; Bolte and Ibisch 2007).

However, on many sites the lack of natural regeneration is not a matter of unsuitable site conditions or the absence of seed trees, but rather a question of high densities of browsing ungulates. To succeed with forest conversion, a balance between forest regeneration and ungulate density is absolutely crucial. The BfN, therefore, welcomes all measures aimed at defusing the conflict between silviculture and game management. Action could include adapting hunting regimes/seasons or establishing ungulate control fences to enable monitoring of ground vegetation and establishment of tree seedlings.

IV. Align forest management with ecosystem considerations

Beyond reactions to acute disturbance events and forest conversion, forest management should always strive to enhance the integrity and functionality of the forest to reduce its vulnerability to the effects of changing environments. Five measures seem to be particularly important: (1) Improve water balance and water retention; (2) Use appropriate machinery and protect forest soils; (3) Allow forests and trees to age; (4) Increase the amount of deadwood; and (5) Increase the area of unmanaged forests. Each of these is discussed in the rest of this section.

Improve water balance and water retention

Stand thinning, timber harvesting, or the establishment of forest/skidding roads should always be conducted in a manner that helps to preserve or improve the forest microclimate and soil water supply. This will buffer temperature extremes and reduce water competition (Bolte and Ibisch 2007; Ellison *et al.* 2017; Vose *et al.* 2016). Broadleaved forests generally have more seepage and groundwater recharge as compared to coniferous forests (Ellison *et al.* 2017; Lasch *et al.* 2012). Other factors and measures which improve the water retention potential of forests include: the amount of deadwood in a forest as this can retain significant quantities of water especially in old forest; the use of soil-conserving forestry technology; the closure of drainages; the discharge of water from forest roads/paths back into the stand; and the reactivation of forest moors. Also, to effectively improve the hydrological regime of a forest, it may be essential to include the surrounding landscape into the water management regime (fig. B 10.4).

Use appropriate machinery and protect forest soils

For timber harvesting and other silvicultural interventions there is often no alternative to the use of heavy machinery, although, this may often contribute to the homogenisation of forests (Puettmann *et al.* 2008). Today, a variety of technical processes are available to meet the increasingly demanding requirements related to wood harvesting and

transport. These have become economically efficient in terms of the value chain and take into account aspects of occupational health, safety, and ergonomics. Despite these advances, such techniques must be applied consistently as well as being subject to a constant process of further improvement and adaptation to the changing climatic conditions (e.g. fewer frost days, more late frost, and more frequent disturbance events) to minimise the negative effects on the forest ecosystem.

The conservation of soils (especially hydromorphic soils and upland/lowland moors) is of particular importance and should be a priority in the development of harvesting methods. Skidding should be always limited to permanently marked trails to avoid unnecessary soil compaction. Driving outside those trails should be prohibited, as it can lead to considerable compaction of soil layers close to the surface, even after one single harvesting event. Eventually this can lead to far-reaching negative or partly irreversible effects on soil properties and destabilise whole forest stands (Hildebrand *et al.* 2000; Schäffer 2002). Soils that are still largely intact should remain as undisturbed as possible in the long term.

Allow forests and trees to age

Currently, it is impossible to definitively assess whether German forests still serve as carbon sinks or if more carbon is emitted (at least at local/regional level) than absorbed (Hüttl 2019). Thus, rotation lengths in forest types, which have shown a lower risk to disturbances, should be extended to compensate for any possible loss of biomass, increase the long-term carbon stock and improve the adaptability of forests.

According to the Third Federal Forest Inventory (BWI 2012), the proportion of old forests (>160 years) was estimated to be only 3.2 % of the total forest area, despite slight increases (Reise *et al.* 2017). Numerous studies agree that large areas of old forests with habitat continuity can better buffer climate extremes than younger forests. Besides their important functions of carbon storage

Fig. B 10.4. In the 'Bienwald' forest conservationists, farmers, and the state forestry agency work together to restore a near-natural water regime in the forest and the surrounding landscape. The large-scale nature conservation project is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (German: Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, BMU) (Photo: Manfred Wüst).

Fig. B 10.5. Area with dying spruce and beech forests on south-west slopes in the western part of the Hainich National Park (Photo: FSU Jena).

and sequestration (Körner 2017; Luyssaert *et al.* 2008; Mund *et al.* 2015; Schrumpf *et al.* 2014) the older forests are also more resistant to heat and drought owing to their high functional complexity and structural diversity (Ellison *et al.* 2017; Norris *et al.* 2012; Noss 2001; von Oheimb *et al.* 2014; Thom *et al.* 2019). Older forests generally have more biomass and more extensive root networks, which enable them to store larger amounts of water and to better access available water resources. Older forests and forests in the decay stage also have positive effects on the diversity of habitats and harbour well-adapted animal, plant, and fungal species, depending on the specific habitat structures. Nevertheless, current observations of extensive loss of old beech *(Fagus sylvatica)*, e.g. in the Hainich National Park (fig. B 10.5), indicate that even these types of forest are not fully immune to the effects of climate change. Further research is required to better understand the underlying causes and to reassess existing knowledge in the light of these observations.

Increase the amount of deadwood

The current dieback can be an opportunity to significantly increase the amount of deadwood in forests. Deadwood contributes considerably to biological diversity and heterogeneity of our forests and hence positively affects forest resilience: i.e. it contributes to the regulation of the microclimate in forests because of its water storage capacity, and its positive effects on humus formation, energy and nutrient cycles, and the regeneration of woody plants (Norris *et al.* 2012).

The Third Federal Forest Inventory estimated the amount of deadwood in German forests to be 20.6 m^3/ha on average in 2012. Deadwood from coniferous species made up two thirds of the total amount of deadwood, and root plates made up more than one quarter (BWI 2012). In comparison, in primary beech *(Fagus sylvatica)* forests of Uholka-Shyrokyi Luh in the Ukraine, the average deadwood amount was 180 m^3/ha (Mund *et al.* 2015). A considerable accumulation of deadwood is also found in forests that have not been managed for at

least 50 years (Bütler and Schlaepfer 2004) (fig. B 10.6). In contrast, the average amount of deadwood in Germany is insufficient and especially certain deadwood types, for instance deadwood from large standing broadleaved species, is largely missing (Reise *et al.* 2017). The current dieback can be a chance to address this deficiency.

Increase the area of unmanaged forests

The national biodiversity strategy (NBS) of the German Federal Government of 2007 set the goal to set aside 5 % of the forest area by 2020 for natural development (BMU 2007). To serve as a role model, the target for public forests is higher, at 10 % of the forest area. However, results from a research project funded by the BfN, shows that the forest area with natural forest development only amounted to 2.8 % of the total forest area in 2019 (Engel 2019). Thus, it is clear that the target of the NBS will not be achieved. As a consequence, efforts to increase the proportion of forest area with natural development should be considerably enhanced and the recognition of their importance for climate protection and adaptation improved.

Unmanaged forests support natural adaptation processes in response to climate change (Cavers and Cottrell 2015; Kulakowski *et al.* 2017; Milad *et al.* 2012; Puettmann *et al.* 2008; Thom *et al.* 2017) and are necessary to maintain the full range of biodiversity typical for forests. Continued development without human intervention enhances both the biodiversity and the ecological integrity of the ecosystem (Müller and Burkhard 2012; Norris *et al.* 2012). Appropriate large areas of largely

Fig. B 10.6. Deadwood of different dimensions and stages of decay in the forest nature reserve Eichhall, Spessart, Bavaria (Photo: Anke Höltermann).

anthropogenically undisturbed forests and the permeability of the forest landscape for animals and plants enable the development of adapted ecosystems in the long term. Areas, in which natural development processes are continuously given priority, are also crucial for scientific research on the impacts of climate change on ecosystems and, therefore, must be included in long-term monitoring programmes.

In the current situation BfN is concerned about the increasing pressure on the administrations of National Parks and Biosphere Reserves to allow the removal of dead trees. It is critical that any kind of human intervention must be avoided in the core zones of these conservation areas. Large-scale disturbances such as storms, insect infestations, and forest fires can support restoration of forest ecosystems by recreating some of the structural complexity and landscape heterogeneity previously lost through intense management (Beudert *et al.* 2015; Lindenmayer *et al.* 2004; Müller *et al.* 2019). Therefore, fellings and clearing-up after disturbances must strictly be limited to buffer zones and only be permitted if sound scientific information indicates a high risk for neighbouring forests.

Suggestions for the implementation

The implementation of the proposed management recommendations is a huge challenge that should be supported by political strategies, federal and state programmes, and appropriate legislation. To this end, BfN calls for changes mainly in the following three areas: (1) Strengthen forest management to support public welfare; (2) Assuming responsibility by the federal government and making legal adjustments; and (3) Extend monitoring of forest ecosystems and intensify applied research.

Strengthen forest management to support public welfare

Approximately half of the German forest area is owned by private forest owners. The federal and state governments provide for forestry promotional programmes as part of the Joint Task for the Improvement of Agricultural Structures and Coastal Protection (German: Gemeinschaftsaufgabe Agrarstruktur und Küstenschutz, GAK) that are targeted at communal and private forest owners.

The public payments allocated through these programmes should be more consistently linked to public welfare. For example, forest owners, who continue to rely on pure coniferous forests, should no longer qualify to receive public support following calamitous events. The same should apply to silvicultural practices, which foster homogeneous forest stands and, thus, have a higher risk of being affected by disturbances.

The current revision of the framework of the EU Common Agricultural Policy (CAP) as well as the GAK provides the opportunity to tighten the requirements for public payments to private forest owners. These payments should be more consistently linked with measures to improve the functionality and integrity of the forest ecosystems. Eligible measures may include: promoting the use of site-adapted, indigenous tree species; retaining deadwood; creating diverse forest edges; and promoting natural reforestation processes over time spans up to 30 years (with or without prior clearing of the forest site). To ensure uptake by forest owners such measures must be economically attractive as well as, in the first instance, offered by the respective state government (Franz *et al.* 2018).

Assuming responsibility by the federal government and making legal adjustments

BfN advocates for adjustments in national legislation related to forests, nature conservation, and hunting in line with the above-mentioned objectives, for example by:

- Emphasising the key role of forests for nature and environment in contrast to a biased focus on the economic benefits of timber production in the Federal Forest Act (German: Bundeswaldgesetz, BWaldG).
- Introducing ambitious objectives for climate and biodiversity policies in state forests, which are mainly owned by the federal government and the federal states. State forests occupy a third of the German forest area.
- Defining the requirements of good practice in forestry in detail. The requirements under nature conservation law can and must be specified and supplemented by further statutory or sub-statutory requirements in a legally binding manner.
- Anchoring the principle ‘forest before game’ through a commitment to adapted game populations in the Federal Hunting Act.

Extend monitoring of forest ecosystems and intensify applied research

Existing forest monitoring programmes should be reviewed to analyse their suitability for assessing the effectiveness of adaptation measures and whether or not they allow conclusions on the suitability of tree species and forest ecosystems under a changing climate. Comprehensive data is already collected in forests through environmental forest monitoring and other forest-related programmes (e.g. the Federal Forest Inventory, forest monitoring on national natural heritage sites, SAC forest monitoring). In the future these programmes need to be expanded in order to:

- Adequately document changes in forests ecosystems caused by climate change at national, regional, and local levels.
- Assess the effects of adaptation measures regarding the preservation of ecosystem functions and biodiversity in the long term.
- Forecast the long-term suitability of forest trees and forest ecosystems under climate change conditions.

Embedding permanent forest monitoring into applied research programmes will promote the knowledge transfer into silvicultural practices and strengthen communication between science and forestry practice. The exchange is crucial to enable a continuous adaptation of silvicultural interventions. Moreover, monitoring should be complemented by long-term, extensive forest ecosystem research addressing fundamental questions of forest ecosystem adaptability and resilience in the face of changing environmental conditions and societal needs.

Conclusion

Preserving and developing resilient forests and forest landscapes under the conditions of climate change is a huge challenge. Only by cooperating and bundling all relevant knowledge and competences can conservationists and foresters find adequate answers to the questions of how forests should be managed in the future to maintain their basic functions and ecological services for current and future generations.

Broadening the mainly use-oriented perspective in forestry and combining it with the knowledge and expertise available from conservation and ecology is a critical step. This wider perspective will help forestry to better understand the complexity, diversity, and heterogeneity of forest ecosystems. In the long term, forest strategies that ignore the significance of these parameters for the functionality and integrity of forests will fail to substantially contribute to climate change mitigation and to the adaptation of forests.

In its latest special report 'Climate Change and Land Systems' (IPCC 2019) the IPCC supports the view that sustainable forest management can support adaptation to climate change while contributing to the reduction of greenhouse gas emissions. Such an opportunity should not be missed!

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Box B 1

Forestry can maintain and enhance biological diversity

T. Haußmann

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Our forests are 'all-rounders': they are sources of raw materials, climate change mitigators, wellness havens, habitats for countless animal and plant species, and much more. Covering 32 % of Germany, forests are a major feature of our country.

Maintaining and enhancing resilience, biological diversity, and the provision of broad ecosystem services in Europe's forests based on people's needs has become an ever-growing challenge for all actors including policy makers, forest owners, forest managers, and nature conservationists. Against the background of climate change and the internationally agreed development goals, the role of multifunctional, professionally managed forests of Europe will remain an important mainstay in the coming decades. Achieving the multifunctionality objective for forests encompasses the necessity to connect people from forest management practice, science, and policy making. It also means we must learn lessons from other sectors and societal groups, and exchange experiences between countries. Therefore, Germany supports the practice-orientated and science-based exchange of experiences under the European Network INTEGRATE (see Box B 2 in this book). This active contribution to implementing the EU Forest Strategy by further enhancing nature protection within sustainable forest management – i.e. supporting the criterion "maintaining and enhancing forest-related biological diversity" – has gained increasing importance over the past years and offers an important basis for the coming years.

Seen from a national perspective and based on the National Forest Inventory, forestry in Germany is sustainable and multifunctional. One aim is to manage the forests as 'close to nature' as possible by using methods such as selection of mixed and site-adapted tree species, longer rotations, selection cutting, and natural regeneration. Currently, at least 5 % of all forests are not used for forestry purposes. The ecological value of the forests in Germany has improved significantly in recent decades. The Red List of endangered biotope types of Germany also shows that development has stabilised in many forest biotopes. However, some forest animal, fungus, and plant species are still deemed to be endangered, and some of these are even threatened with extinction. This applies in particular to species that are dependent on old-growth forests, undisrupted forest development, and old stands and deadwood. Other species, on the other hand, are dependent on historical forms of forest management. It is, therefore, necessary to maintain a diversity of habitats and species, and further improve the ecological condition of forests with well-targeted and effective measures. Efforts to promote the further conversion of remaining single-species-stands into more resilient mixed forests need to be continued and scaled-up.

To this end, various positive approaches have already been documented within Germany as also presented in this publication. It is important to underline that those good practice forest enterprises take advantage of the balance between enhancing the biodiversity while at the same time harvesting the renewable resource timber in a sustainable way. The use of timber still accounts for 95 % of the income of a forest owner and provides the society with this local ecological material. At the same time, the forests provide positive conditions for many species, some of them rare and endangered. If forest management is done carefully and with particular attention paid to enhancing nature protection, there is clear evidence that the species diversity in managed forests can be even higher than in unmanaged forests. In addition, well-managed and accessible forests serve many other functions and can be very attractive for people, allowing visiting for recreation and sports and for supporting health recovery.

With this understanding: our forests are all-rounders.

Fig. 1. Dead and dying Norway spruce *(Picea abies)* patches in private forests: growing on the wrong sites, weakened by climate warming effects, and finally doomed to be killed by bark beetles. This is a frequent situation in Germany (upper photo). The lower photo shows the 'optimal' mixed forest consisting of at least three main tree species. Such forests are developing already in many areas since the conversion from monocultures to mixed forests is ongoing (Photos: Ulrich Wasem).

Vision of nature conservation in Swiss forests

B 11

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Forest covers over a third of the area of Switzerland and represents one of the most important biodiversity reservoirs, harbouring more than 40 % of species. Aggregated indicators such as deadwood volumes, structural diversity, and tree-species richness have shown a positive development over the last two to three decades. These suggest a positive trajectory, especially when compared to other habitats. Nonetheless, scores of threatened and declining species across multiple taxa call for caution. The plurality of interests, small-scale ownership structures, and biophysical heterogeneity challenge the implementation of national strategies for conservation, and yet have been key in shaping and preserving the diversity of forest habitats to date. Climate change poses a great challenge to the current forest landscape, but also presents opportunities for synergy between production and conservation. Biotic invasion is of growing concern and is likely to get worse in the future. In this chapter, we review the current strategy for biodiversity conservation in Swiss forests, and discuss its current set up, implementation mechanisms, and limits. We thus present an updated vision that specifically aims to build on the current successes and address the main shortfalls. A vision for nature conservation must address deficits specific to natural forests, as well as biodiversity associated with forest types shaped by culture over centuries, both of which have declined. It needs to revisit close to nature silviculture in the light of climate change, specifically considering opportunities for biodiversity. Active conservation measures remain essential. Ultimately, the vision needs to expand its scope to the wider landscape, tackling sectoral barriers. Many threats to biodiversity conservation in forests come from outside forests and the forest sector; conversely, the forest sector has a key role to play in the conception and implementation of a nationwide ecological infrastructure that is paramount to halting the ongoing and grave loss of biodiversity.

Premise

Despite the modest size of Switzerland, its forests are ecologically very diverse. This diversity originates from large geological, tectonic, biogeographical, and climatic gradients spanning the country. In turn, this results in high biological diversity at multiple scales, from ecosystems to populations to species. Estimates consider over 40 % of the ca. 64 000 native species as forest species, or being dependent on forests for at least one life stage (BAFU 2019). In addition, extensive forest edges play an important role as refuges for numerous mammals, birds, and insects threatened by the dominance of intensive agriculture.

< Fig. B 11.1. Swiss stone pine close to the treeline are often characteristic and monumental trees reaching old ages and high values for biodiversity and landscape (Photo: Markus Bolliger).

Human impact: both burden and facilitator

About half of Swiss forests were cleared in pre-Roman times, and the remainder have been shaped by forestry and cattle grazing, with marked regional differences. Primary forests, in a strict sense, are limited to a handful of small patches of spruce

(Picea abies) and pine *(Pinus sylvestris, Pinus cembra)* in secluded and rocky slopes in the Alps.

Forest management, from the early Middle Ages through to the eighteenth century, has depleted forests in terms of their extent and wood stocks. On the other hand, different traditions have increased the diversity of forest habitats. Silvopasture, different coppice forms, as well as important plantations for food and fodder production such as chestnut *(Castanea sativa)* and oak (*Quercus* spp.), created forests with sparse tree cover, favouring thermophilic flora and fauna.

During the nineteenth century, the onset of the industrial economy and infrastructure expansion piled additional pressure on forests. Decades of higher exploitation and clearing led to serious problems with landslides and mudslides in the valleys as well as flooding in the plains because of, among other reasons, lower upstream water retention. The situation became sufficiently serious to spur legislation mandating the conservation of the total forest area, as well as sharply dividing agriculture from woodland. A subsequent reforestation effort promoted fast-growing and economically important conifer species, mostly spruce *(Picea abies)*, also in lowland broadleaf habitats. The legacy of this period lasts to the current day, from the legal base protecting forest area to the uniform conifer stands that replaced mixed broadleaf-conifer forests; in addition, the segregated land-use diminished connectivity between forests and open land through sharp forest edges and habitat-rich silvopasture giving way to dense and darker stands. Nonetheless, a long-standing tradition of 'close-to-nature forestry' is manifest in a substantial proportion of forests persisting with near-natural species composition, providing grounds for biodiversity conservation. Nowadays, large-scale clearcutting is prohibited; forests primarily develop and regenerate naturally. Punctual planting restores protective function following natural disturbances, especially on steep slopes in the Alps, and often promotes valuable native species where no natural regeneration is available. On the other hand, omnipresent practices such as bark beetle containment, clearing of areas affected by storms, or highly managed oak stands, exert pressure on the identity of close-to-nature forestry.

For decades, forestry personnel operated under the assumption that this type of forestry would effectively ensure biodiversity conservation. However, this backwash theory has proved partly wrong. Indeed, scores of forest species populate the Red Lists: hundreds among the 6000 xylobiontic species are threatened to various degrees, including wood-decomposing mushrooms, beetles, syrphid flies, and wild bees, as well as thermophilic species such as orchids and butterflies. Biodiversity suffers from the under-representation of specific development stages, and in particular: (i) species-rich, open, pioneer forests, and (ii) old-growth, decaying stands. These deficits are partly a legacy of the past land-use history (discussed above), and a consequence of the short (60–150 years) turnover practiced in production forestry, which hinders the full life cycle. Therefore, modern forestry should aim to obtain and maintain near-natural stands on all forest lands, with a high level of structural diversity, including well-distributed age-classes, as its overarching goal.

Ecology meets economy: Biologically diverse forests are more resilient to climate change

Close-to-nature silviculture, within the limits discussed above, provides the basis for integrative conservation of forest biodiversity, offering suitable habitat for many species. Importantly, it also offers a base to tackle climate change. For instance, natural regeneration of trees and stands is key to adaptation in a changing environment. However, it is currently debated to what extent forests will be able to successfully track the fast-changing conditions, with regional models for Switzerland indicating increases in temperature and decrease in rainfall above global averages. Altitudinal distribution of tree species shift upwards, while lower altitude climate is shifting to sub-Mediterranean conditions that are novel to the country. The speed of environmental change, contrasted with the long turnover of forests, implies that even species adapted to current stand conditions may fall out of their climatic niche. Selecting and promoting forests stands adapted to current conditions is no longer a guarantee for the future. The dominance of beech *(Fagus sylvatica)* forests in the lowlands will give way to more diverse forests where drought tolerant species such as (ecologically valuable) oaks will become more common. Economically important but uniform conifer stands on broadleaf habitats will not be able to withstand heat and water stress interplaying with biotic factors such as bark beetle. The magnitude of change and its implications for forestry are considerable, especially at the lower altitudes.

Fig. B 11.2. Deadwood is a very important component of forests, and is still underrepresented in many managed forests. Such splintered snags within a mixed forest consisting of broadleaved and coniferous trees are elements to be promoted (Photo: Markus Bolliger).

Forestry is tasked with maintaining the provision of multiple forest functions during a transitional stage, while laying the groundwork for an uncertain future. There is an uncontested need for forests that are more diverse and resilient to multiple, uncertain stressors. This goes beyond the mere number of tree species, encompassing all dimensions of forest diversity from structural properties to age-class composition, from microhabitats to genetic diversity. The need to promote biologically diverse forests as the most effective insurance against climate change implies that, ecologically, forests are poised to gain. Other functions, wood production in particular, need to adapt their *modus operandi* in the short term, resisting a temptation to fight against the tide with excessive forest engineering in the form plantations of introduced species, phytosanitary intervention, and even shorter rotations. Reshaping forests to meet future challenges requires a delicate balance between what needs to change in forests, and transformation needed in the forestry sector itself. Striking this balance is key to aligning economy and ecology in the long term, harnessing an elusive win-win under the framework of multifunctional forestry.

Friends or foes? Alien species pose a long-term risk

In the debate on how best to adapt forests for the unravelling environmental changes, there is controversy over the role of exotic tree species. The timber industry sees the planting of exotic trees such as Douglas fir *(Pseudotsuga menziesii)*, American red oak *(Quercus rubra)* and black walnut *(Juglans nigra)* as a chance to economically compensate for the natural decline and the 'phasing out' of spruce and larch *(Larix decidua)* at low elevations. However, from the viewpoint of conservation, exotic trees are often considered detrimental to biodiversity, as they may fail to provide habitat for native fauna such as insects. The main concern remains the risk of biotic invasion. Douglas fir has proved potentially invasive on dry soils with low-productivity, exactly where it could best play a role as a spruce substitute. The risks of introducing exotic species are exacerbated by the uncertainty about future climatic and biotic conditions, such as competitive ability against native species. Shifts in either abiotic or biotic conditions could lead to drastic changes in their ecological behaviour. Conservation advocates thus call for caution in the use of alien tree species arguing that suitable native alternatives are sufficient, while forest managers

claim the need to retain some flexibility in their use.

Of more concern than the use of exotic tree species is the spontaneous diffusion of invasive neobiota. Rising temperatures and dispersal vectors such as global trade have led to significant spreading in forests; species such as the Canadian goldenrod *(Solidago canadensis)*, Himalayan balsam *(Impatiens glandulifera)*, Japanese knotweed (*Reynoutria japonica*; syn. *Fallopia japonica, Polygonum cuspidatum*), butterfly bush *(Buddleja davidii)*, and others are locally of serious concern in Switzerland (as well as in other European countries). Imported plants and seed facilitate the diffusion of animals, often insects, exacerbating the problem. Their diffusion displaces native species, ground cover, perennial bushes, and associated specialised fauna, thus reducing biodiversity. Importantly, they can also suppress natural regeneration of tree species, threatening a core principle of close-to-nature forestry. A pragmatic attitude in the management of invasive neophytes is necessary. The prospect of total eradication has faded, despite increasing investments at federal and regional levels, and attention to early detection. A prioritisation strategy concentrates the eradication efforts to maintain forest functions and to protect critically endangered habitats such as riverine wetlands. There is also evidence that some interventions to favour biodiversity, such as clearings for the establishment of thermophile light forests, have unintentionally favoured the spread of invasive neophytes, calling for an integrated approach to their management and the proactive sharing of lessons learned. While much of the discussion around neobiota focuses on fighting their spread, a root cause of the problem, namely the widespread commercial introduction, is perhaps receiving too little attention. Several of the problematic species found in forests continue to adorn our gardens and are readily available to consumers from nurseries and garden centres.

Biodiversity conservation with 250 000 partners

In Switzerland, nature conservation falls under the co-responsibility of the federal state and the 26 cantons, which together own only approximately 7 % of forest land. The implementation of forest policies thus depends on the consent and active collaboration of over 250 000 forests owners: municipalities, citizen communes, and thousands of private (small) holdings (ca. 244 000). This plethora of owners manage their forests according to different traditions shaped by a complex interplay of the cultural and biophysical heterogeneity of the country. Such diversity poses a major challenge in designing and implementing national strategies, in accordance with international commitments and in congruence with the heterogeneous base, requiring a layered approach. The federal state thus complements its strategic role with funding disbursed to the cantons to support activities in line with the national priorities. With this federal money, supplemented by their own funds, the cantons compensate forest owners willing to implement measures to promote biodiversity. A striking feature of the system is perhaps that, while the public sector has committed to targets, the implementation on the ground relies on the active and voluntary participation of forest owners. The communes represent a critical node in this system. As public entities, they ought to be considered as integral institutional partners in the promotion of public interests such as biodiversity conservation. In reality, however, economic aspects such as local job creation and retention often prevail. A stronger commitment of the local-level public stakeholders to the higher-level public interest would facilitate and strengthen implementation by the cantons.

Implementation

As previously discussed, close-to-nature silviculture provides a valuable framework for nature conservation. However, it is important to recognise its limits, such as the under-representation of the pioneer and late stages of the whole forest life cycle, or the conservation of high-value habitats of natural or cultural-historical origins. Explicit conservation measures remain paramount to halt and reverse the ongoing loss of biodiversity.

Forest conservation efforts rely on a coherent and shared strategy between forest stakeholders, providing common ground and purpose for targeted implementation. On this basis, the Swiss confederation negotiates with each of the 26 cantons the kind and quantity of deliverables in 4-year periods. The layered strategy, including national as well as regional objectives, allows cantons to act in accordance with the local context and in fulfilment

Table B 11.1. Conservation measures: List of main domains, specific measures and associated indicators or general targets substantiating the federal strategy for forest biodiversity conservation in collaboration with the cantons. The federal authorities work with the cantons, forest owners and other stakeholders towards a common strategy for conservation in the forest sector. The strategy includes six measure domains, each tackling a key ecological deficit as well as the need for continued generation and dissemination of knowledge. Specific measures give foresters and stakeholders ample choices of action to suit the local context.

Measure domain	Specific measures	Indicators or 2030 targets
1. Allowing the natural development of forests	– Establishment of natural forest reserves with long-term agreements or contracts	– Natural forest reserves on >5 % of the forest area – 30 reserves with > 500 ha
2. Promotion of old-growth forests and deadwood	– Establishment of natural forest reserves – Protection of old-growth and deadwood areas – Preservation of lying and standing dead trees – Early detection and life-time preservation of habitat trees in managed forests (10 trees/ha)	– 20–25 m^3 deadwood/ha in every forest – 3–5 habitat trees/ha OR 3 old-growth and deadwood-islands of ≥ 1 ha/km^2
1. Protection and valorisation of ecologically valuable habitats	– Preservation and restoration of moist forests and wet forest biotopes – Preservation of light/open forests – Reactivation resp. continuation of old traditional management forms like pastured woodland, coppice and mixed coppices, and chestnut groves – Establishment of special reserves	– Ecologically valuable forest edges are upgraded and maintained – 100 % of habitats of national priority are in a near-natural condition or consist of tree species which are important for biodiversity
4. Promotion of national priority species	– Species-centric conservation measures – Restoration and upgrading of habitats – Planting of rare and ecologically valuable tree species – Establishment of special reserves – Interconnection of habitats appropriate to the needs of the species concerned – Providing species conservation data and information to forestry	– In every region at least 10 national priority species (NPL) benefit from specific conservation measures
5. Conservation of genetic diversity	– Natural regeneration is prioritised – Ecologically appropriate provenances for plantations – Establishment of forests reserves with genetic conservation as primary objective – Establishment of seedbanks	– Population of target species are protected and listed on the EUFORGEN database
6. Knowledge transfer and research	– Promotion of knowledge transfer from research into conservation practices – Promotion of information- and experience-exchange between foresters and nature conservationists – Rising public awareness on the importance of nature conservation in forests – Support of a working group 'forest biodiversity' dealing with knowledge- and experience-exchange between all stakeholders	– Ad-hoc analyses of forest personnel and public demonstrate an increase in capacity and awareness, respectively

of their own commitments. The confederation thus funds activities in line with the national priorities, maintains an oversight role, but also provides stakeholders with technical expertise and knowledge transfer from research to practice. The implementation on the ground, in collaboration with forest owners, resides with the cantons. A trusted system of collaboration between forest stakeholders from the federal to the local level, with cantonal forestry personnel playing a key role in the implementation, is indispensable for realising the strategy on the ground. Equally important is the level of support of the strategy itself among stakeholders, particularly practitioners who can implement it effectively if personally invested. Any new vision and subsequent strategy should therefore be 'ground-truthed' through participative processes with all stakeholders that often expose the limits to integrative approaches and highlight hard trade-offs.

Fig. B 11.3. 20–25 m³ of deadwood are envisaged in every forest in Switzerland according to the federal strategy for forest biodiversity (Photo: Markus Bolliger).

At the core of the strategy is a recognised need for sufficient forest areas of ecologically meaningful dimensions where biodiversity has priority over any human interest and activity. To this end, it is necessary to legally secure areas devoted to nature, commonly called 'forest reserves'. Reserves are typically established through a management contract with the owner, who is compensated for complying with the rules and objectives of the reserve for a period of at least 50 years or longer. In natural forest reserves, forests shall develop naturally through the entire successional cycle without any interference. Natural dynamics lead, for example, to the accumulation of deadwood; this is a key ecological resource for over 6000 species that is typically deficient, in quality and quantity, in managed forests. The other major type of reserve, referred to as 'special reserves', provides legal protection to areas where active conservation measures are planned over a period of at least 25 years. This type of reserve is commonly used to protect the habitat of a particular species, often an 'umbrella' species such as the western capercaillie *(Tetrao urogallus),* or rare habitats needing active management to retain their ecological value.

Management contracts between the public sphere and the forest owner are proving a versatile, pragmatic instrument to secure investments in biodiversity conservation. Forests reserves now cover 6.3 % of the total forest area, more than double since the inception of the current system a decade ago. The political objective of 10 % until 2030 thus seems within reach. Nonetheless, the effectiveness of forest reserves depends on their quality, size, distribution, connectivity and, last but not least, the ecological value of the 90 % of forest that is not under strict natural protection. Protecting natural processes that take centuries to unfold through fixed-length management contracts strongly depends on their renewal in the future, exposing a substantial limit of this conservation tool. While national monitoring programmes are showing encouraging signs on the ecological value of forest reserves (Brang *et al.* 2011), the overall success or failure of the forest conservation strategy will strongly depend on the delicate interplay between strict protection on specific sites, conservation measures outside forest reserves (such as forest margins), and sustainable use on the vast majority of the forest area.

Fig. B 11.4. Old-growth and connecting elements with broken and crooked trees along forest edges are important measures that allow migration of species (Photo: Markus Bolliger).

A vision for the future

Biodiversity is recognised for its intrinsic value and is managed as a precondition for the continued provision of forest functions. Sustainable forest management optimises trade-offs and synergies between forest functions underpinned by biodiversity. Close-to-nature silviculture continues to provide the basis for biodiversity conservation and responds to new needs posed by climate change. Specific conservation measures complement the integrative foundation to tackle ecological deficits. In practice, mixed forests of climate resistant, genetically diverse, indigenous broadleaved stands replace conifer plantations at lower altitudes. All forest successional stages are present in near-natural distributions. Forest reserves, where biodiversity is the main function, cover sufficient areas to halt the loss of threatened species and ensure ecological connectivity of forest habitats. Key ecological resources such as deadwood (figs B 11.2 and B 11.3) cover the requirements of all organism groups (e.g. xylobionts) across all forest types and designated functions. Neobiota do not threaten the indigenous flora and fauna through priority management and contained introduction vectors. Forests play a key role in the nationwide ecological infrastructure, guaranteeing connectivity of biodiversity hotspots (fig. B 11.4) and integrating sites of high ecological value into production forests: rare forest associations, habitat trees, wildlife refuges and corridors, old-growth elements, and forest ecotones persist outside of forest reserves.

At present, there is reason for mild optimism about the state of forest biodiversity in Switzerland. According to the latest national forest inventory (Brändli *et al.* 2020), forests are becoming more near-natural in their structural diversity and stand composition. Positive trends in most woodpecker populations going hand in hand with increasing quantities of deadwood suggest that insects may be more abundant or recovering, but faunistic data on forest species besides higher taxa such as birds and mammals remain patchy. Despite some positive evidence, caution is well advised for several reasons. Firstly, progress is often measured against a legacy of overexploitation in the previous centuries, as discussed above, and needs to be interpreted in this context. In addition, some of the advances observed in recent years may be as much

a consequence of historically low timber prices and production pressure as conservation efforts. A successful conservation strategy should ensure progress also under more favourable economic conditions for forestry; given the returning attention to wood as a sustainable energy source, a stress test may already be on its way. Finally, the positive evolution of biodiversity in forests is often expressed in 'relative' terms compared to other habitats. Evidence shows that forests are faring better than farmlands or waterways, and this is indeed an important, motivational signal for the forestry sector; however, this should not be equated to a positive evolution in absolute terms.

The current vision sees close-to-nature forestry as the prerequisite for ensuring different functions such as production, protection, recreation, and biodiversity. This vision, anchored in the forest policy, has the merit of establishing an equivalence between all functions, including biodiversity. At the same time, it falls short of highlighting the dual role of biodiversity as a function per se (i.e. a public good) as well as underpinning the provision of all other functions and services. This duality is well exemplified by the previously discussed transition from uniform conifer stands to biodiverse broadleaf forests: while biodiversity as a public good can gain from such transition, the transition also ultimately underpins production and protection in the long run. Failing to fully appreciate biodiversity in this capacity implies a failure to harness synergies with the other functions. Internalising biodiversity in the management of other primary functions thus needs to lay at the heart of a vision for the future, strengthening the integrative approach while continuing to promote biodiversity as a priority function where needed.

One of the biggest challenges for forest biodiversity conservation, however, awaits at the edge of the forest and beyond. Many species, especially insects, rely on habitats within as well as outside forests to complete their life cycle. Animals such as deer *(Cervus elaphus* and *Capreolus capreolus*), chamois *(Rupicapra rupicapra),* boar *(Sus scrofa),* wolf *(Canis lupus),* brown hare *(Lepus europaeus),* long-eared owl *(Asio otus),* and blackbird *(Turdus merula),* to name just a few, are not restricted to woodland, but find their food also, or even mainly, in the open landscape. Intensive farming, expanding settlements, roads, and railway barriers all threaten countless species, of which many are 'forest' species. For long-term species survival, good forest practices alone will not be sufficient. The concept of connectivity at the national level, and the implementation of an ecological infrastructure is paramount. In this complex inter-sectoral endeavour, foresters should not be shy to leave the woods and take a seat at the table. The ecological importance of forests and the track record of many successes make them an indispensable partner.

A new vision for forest biodiversity conservation thus needs to look inward, and better appreciate the role of biodiversity as a foundation for other function and services, as well as looking outwards, towards the wider landscape where connectivity and ecosystem function play a key role for sustaining biodiversity. We articulate this vision in a set of objectives that build on the current strategy:

Objectives

1. Biodiversity conservation is integral to the planning and execution of all forestry activities, explicitly aiming to harness synergies wherever possible, especially in the context of climate change.
2. Forestry allows for stable and viable populations of forest species, and pays particular attention to the presence of endangered species and their ecological requirements.
3. Sufficient forest area is devoted to biodiversity and natural dynamics, ensuring that populations of endangered, national priority species and habitats are preserved, and their threat status diminished. Deadwood as a fundamental ecological resource continues to increase in all biogeographic regions.
4. Ecological connectivity between forest habitats is safeguarded or restored. Structured forest margins connect forests to non-forest habitats.
5. Forests play an integral role in the nationwide ecological infrastructure: they connect biodiversity hotspots, foster wildlife corridors and dispersal axes, and enhance ecosystem function.
6. Management practices of cultural and historical value that have a positive impact on biodiversity are maintained and promoted in representative areas. These include silvopastures, forms of coppice and nut-agroforestry (chestnut, walnut, oak).
7. The presence of non-native tree species remains limited and does not compromise the near-natural composition and further ecological proper-

ties of the stands such as associated fauna and soil biogeochemistry.
8. Invasive neophytes do not compromise the ecological quality of habitats, do not harm native biodiversity, and do not pose a threat to natural regeneration.
9. Biodiversity conservation gains significance in applied research, forestry studies, and training.
10. Bottom-up initiatives of forest owners in favour to biodiversity are sustained financially by the public sector and encouraged through raised awareness as well as technical assistance.

Conclusions

The current implementation framework is proving successful in reaching the specific set targets, such as hectares of forest reserves, upgraded forest margins, etc. However, the actual ecological impacts remain largely unknown. A comprehensive analysis is planned towards the end of the current strategy period in 2030. In particular, the impact of the specific conservation measures will be assessed in the context of close-to-nature silviculture. As previously stated, the success of conservation measures will largely depend on their ability to address the limits of current forestry practices in conserving biodiversity. Impact assessment, supported by advances in methods and technologies, should thus further gain importance in defining future direction on the basis of emerging evidence. At the heart of a future vision, however, there needs to be a firm recognition that biodiversity is indispensable for the future of sustainable forestry. Forestry and foresters are therefore invited to lead the way in showing how, amidst a worldwide biodiversity crisis, biodiversity can be part of the solution to their own sectoral challenges.

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Driving factors for integrated forest management in Europe – findings from an empirical case study assessment

B 12

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All across Europe, the increasing importance attributed to forest biodiversity has led to forest management practices that try to incorporate conservation practices into forestry. This Integrated Forest Management (IFM) is a popular but heterogeneous concept that has been applied in different ways to accommodate various local traditions, climatic, and geographic conditions. In this chapter, we briefly present the findings of an extensive case study consisting of 28 practical cases in 9 European countries. The study was carried out to understand and map out the current and future social, technological, ecological, economic, and political driving forces of IFM in practice. The selected case studies cover different social environments, ownership structures, and biogeographical regions. National experts as well as forest practitioners were interviewed to gain understanding of the national stance on IFM. By doing this, the study attempts to look past the obvious differences between the cases and to identify the main common factors (social, technological, economic, ecological, and political) that hamper or facilitate IFM.

Introduction

As society changes, so do societal demands on forests. Where once forests primarily served as sources of wood in the past, improving knowledge on ecological processes has led to the insight that forests also serve other direct and indirect functions. Erosion control and protection from avalanches are two examples. The idea of nature conservation, focused on the intrinsic value of nature, started to gain prominence in the nineteenth century, and by the twentieth century, the social value and the recreational function of forests were added to the list. Nowadays, climate change mitigation has become another demand that forests must respond to.

< Fig. B 12.1. The Hallerbos forest in Belgium is a scenic hotspot that attracts millions of people every year. It is an example of how integrated forest management can contribute to the valorisation of a regional specialty while taking other forest goods and services into account (Photo: Pierre Kestemont).

To accommodate all these different expectations, there are two basic strategies: segregation and integration (see Bollman and Braunisch 2013; Krumm *et al.* 2013). The segregative approach identifies areas based on their primary function. A productive plantation may be found alongside a strict forest reserve and a recreational forest. The alternative is to unite different forest functions in the same forest. This so-called Integrated Forest Management (IFM) is becoming more popular in Europe as an approach to combine multiple functions within the same forest area. The segregative approach and the IFM approach can be – and usually are to some extent – combined.

While the effects of IFM on biodiversity are increasingly attracting scientific interest, the motivations and opportunities for forest managers and forest owners to actually implement IFM form the keystones of the concept. In our research we tried to find out how and why forest managers try to support biodiversity in their managed forests. The factors that – positively or negatively – influence the decisions pertaining to the implementation of

nature conservation measures into forest management were investigated and the results are presented in this chapter. More precisely, the following questions are addressed:

1. How do forest managers and experts understand and practise the integration of nature conservation into forest management in different contexts in Europe?
2. What facilitates and what impedes the integration of nature conservation measures into forest management?

Research approach

Forty-two respondents from nine European countries were interviewed using an in-depth interview guideline with open questions and a standardised Likert-scale questionnaire (see Aggestam *et al.* 2020). Twenty-eight interviews were conducted with forest managers at the operational level (see Maier and Winkel 2017), and fourteen interviews were conducted with policy experts on forest management and conservation in the respective countries (fig. B 12.2.). The selection of cases and interviewees aimed to represent the diversity of Europe's forests and forest management systems (based on Duncker *et al.* 2012), using the authors' professional network and snowball sampling via the Integrate Network, an alliance of representatives of different European countries that promotes the integration of nature conservation into sustainable forest management at the policy, practice, and research levels.The interviewees were asked about the forest management practices in their forest district or country, with a focus on nature conservation measures, and to give their views on the history and future of forest management in their region.

How do forest managers promote forest biodiversity?

The most common nature conservation measures expressed by the interviewees did not require active management, but rather aimed at the retention of forest structures or areas. All respondents reported nature conservation as being of 'some importance' in their daily job. The degree to which biodiversity measures were integrated, however, varied widely and depended on the management

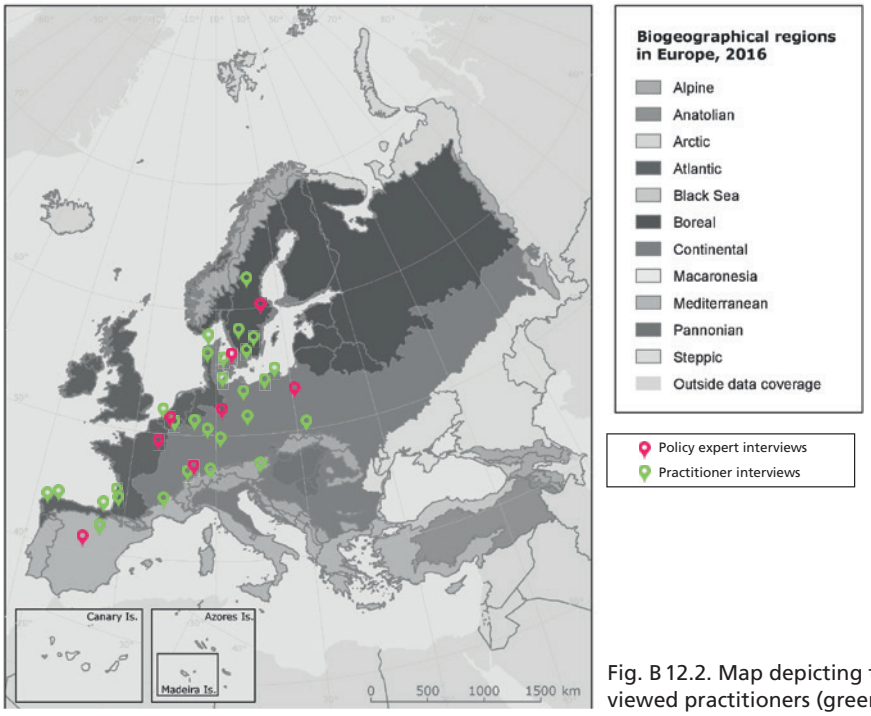

Fig. B 12.2. Map depicting the location of the interviewed practitioners (green) and national experts (pink).

Table B 12.1. Selection matrix for the study cases.

	Even-aged mgmt./ rural		Even-aged mgmt./ urban		Selection forestry/ urban		Selection forestry/ rural	
	Public	Private	Public	Private	Public	Private	Public	Private
Central/Eastern Europe	2		1		4		1	
Northern Europe		2		1		1	2	1
Atlantic region	1	2		1	1		1	1
Mediterranean region	1	1						
Alpine region	1				1		1	1

priorities of the forest enterprise. The following paragraphs highlight some measures related to biodiversity conservation and resilience that were prevalent in the interviews.

Deadwood and habitat tree retention were by far the most common tools to increase forest biodiversity. The reason behind this is presumably the easy implementation. Costs were perceived as relatively low since they do not consist of active management interventions and carry a limited opportunity cost related to the space occupied by the habitat tree or old tree island. There were considerable variations between the cases; in some forests rather large deadwood island are left (e.g. in Bonn, Germany, where some old-growth stands are completely taken out of management), whereas in other forests this practice is restricted to a few trees per hectare so as not interfere with subsequent replanting (e.g. in the case of Vaucluse, France). The increased public knowledge on the value of deadwood as both a habitat for saproxylic species and a long-term source of nutrients and water for living trees contributed to the popularity of this strategy. The only cases where deadwood retention was not implemented as a measure was one highly productive maritime pine monoculture in the Atlantic zone, where sometimes even stump harvesting for bioenergy production occurs. However, even in the regions where stumps are removed, it is a controversial practice because of the negative impacts on soil organic matter, biodiversity, and the increased likelihood of erosion.

This leads to the importance of **soil protection, water management, and protection from natural hazards,** which are well-known elements in sustainable forest management. In many Alpine and Mediterranean cases, erosion, rainwater run-off, and avalanche prevention were top priorities. Additionally, the interviewees stated that water is often the limiting factor for tree growth in Mediterranean ecosystems, and fires pose a grave threat to forest ecosystems, which further increases the importance of sustainable water management. Concretely, this means that in many of these cases, clearcuts were avoided or even prohibited. Species mixtures were encouraged in coniferous stands as the mixed species litter, especially including broadleaf litter, may enhance the soil quality in terms of water and nutrient absorption.

Diversity in terms of species, genetics, and structures was generally seen as beneficial in terms of maximising biodiversity, but also enhancing forest stability and resilience to a variety of biotic and abiotic threats. Specific measures included favouring under-represented species, increasing the share of broadleaved species, and using suitable-to-site provenances. Also, in some cases interviewees viewed the introduction of non-native species and provenances as a positive development.

The 'nature conservation' measures showed a remarkable overlap with measures intended to 'enhance the resilience of forests'. Many of the interviewees saw that there was a strong causal link between the biodiversity and resilience of forests.

Especially in Natura2000 areas designated under the Birds and Habitats Directives, **specific species protection** was often a management goal that complements 'standard' nature conservation measures. These measures tend to be very specific and depend on the local habitat type, ranging from creating puddles and ponds for certain amphibians, to promoting some tree species over others.

Examples

The integration of nature conservation measures in forest management can be witnessed in all European forest systems, be they public or private, urban or rural, big or small. However, integrating these measures does not make the forest a nature reserve; the degree to which production and conservation

Fig. B 12.3. large-scale clearcut with stump harvesting. Oaks (*Quercus* spp.) are left in the stand for PEFC (Programme for the Endorsement of Forest Certification) certification and for increased resilience (Photo: Jakob Derks).

Fig. B 12.4. The slopes of the Kottenforst embracing the city of Bonn. Aesthetic appeal and recreational potential are crucial for this area (Photo: Jakob Derks).

can be coupled varies considerably, which is exemplified below with a few cases from our research.
Example 1: Focus on timber production
Landes de Gascogne, France

– Atlantic region
– Private
– Rural
– Even-aged

Maritime pine *(Pinus pinaster)* is the 'bread and butter' of a very productive forest sector in southwestern France. Nonetheless some nature conservation measures are common, mainly the retention of oaks (*Quercus* spp.) during clearcuts in order to comply with the PEFC certification standards, or the planting of broadleaved trees along forest edges (fig. B 12.3). The purpose of these is manifold. They mainly act as wind and fire breaks and help to control the spread of pests and diseases such as maritime pine bast scale *(Matsucoccus feytaudi)*. In this sense, the nature conservation measures that are in place are largely – but not exclusively – aimed at enhancing forest resistance and resilience and also serve the economic interests of the enterprise.

Example 2: Focus on recreation and biodiversity
Kottenforst, Germany

– Central region
– Public
– Urban
– Selection

The Kottenforst in Germany is a typical urban forest that provides an array of social functions to its many visitors (fig. B 12.4). It is also part of the Natura 2000 network. Most of the forest is classified as habitat type 9160 (oak–hornbeam forests of the *Carpinion betuli* alliance) and the management strives to reach a favourable conservation state. Nature protection, for its own sake, because of legal requirements and to comply with the visitor expectations, is thus an important management goal. Clearcuts are restricted to unstable stands (notably bark-beetle infested Norway spruce, *Picea abies*, stands), most stands contain deadwood and habitat trees, ponds for amphibians are promoted and the tree composition is being diversified. Deadwood and veteran trees are not restricted to certain

individuals across the forest; a few forest stands have been completely taken out of management.
Example 3: Focus on protection
Sankt Gallen Alps, Switzerland

– Alpine region
– Public
– Rural
– Selection

In the Swiss Alps, protection against erosion, rockfall, and avalanches is the most important forest function (fig. B 12.5). An adequate management system inherently entails measures that benefit biodiversity. They include selection cuttings aiming for stable trees and the retention of lying deadwood. The stand needs to be stable and resilient. Clearing the land is to be avoided at all costs to provide enduring protection from rockfall. Subsidy systems are in place to support this laborious and unprofitable management system.

Fig. B 12.5. The slopes above the Walensee, protecting the town of Weesen from avalanches and landslides (Photo: Rolf Ehrbar).

Why do forest managers promote biodiversity?

It is clear from the interviews that nature conservation measures are, to various degrees, widely integrated into productive forest management across Europe. The reasons behind this are manifold. Among the many different factors that were found to influence decisions on IFM, we can identify three categories: (i) factors which positively affect IFM, (ii) factors which negatively affect IFM, and (iii) factors which can either have a positive or negative influence, depending on the local circumstances.

Impeding factors.
A lack of support and incentives for ecosystem services other than wood production, especially if the production targets are high, was described as impeding the implementation of nature conservation measures. The positive externalities of IFM for the larger ecosystems were perceived as being largely disregarded by the relevant bodies.

Scattered forest ownership was reported by some as a barrier to fast and widespread implementation of IFM. It was mainly public forest managers that made this statement, and less so private forest owners. Some respondents stated that a diversity of ownership may also support diversity in forest management.

Market demands were most frequently mentioned as a factor that hindered the implementation of conservation measures in IFM. The majority of interviewees reported that the current demand for wood puts considerable pressure on them to harvest intensively. Many of the interviewed public foresters indicated that from their perspective trade-offs between production and biodiversity protection remain problematic. The increasing demand for bioenergy lowers the amount of deadwood and the focus of wood industries on specific tree species and timber size assortments means there is a limited incentive for forest diversification. Forest management was seen as being strongly related to wood market developments. Hence, a more diverse market demand would be a very positive driver of IFM.

Facilitating factors
General economic considerations were mentioned by a third of the respondents as a main management target, making it the single most widely acknowledged forest management goal. It was the only management target that was voiced in every interview, to varying degrees. While the current demands from the wood markets were perceived as impeding IFM, several respondents stressed that a long-term economic profitability is the best incen-

tive to keep the forest healthy, diverse, and rich in terms of biodiversity. A healthy forest means guaranteeing sustained production, and a part of the timber revenues can be used to finance conservation measures.

The **intrinsic motivation** of forest managers was seen as the most facilitating factor for the integration of nature conservation measures in forest management. Many respondents stressed their education, experience, knowledge, and their responsibility to future generations as a main driver. The importance of forest biodiversity was widely understood by all respondents. Many see themselves as wardens of a resource that they can only temporarily influence before handing it over to the next generation. This sense of responsibility greatly contributes to their willingness to implement nature conservation measures.

Forest-related legislation was viewed as a strong driver for the integration of nature conservation measures in forest management by most of the interviewees, although the implementation was described as partly lagging behind. National laws were typically perceived as crucial for foresters' performance and supporting their efforts in implementing nature conservation measures. European legislation, most notably Natura2000 (the Birds and Habitats Directives), were seen as an important but sometimes also a cumbersome tool for the enforcement of nature protection measures.

Ambivalent factors.

The relationships between stakeholder groups – foresters, conservationists, and civil society – were considered to be shifting and were perceived as being at a crossroads. The environmental sector (mainly nature conservation organisations) was regarded by the interviewed foresters as being successful at reaching out to the broader society, while the communication of the forest sector was seen as inefficient and less effective. Foresters felt that they needed to put additional efforts in communicating their nature conservation activities. This is especially true with regard to communicating with the urban society, whose views were seen as being dominated by recreational and aesthetic desires. IFM has a potential to increase people's acceptance of forest management; the selection logging operations with an emphasis on nature conservation often have a lower visual impact and are more easily accepted by the public.

Public pressure from various stakeholder groups, but mostly voiced through media and environmental NGOs, was the most often mentioned driver for the integration of nature conservation measures in forest management. In most cases, societal expectations were seen as supporting (but also as challenging) when it comes to the integration of more nature conservation measures into forest management. In many cases however, IFM was viewed as not sufficient by itself, and foresters reported pressure to cease all logging operations for the sake of either recreation or nature protection. Many interviewees also perceived rather contradictory public expectations, but they agreed that forest managers' ability to respond to a variety of societal demands was absolutely critical.

Knowledge in society plays an important but ambivalent role in the attempt to merge production and protection in managed forests. Many respondents indicated a growing environmental awareness in society, but a lack of knowledge on management of forests for different ecosystem services, resulting in 'black and white' views, and a lack of understanding of the long-term perspective underlying the management of forests.

Technological innovations were viewed as having the potential to improve the implementation of IFM mainly through more accurate and faster data gathering, but in some cases may inhibit the implementation of conservation measures. Generally, innovations in the realm of remote sensing and inventories were seen as positive. Heavy machinery used for logging operations was perceived ambivalently, as it may potentially harm nature conservation goals if not used wisely, but also has the potential to limit negative impact on habitats, when properly applied.

Conclusion

The majority of interviewees reported feeling an intrinsic urge to respect the natural processes in their forests and to safeguard their productivity for the coming generations. External drivers added to this motivation. The long-term financial profitability of the forest requires long-term stability. Measures that safeguard forest resilience and thus the financial return in the long run tend to coincide with those aimed at nature conservation.

The requirements of the wood market were perceived as the factor that most hinders the implementation of biodiversity into managed forests. A more diversified wood market is thus instrumental to the development of a more viable and sustainable forest sector. According to many of the respondents, cascading wood use and specific value chains for different wood species and different wood qualities could lead to more varied forests without the need for external incentives. Policy strategies could aim at providing financial support and incentives for non-marketable ecosystem services.

Our research shows that social drivers play an important role in the perception and uptake of IFM among forest practitioners. Two perceived general tendencies regarding public perception on forestry could be distinguished. Many of the interviewed foresters felt that the knowledge of forest ecosystems among the public seems to be increasing, but at the same time that the public understanding of the role, aims, and effects of forest management is often insufficient or even in decline. Combined with the increasing outspokenness and the contradictory demands of different stakeholder groups, this poses a major challenge for many forest managers.

Integrated Forest Management comes in many shapes and forms across Europe. In regions with a tradition of continuous cover forestry (such as in the German Kottenforst example), the integration of nature conservation into forestry is obvious; however, even in very intensively managed forestry systems, the perceived importance of measures that protect soil, water, and biodiversity is also on the rise. The French Landes de Gascogne example shows that retention forestry, whether it is for certification purposes or not, has become a regular practice. How IFM is practised in Europe is rooted in different forest management traditions, and strongly influenced by both biogeographical and social circumstances. It is important to acknowledge the diversity and flexibility of the implementation of the IFM concept in order to respond to different regional and local contexts; this can be seen as an opportunity. While this chapter only briefly touched upon three of our twenty-eight case studies, this book presents a multitude of examples from all over Europe where forest managers and conservationists present in-depth information on highly diverse forests.

Acknowledgements

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https://integratenetwork.org/

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Box B2

The European Network Integrate – promoting the integration of nature conservation into sustainable forest management

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How can nature conservation be effectively integrated into multifunctional forests? This question has received increased attention in the policy debate at national, European, and global levels. This applies in particular in the course of climate change, the alarming decline in biodiversity, and the continuous loss of natural habitats. What is the appropriate amount of set-aside forests? How can the economic, ecological, and societal needs be balanced in managed forests? These and other topics are hotly debated amongst policy makers, experts, and scientists in the context of biodiversity conservation in forests; however, the debates are often characterised by distrust, lack of understanding, or indirect communication amongst the different actors.

Fig. 1. Map of the European Network Integrate member countries.

Integrating biodiversity conservation in managed forests will, undoubtedly, remain of critical importance as most of Europe's forests will also continue to be utilised with the aim of ensuring the provision of a broad range of ecosystem services. Foresters and forest enterprises have developed a rich portfolio of integrative concepts in different parts of Europe. These concepts take into account research findings and practical experiences for addressing these challenges.

The European Network Integrate was established by decision of the Standing Forestry Committee of the European Commission in 2016. It aims at increasing the mutual understanding between different stakeholders, identifies and analyses good practices that integrate nature conservation in managed forests, encourages the sharing and promotion of success stories, and derives recommendations addressed at both policy makers and forest practitioners. Further, the network facilitates knowledge transfer and capacity building amongst all sectors involved and promotes cross-border expert visits and exchanges.

The European Network Integrate, currently chaired by Switzerland, is voluntary and driven by its members. Participation by members, observers, and experts in meetings and field visits is at the heart of the network activities. This approach allows for open discussion with all stakeholders about current and emerging challenges about forest biodiversity in different parts of Europe, and options concerning how forest management can address those challenges. One central feature that supports this work is the network of marteloscopes. The marteloscopes are demonstration and learning sites for education in the fields of forestry and nature protection. The marteloscopes also have various research applications. More than 100 such sites have so far been established across Europe (for more details on marteloscopes see Box C4).

As of October 2020, there were 21 member organisations from 18 European countries (both EU and non-EU) in the European Network Integrate as well as the European Commission as an observer

(fig. 1); about 50 representatives from policy and research related to forest management and nature conservation are involved in the network. There is an open invitation to other European countries to join. The network provides regular feedback on its activities to the Standing Forestry Committee and other European fora. The European Forest Institute acts as the network facilitator and scientific advisor based on project funding granted by the German Federal Ministry of Food and Agriculture.

Integrate Network

facilitated by EFI

More information
https://integratenetwork.org/
https://integratenetwork.org/brochure/brochure.html

Fig. 2. Marteloscope in a mixed broadleaved forest in western Czech Republic, Čečiny (Photo: Andreas Rigling).

Relative investment in workpower and finances of the entreprise in different goods and services. Each line corresponds to a 20 % increase, from 0 to 80 %.

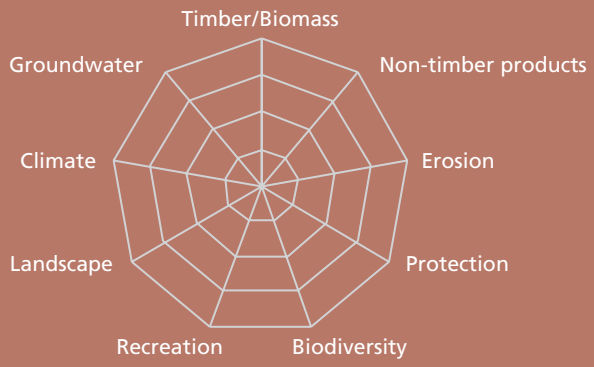


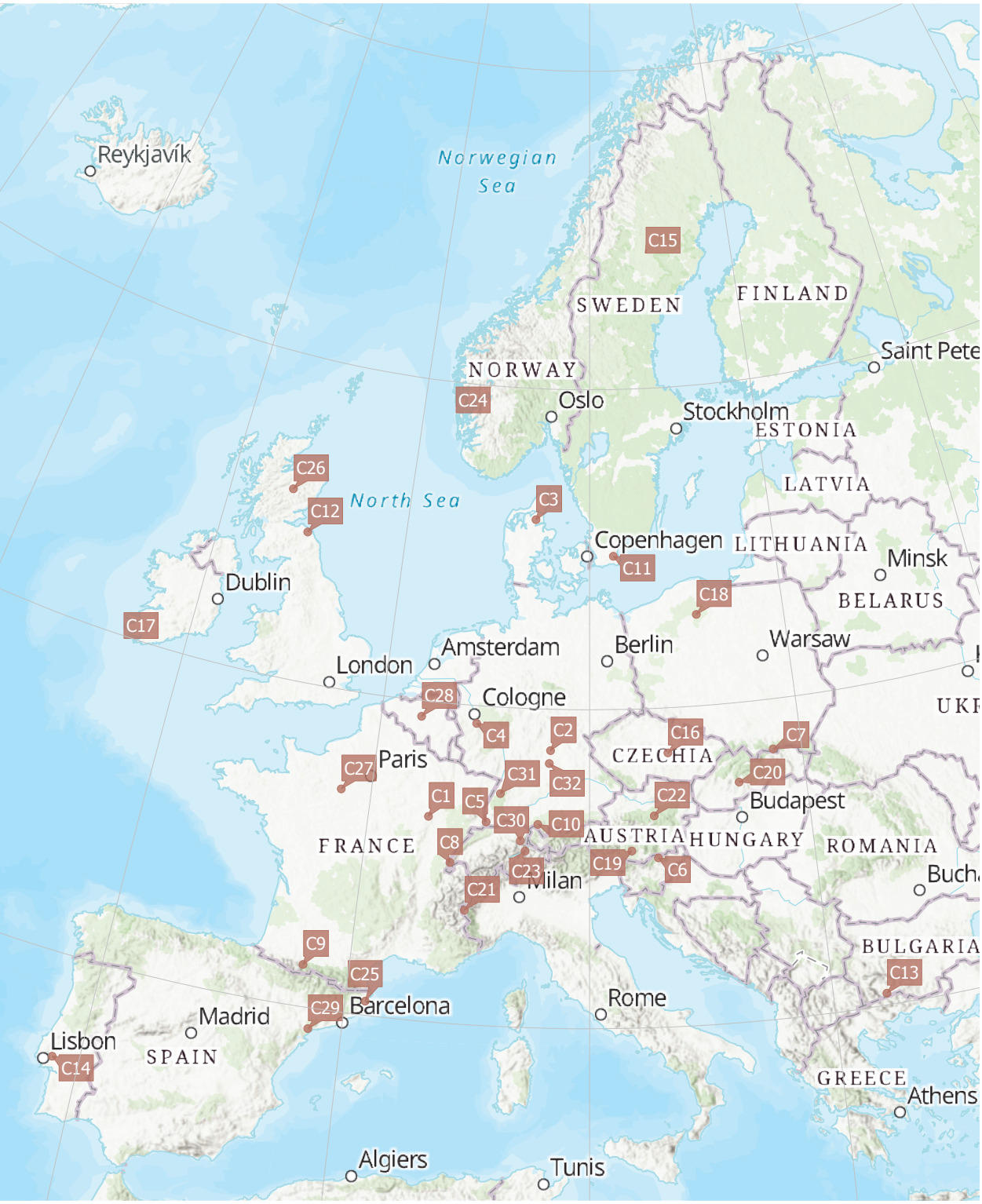
Fig. C 1. Dead Norway spruce trees are visible as grey between Silver fir and European beech. The extensive drought periods 2018, 2019 and 2020 have weakened especially spruce and finally caused bark beetle attacks in this area in the southern black forest and indicate massive losses for forest owners. This is an exemplary picture of a forest that is changing – the economical basis as well as the ecological equipment is adapting. The forest owners have to find solutions to increase resilience and to positively stimulate biodiversity conservation (Photo: Frank Krumm).

Part C Practice examples

The 12 chapters in part B describe the framework within which managers in many enterprises in Europe have to work. The basic conditions include factors such as heritage, laws, and ownership relations. Even though not all framework conditions can be covered, the chapters show how big the variation of biogeographic regions over relatively short distances can be. In Europe there is a multitude of different political frameworks and also a broad variety of sociocultural backgrounds. It is very clear that there is not one solution to the demands to supply a variety of ecosystem services and the challenges posed by the diverse conditions in different regions. The case studies in part C have been selected to represent the broad spectrum across different gradients and show how enterprises deal with challenges to provide different ecosystem services. The examples are clustered into six different groups according to the main forest functions: Timber production forests in lowland areas (C1–C5); Timber production in mountainous areas (C6–C10); Intensive forest management (with focus on timber production) (C11–C20); Protection against natural hazards (C21–C25); Tourism and scenic beauty and densely settled areas, cities, and urban landscapes (C26–C29); and Managing for species diversity and habitat maintenance (C30–C32).There are, of course, overlaps and some case studies do not clearly fit into only one group. However, we hope to illustrate that the different conditions and demands call for different approaches. We are well aware that that we can only cover a fraction of the diversity of approaches and there are certainly other functions that have not been covered by the selected examples.

The authors of the case studies in part C were asked to fill a table with the aim of representing in which ecosystem function resources and capacities are invested. To guarantee a certain common understanding of the terminology across borders, we defined nine ecosystem services and products – according to the Millennium Ecosystem Assessment MEA (see introduction): Timber/Biomass (T/B), Non-timber products (NTP), Erosion (E), Protection (P), Biodiversity (B), Recreation (R), Landscape (L), Climate (C), and Groundwater (G). We asked the forest managers to estimate how much (in percentage terms in 10 % steps) of their total capacity is invested in each service function.

At the beginning of every chapter, a 'spider graph' indicates the outcome of this estimation and shows the service portfolio for each case study. The lines correspond to 20 % steps. These graphs provide a very rough overview of the priorities in the different cases based on the estimations of the authors.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Stockholm
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C 1

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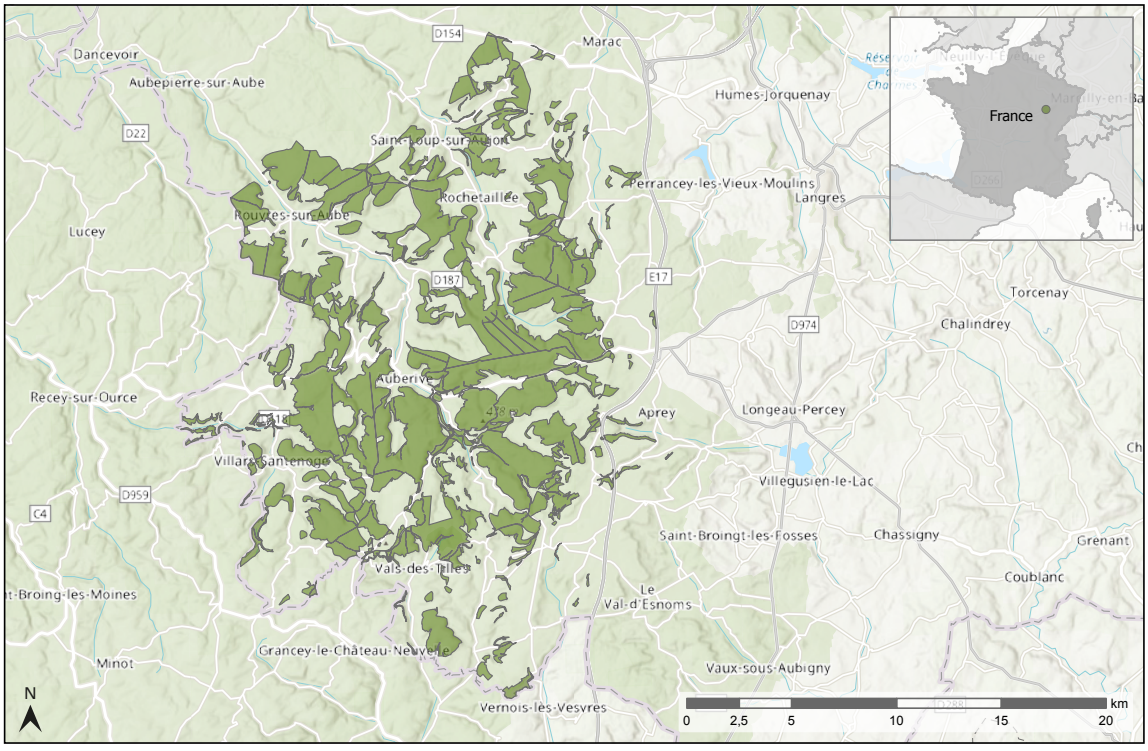
Context, legal frame and ownership structure

The public forest of Auberive comprises more than 16 500 ha of broadleaf-dominated stands. Of this, 8000 ha of the forest belong to several local communities that have decided to mutualise its management and entrust it to the 'Office National des Forêts' (ONF; the French national forest service). In 1974, the communities created an association named 'Syndicat intercommunal de gestion forestière de la région d'Auberive' (SIGFRA: Associa-



< Fig. C 1.1. Colourful autumn in Auberive. The forests are dominated by broadleaves and represent a rich species portfolio. Many forest areas have historically been managed as coppice with standards (Photo: Jean-Jacques Boutteaux).

Statement

"Continuous cover forest management integrating the economical, ecological and social functions is the main aim of Auberive's forests. Extremely diverse forest types, tree species and forest history lead us to this choice, and towards the production of high quality wood."

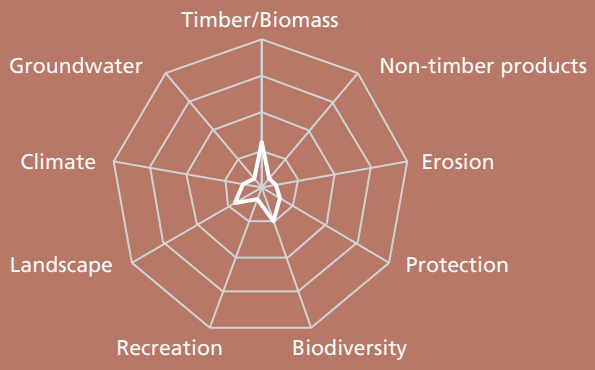


Table C 1.1. General information on the forests of the Auberive public forest.

Forest community	Mixed beech-oak-hornbeam forest, particularly rich in tree species (24 species in total)
Total forest area	16 500 ha, the SIGFRA represents 8030 ha
Main management type	Uneven-aged continuous cover (20 years conversion from coppice-with-standards)
Total volume (2008)	176 m^3/ha
Annual growth	4.2 m^3/ha
Annual Use (volume harvested)	3.5 m^3/ha
Deadwood	
Altitude	300–500 m a.s.l.
Ownership	Local communities
Geology and substrate	Limestone and marls
Protected area (total)	123 ha special forest reserve (two reserves of 76 and 47 ha) 245 ha 'ageing' islands (85 ha set-asides, 160 ha ageing islands sensu stricto). SAC 11 465.5 ha SPA 11 528.2 ha
169 ha Special habitat protection	
Nature protection area (Natura 2000)	410 ha
Protective function	NA

tion of Auberive's municipalities for forest management). SIGFRA was the first association of its kind and is still the biggest one in France today.

The climate is semi-continental, with the average annual precipitation amounting to 900 mm, evenly throughout the year. The elevation ranges from 300 to 500 m a.s.l. Soils types are very diverse: the substrate is made of limestone and marls, but soil types vary considerably with topography, from plateaux, where soils are relatively superficial, to gullies and valleys that can sometimes be quite deep, where soils are deeper.

Historically, the forest was treated as coppice-with-standards until the 1930s. In 1960 and 1980, under the auspices of the 'Fonds Forestier National' (National Forest Fund), the forest was partially planted with conifers – mainly Norway spruce *(Picea abies),* but also silver fir *(Abies alba)* and Douglas fir *(Pseudotsuga menziesii);* currently, these species totalise an area of 700 ha. The rest of the forest is dominated by broadleaves (96 %), notably oaks (*Quercus robur* and *Q. petraea*) and beech *(Fagus sylvatica),* which altogether represent 78 % of the stands. The owners want to maintain tree species diversity, and notably the introduced conifers.

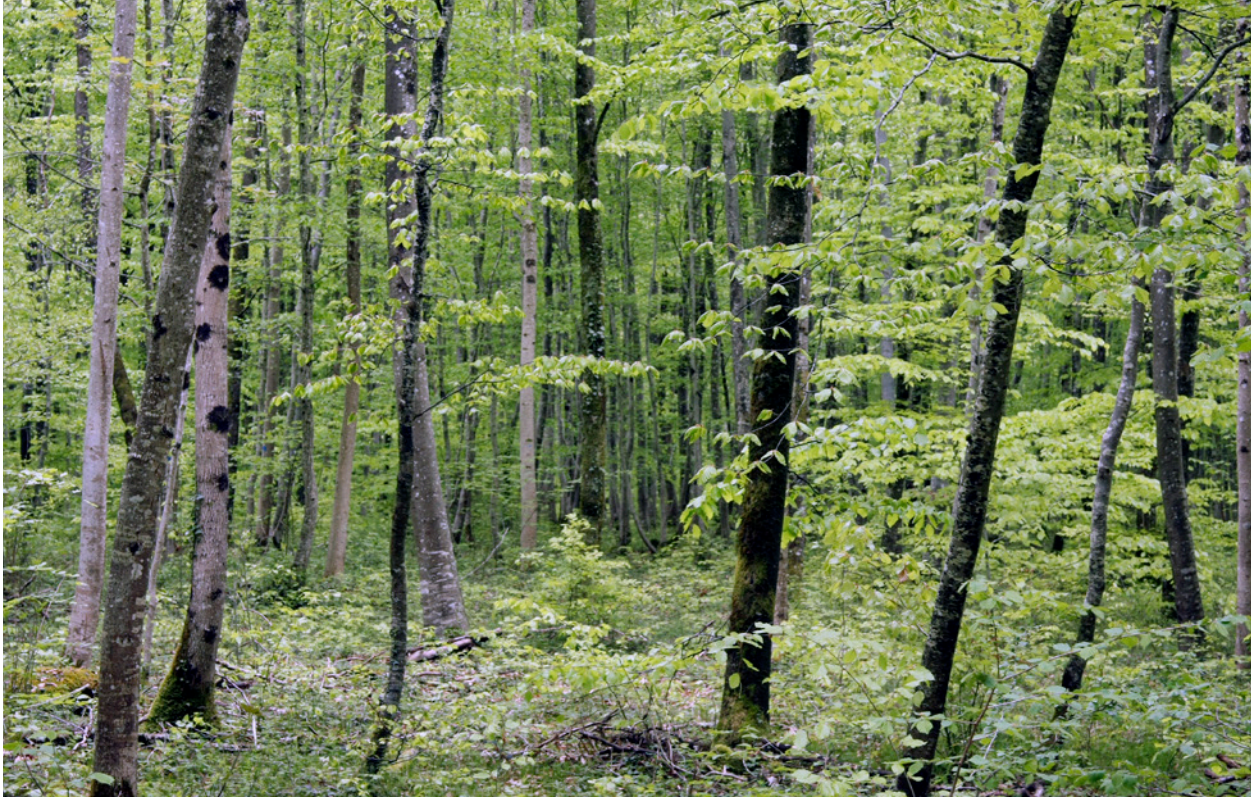


Fig. C1.2. Typical forest stand with small diameters and many different broadleaved species, such as hornbeam (*Carpinus betulus),* ash *(Fraxinus excelsior),* lime (*Tilia* spp.), oak (*Quercus* spp.), maple (*Acer* spp.), and beech *(Fagus sylvatica).*

Management

In the early 1990s, local inhabitants expressed their disapproval and negative opinions about the visible clear cuts. In addition to the aesthetic modification of the landscape, the local councillors advanced an economic argument against the harvesting of young trees with a high potential value. To solve the conflict, the ONF proposed a change in forest management. Consequently, over the last 20 years, forest management was gradually converted towards uneven-aged, continuous cover silviculture, with large and high-quality broadleaves as a main production target. Protection of ecosystems and landscapes was a joint target of the overall management scheme. More precisely, the aim is to favour the dominant indigenous tree species, namely beech, sessile oak *(Q. petraea),* pedunculate oak *(Q. robur),* hornbeam *(Carpinus betulus),* while maintaining secondary tree species that also have a production role – such as maples (*Acer* spp.), rowan *(Sorbus aucuparia),* ash *(Fraxinus excelsior),* lime (*Tilia* spp.). In total, there are at least 24 different tree species (fig. C1.2).

The uneven-aged management concept that has taken place for the last 20 years is based on four main principles:

1. Aiming towards and improving the quality, and therefore value, of individual trees individually, whatever their species, age, spatial distribution and dominance.
2. Ensuring perennial regeneration and renewal everywhere, and notably maintaining the mixture of tree species, ages and dimensions to increase the overall resilience (either ecological or economic).
3. Harvesting trees to optimise the economic return, defined as a compromise between diameter, quality and tree species; the higher the quality, the higher the harvesting diameter.
4. Ensuring optimised and regular revenues, while minimising costs of natural and artificial regeneration. This aim is a consequence of the application of the three previous principles.

The application of these general concepts maintains a continuous cover as well as a constant improvement of the overall value of the trees and

timber. The total volume harvested is equivalent to the annual increment; it is assumed that the balance between production and regeneration has been reached.

The evolution of the capital is monitored, at the forest scale, through a network of 1350 permanent plots installed in 1998 and distributed over approximately half of the surface area (managed as uneven-aged). Each plot is measured once every 10 years, and to date, ¾ of the plots have been measured twice, representing more than 3000 ha. Three inventories have been performed: the first took place in 1998–1999, the second in 2007–2009, and the third began in 2016 and is about to be completed. Annual management costs are 17 €/ha while the annual cost of the inventory (including plot set-up, measurement and data management) is estimated at 4.3 €/ha. The results presented here concern only the two first inventory campaigns.

Economy

The equilibrium capital in terms of basal area has been reached and accounts for 14 to 18 m²/ha. Mean stem density has slightly decreased from 205 stems/ha in 1998 to 191 stem/ha in 2008, while the total commercial volume has increased from 170 m³/ha in 1998 to 176 m³/ha in 2008. This is mainly due to an increase of 5 % in the proportion of large trees (diameter at breast height, dbh ≥47.5 cm). To date, a large majority of the harvesting has concerned coppice trees, which were considered over-abundant 20 years ago, and were detrimental for light environment (that should be diffuse and continuous). This annual harvest of coppice trees for firewood, pulpwood and industrial wood amounts to 3–5 m²/ha (35–60 m³/ha).

The annual increment in terms of basal area is 0.34 m²/ha, which corresponds to an annual increase of 4.2 m³/ha in terms of commercial volume. These values are comparable to those found in similar forest types in the area. Large trees (dbh ≥47.5 cm), mainly beech, account for the majority of the increment (fig. C 1.3). This confirms the importance of favouring large high-quality trees to optimise increment, notably in the view of increases in the proportion of the best qualities (A and B) over the last years. This indicates an improvement in terms of quantity and quality (and therefore overall capital value). Between 1998 and 2008, the consumption value – that corresponds to the income theoretically obtained if all the commercial trees would be harvested and sold – has increased by 11 %, to reach 6300 €/ha. In other words, on average, the trees growing today yield a better profit than the trees which grew ten years ago.

The future value is still below the consumption value, since the initial state of the forest – formerly coppice-with-standards with over-abundant coppice – was detrimental to the overall quality and quantity of the regeneration, thus negatively affecting the future value. However, the quality of the regeneration (initial stages) is slowly, but surely, increasing and represents a potential value of 5045 €/ha.

Between 1998 and 2008, the annual mean harvested volume was 3.5 m³/ha. Since 2003, the proportion of oaks and other broadleaves in the volume of lumber sold has consistently increased from almost 0 % in 2003 to 50 % of the income in 2015. The windstorms Lothar and Martin in 1999 have deeply affected the market for A and B-quality beech. C-quality wood is still valuable, however, and this has been the main production type over the last 10 years. Because of the collapse in beech market prices, the annual balance was sometimes negative. Harvesting targeted towards other tree species has allowed the commercial annual balance to be increased from –9 €/ha to +81 €/ha over the last six years.

Fig. C 1.3. Valuable trees bigger than 47.5 cm dbh harvested in stands formerly managed as coppice trees.

Ecology and biodiversity

In total, 1235 ha of the forest are designated as 'Zones Naturelles d'intérêt Ecologique, Floristique et Faunistique') (ZNIEFF; natural areas of ecological, flora and fauna interest), 410 ha are designated as Natura 2000 areas under the European Habitats Directive, and 130 ha are designated as special reserves (mainly calcareous grasslands and marshes). Conservation-oriented management towards these habitats consists of maintenance of these open areas (grasslands and marshes) as well as biodiversity-friendly forest measures. These measures are integrated in the uneven-aged forest management and include the preservation of a multi-layered forest cover, the mixture of tree species and the conservation of habitat trees, in accordance with production objectives.

The density of inventoried and preserved habitat trees is about 1.7 stems/ha with almost half of these dead trees and snags. In addition, trees bearing black woodpecker *(Dryocopus martius)* cavities or raptor nests are mapped and identified during tree designation operations.

A total of 245 ha have recently been designated as 'ageing' islands by the ONF and the local authorities. Ageing islands consist of small areas where there is strictly no harvesting (set-asides, amounting to 85 ha), and also areas where the rotation length is increased by 20 % (ageing islands sensu stricto, amounting to 160 ha).

Finally, the forest is known as a regular nesting site for black stork *(Ciconia nigra)* and provides habitats for other rare species, such as *Hericium coralloides, Cephalanthera rubra*, *Cypripedium calceolus,* and *Lobaria pulmonaria* (fig. C 1.4).

Social and societal aspects

The forest is accessible to the public with several walking, mountain bike and horse trails. However, the frequency of visitors remains relatively low, since the population density of the area is very low

Fig. C 1.4. Many different species with high demands are found in the forest of Auberive: *Ciconia nigra* (a), *Hericium coralloides* (b), *Cephalanthera rubra* (c), *Cypripedium calceolus* (d) or *Lobaria pulmonaria* (e) (Photos: Jean-Jacques Boutteaux).

(4 inhabitants/km²). Social consideration is still quite important: it was originally the reason for the change in forest management. Because of the selective continuous cover clearings, forestry interventions have a very small visual impact and favour the acceptance of harvesting operations and cuttings. Such a cohabitation is necessary since wood production is the primary objective of the forest. Therefore, road and harvesting tracks are numerous, and care needs to be paid to ensure adequate information and notice of harvesting operations.

Resilience

Poles and small trees (dbh <22.5 cm) represent 61 % of the total stem density per hectare. This guarantees an optimal regeneration with a notable increase in the number of future coniferous stems (+82 %). Among this, the number of potential high-quality stems also increases (+2 %) which ensures the adaptation capacities of young trees to react to dedicated interventions. The decrease in the understory and coppice proportion was one of

Fig. C 1.5. Different demands in Auberive's forests. Hunting is a popular forest service, represented here by a red deer (a). Habitats for species nesting in tree cavities is gaining more and more attention within society (b) and scenic beautiful spots are popular among hikers and tourists (c). Excursions for foresters but also for the interested public are promoted in the area of Auberive (d) (Photos: Jean-Jacques Boutteaux).

the main objectives over the last two decades, and resulted in a decrease of 40 % of the stem density between 1998 and 2009. The remaining coppices now serve to adjust levels of diffuse light for young future trees. Therefore, coppice and understory trees are maintained at low, but constant, levels through targeted interventions: selective harvesting of coppice, targeting larger individual trees that could be detrimental to the canopy development of standards and large trees. Such interventions allow the maintenance of diffuse light levels, and for the control of herbaceous and semi-herbaceous understory competitors, notably bramble (*Rubus* spp.). This balance between light levels and vegetation control aims at producing straight, branchless, high-quality boles.

Between 1998 and 2009, the density of 50 to 300 cm-high poles has increased by 29 %. These trees are particularly diverse in terms of species, which is reinforced by the management that favours other tree species at the expense of beech: the density of beech with height <1.5 m and height >3 m has decreased by 23 %. As a consequence, no artificial regeneration has occurred over the last 25 years; there has been no need for artificial regeneration, even after the windstorms of 1999.

Conclusion

In this forest, the capital turnover time is 38 years in terms of value and 41 years in terms of volume. This corresponds to the time needed to harvest and renew an equivalent value or standing volume at a given date. These figures show a reasonable management of the existing capital and its constant improvement, and means that the silvicultural system is economically and ecologically resilient; this is important in the face of forthcoming changes – notably climate change.

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Ebrach – Learning from nature: Integrative forest management

C2

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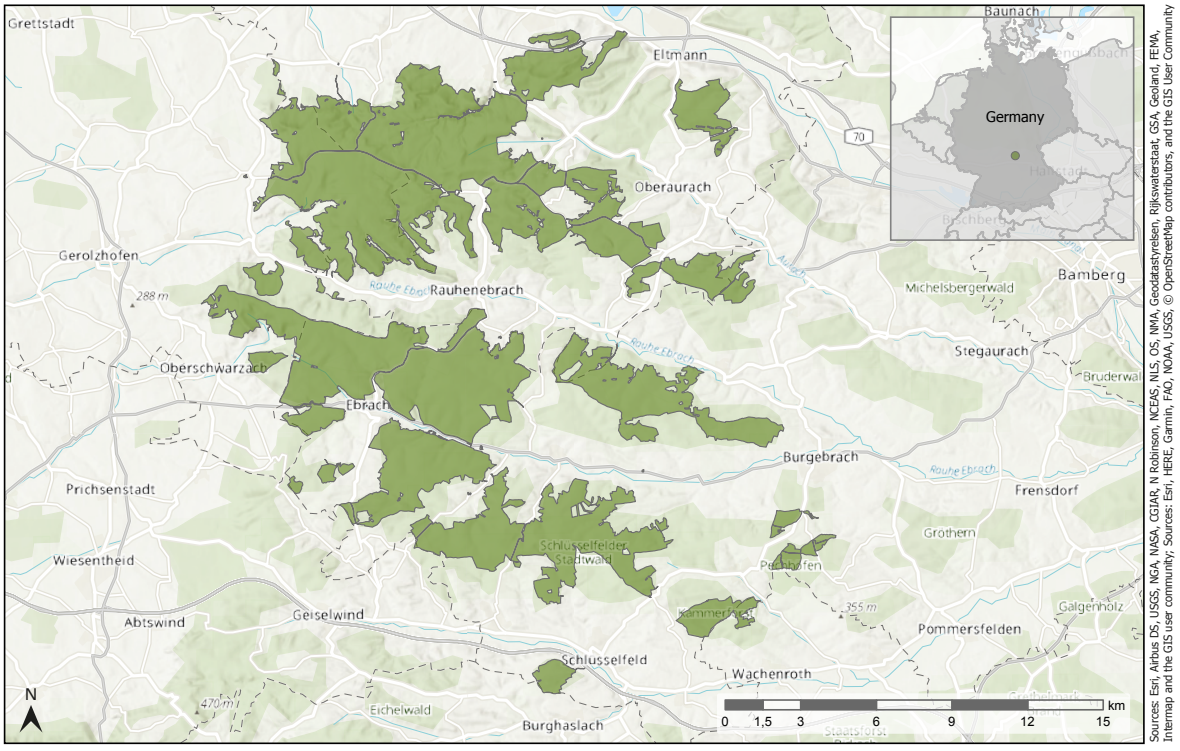
Since the reorganisation of the Bavarian forest administration in 2005, state forests have been managed by 41 regional state forest enterprises (Bayerische Staatsforsten, BaySF). The Ebrach State Forest Enterprise is made up of the state forests of the former forest districts Ebrach, Gerolzhofen, Eltmann, and Burgebrach. It manages an area of around 17 000 ha in the Steigerwald region, located in the Keuper uplands (formed in the mid-Triassic period) of Franconia between Würzburg and Nürnberg in north-western Bavaria. The State Forest Enterprise Ebrach is responsible for one of the most



< Fig. C2.1. The Keuper uplands as part of the southern German Scarplands rise abruptly from the Franconian plateau and form the gently undulating landscape of the Steigerwald region with its extensive beech forests (Photo: Martin Hertel, Bayerische Staatsforsten AöR).

Statement

"Reconciling biodiversity conservation and timber production."

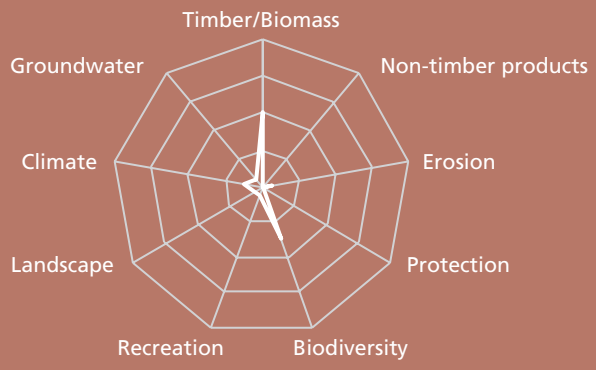


Table C2.1. General information on the forests of the State Forest Enterprise Ebrach.

Total forest area	16500 ha (1200 ha set-aside area; timber production on 15300 ha)
Main management types	Irregular group shelterwood, group and single-tree selection systems
Total volume	388 m³/ha (6400000 m³ in total)
Annual growth	10.6 m³/ha/a (168000 m³ in total)
Annual cutting rate	7.7m³/ha
Deadwood	23 m³/ha
Ownership	State forest
Climate	7.5 °C mean annual temperature, 850 mm mean annual precipitation
Geology	Mostly Keuper – gypsum and dolomite marls, clay and sandstones that were deposited during the Middle and Late Triassic epochs (about 220 million years ago)
Soils	Small scale mosaic of sandy, marly or clayey soils, mostly nutrient rich; 50 % of soils are largely impenetrable for fine roots, 75 % are sensitive to soil damage by forestry machines
Protected area	1200 ha set-aside area
Natura2000 area	SAC 11465.5 ha SPA 11528.2 ha

important beech *(Fagus sylvatica)* forests in Germany. The forests are composed of 75 % broadleaved species – beech ca. 44 %, oak (*Quercus* spp.) ca. 21 % – and 25 % coniferous species – Scots pine *(Pinus sylvestris)* being the main species ca. 13 % (fig. C2.2). The average growing stock is ca. 388 m³/ha with an annual growth rate of 168000 m³. The annual cutting rate amounts to approximately 120000 m³, of which 95000 m³ are sold as timber and 25000 m³ remain as lying deadwood in the forest. As can be seen from the difference between growth rate and cutting rate, it is planned to further increase the growing stock on the productive forest area. A system of permanent inventory plots (200 × 200 m) over the whole forest area provides accurate data as a basis for the 10-year forest management plans.

The overall management aim for the Ebrach state forests is to optimise the total value of all ecosystem services available rather than maximising a single service. Around 90 % of the broadleaved timber is marketed in the region to more than 25 sawmills, most of them family run businesses specialising in products from broadleaved species. Almost 20000 m³ of fuelwood sold to 2000 local commercial and private customers make Ebrach State Forest Enterprise one of the largest fuelwood producers in Germany. The enterprise provides employment for 60 forest employees and 12 local contractors and their staff. More than 600 springs and 241 ha of designated areas for drinking water production make the state forests a major provider of high-quality drinking water for the surrounding

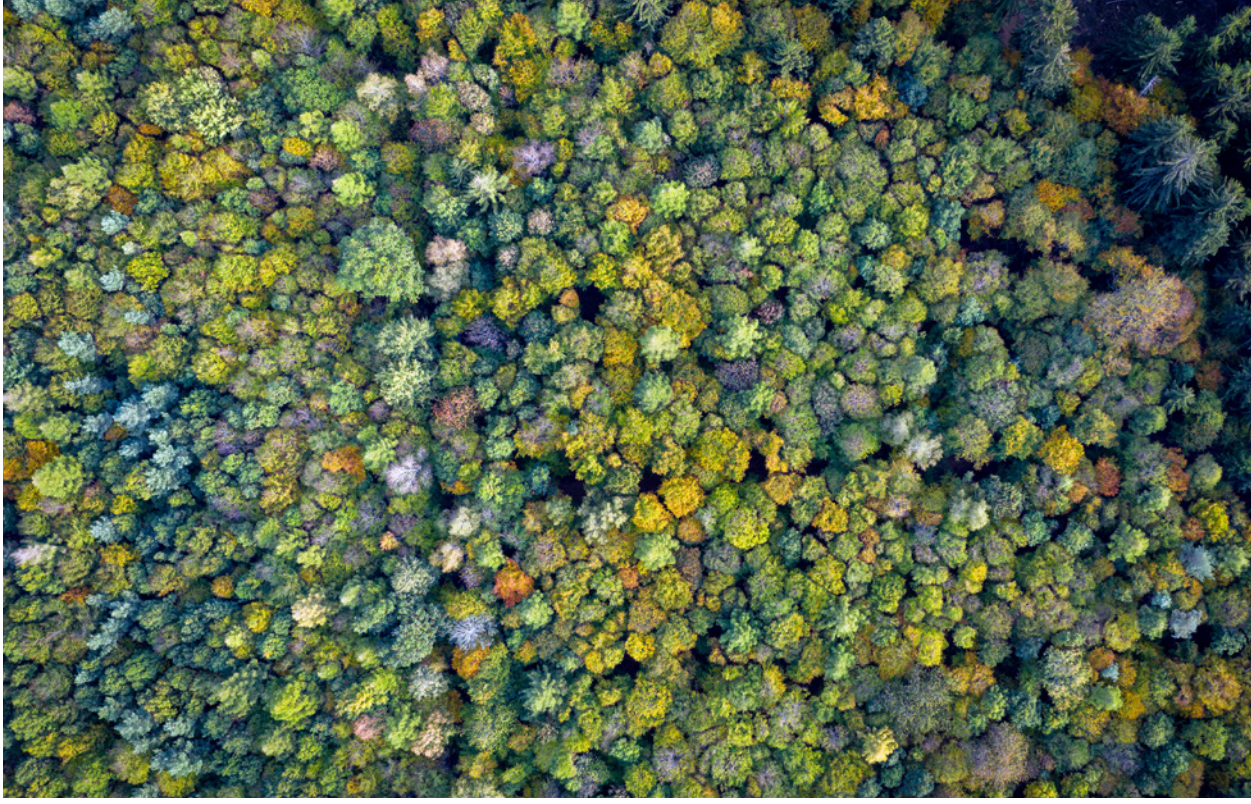


Fig. C2.2. The richness of tree species is characteristic of the diverse Keuper soils. Past forest management practices have changed forest composition over the centuries from oak to beech dominated forests (Photo: Martin Hertel, Bayerische Staatsforsten AöR).

communities. Around 336 km of designated hiking trails are available for the many visitors who come to the Steigerwald region for recreation. Additionally, 10 trekking camp sites are available for exclusive outdoor experiences. Between 60 and 70 hunters have temporary hunting permits and more than 1000 hunters attend the 40 driven hunts every year. Both groups make essential contributions to meet the target of 1000 roe deer *(Capreolus capreolus)* that are killed annually based on a 3-year management plan. On average, seven roe deer are killed on every 100 ha per year. About 30 % of the game meat – including 200–300 wild boar *(Sus scrofa)* – is marketed directly by the forest enterprise.

With a special emphasis on saproxylic organisms, biodiversity conservation is central to the local integrative forest management concept (fig. C2.3). The centrepiece of this concept is a carefully selected and cross-linked system of set-aside and minimal impact forest areas linking dispersed habitats (Mergner 2018; MacArthur and Wilson 1967). The management concept is often called the Trittsteinkonzept ('stepping stone' concept).

Forest history and cultural heritage

The forests of the northern Steigerwald region were part of the Frankish crownland after the Franks' defeat of the Thuringians. They belonged first to the Merovingian dynasty, and later to the Carolingian dynasty. The administration of the entire region was in the hands of counts residing in the town of Volkach. At the beginning of the eleventh century the prince bishops of Würzburg were granted the count's rights over most of the eastern Frankish territories. In the year 1023 the hunting privilege for the Steigerwald forests was granted to Prince Bishop Meginhard I by Emperor Henry II, whereas the eastern part of the northern Steigerwald region came under the rule of the archbishops of Bamberg. Several ruins of castles and other buildings in the forest are evidence of this historic development (e.g. the ruins of Zabelstein Castle, Scherenburg Castle, and St. Gangolf's Church). This had a tremendous influence on the forest management practices of the time: the foresters of the prince bishops in Würzburg aimed at preserving the original character of the broadleaved forests whereas

the foresters of the Bamberg realm were widely introducing Scots pine. From 1151 until secularisation in 1803, the forests directly around Ebrach belonged to the Cistercian monastery founded in 1127. Approximately 20 % of today's forested area was under agricultural use at that time. Several settlements were abandoned already in fourteenth century (so-called deserted sites) on the instruction from the Cistercian monks since timber production was more profitable than farming. During the seventeenth and eighteenth centuries the common silvicultural practice of 'coppice with standards' favoured tree species such as oaks *(Q. petraea)* and hornbeams *(Carpinus betulus).* In the second half of the seventeenth century, several glass kilns were established in the northern Steigerwald forests to make more efficient and direct use of the timber resources available. The crown and plate glass produced there was highly appreciated and was exported as far as Holland and England. The architect Balthasar Neumann used glass from Fabrikschleichach in the famous Würzburg Residence (a Baroque palace).

At the beginning of the nineteenth century, the forests of the Würzbug and Bamberg dioceses fell under the rule of the Kingdom of Bavaria. After that, the common practice of composition cutting (a special coppice with standards system dominated by oak and characterised by high growing stock) was converted to high forests dominated by broadleaves. The preconditions for beech dominance were created by new silvicultural practices where the canopy remained largely closed and also massive mast seeding occurred (e.g. in 1811, 1820, and 1822). As a consequence, from a misinterpretation of Karl Gayer's concept of mixed forests (1886), shelterwood cutting was introduced to establish mixed stands of beech, oak, hornbeam, Scots pine, Norway spruce *(Picea abies),* and larch *(Larix decidua)* from 1880 to 1913. After a ministerial assessment of the state of the forests in 1913 the introduction of group shelterwood cutting was ordered as the principal regeneration instrument

< Fig. C2.3. Approximately 500 saproxylic coleoptera species occur in the Steigerwald region, many of them indicators of near-natural forest conditions (e.g. *Triplax rufipes, Bolitophagus reticulatus, Mycetophagus quadripustulatus, Sinodendron cylindricum, Ampedus nigroflavus*) (Photos: Reinhard Weidlich).

with the aim to increase the share of conifers. This practice continued until the 1950s and caused oak regeneration to be disrupted. Beech as the main tree species decreased by almost 30 % of the original distribution in 1930. The amount of Norway spruce on the other hand, increased by more than 20 % in the newly established age classes. Fast growth in the early years after establishment resulted in generally low-quality timber. The hunting ideology during the Third Reich period (from 1933 to 1945) caused a sharp increase in the roe deer population that continued until the late twentieth century. As a consequence, natural regeneration dynamics ceased and forced clearcutting followed by re-planting with conifers became the common practice.

From the late 1940s until 1980, the annual cutting rate in the former forest district Ebrach was considerably higher than the Bavarian average of 6 to 6.5 m³/ha, e.g. from 1962 to 1971, approximately 9.5 m³/ha were harvested every year. The increased cutting rate was supposed to reduce the surplus stock of large and old beech stands that was stated in the forest management plan of 1962. A radical change of the silvicultural practices was introduced in 1973 by the district forest officer Dr. Georg Sperber: close-to-nature forestry, intensive reduction of the high roe deer populations, and fencing led to large-scale regeneration of broadleaved species. Intensive but careful treatment of the old beech stands is now represented in two-layered or irregularly structured stands. However, the planned increase of the growing stock was hampered by the windstorms Vivian and Wiebke in 1992. These storms resulted in approximately 150 000 m³ of downed timber. For this reason, the average growing stock of 330 m³/ha at the end of the twentieth century was comparatively low.

A special development characterises the forests around the village Fabrikschleichach. During WWII, the forests of the Steigerwald region had to deliver high amounts of timber to support the war economy. The annual cutting rate amounted to 15 m³/ha far exceeding sustainable levels. In contrast to his colleagues in the neighbouring forest districts, Moritz Pflaum, head of the former forest district Fabrikschleichach, did not accomplish this overcutting in the form of large-scale clearcuts but from intensive thinning and negative selection. This practice was more-or-less identical with the principles of modern elite tree concepts in broadleaved stands. As a consequence of early and intensive thinning, most trees have developed comparatively short trunks but large crowns; this reduces the risk of redheart (discolouration of the heartwood that reduces the value of the timber) in old beech trees considerably. The downside of this intensive management was the stark decrease of tree-related biodiversity. In contrast to the surrounding forests that did not experience such intensive management at that time, sensitive and little mobile fauna has disappeared, especially saproxylic insects.

Fig. C2.4. Historic maps from the eighteenth century illustrate the forest management practices of the Cistercian abbey of Ebrach with a strong focus on the production of large oaks (Source: Bavarian State Archive Würzburg).

Closer to nature: Aims and strategies

The main silvicultural aim in Ebrach is to preserve the beech-dominated character of the Steigerwald region and at the same time to maintain climate resilience of the forest ecosystems. Single-tree harvesting and natural regeneration are the basis to develop structurally diverse and uneven-aged forests. Securing and improving the habitat diversity for forest species, however, has led to rethinking the management principles of the close-to-nature silviculture that was the main strategy in Ebrach from 1973 (Bollmann 2011; Gossner *et al.* 2013). Thus, it becomes more and more important to manage the Ebrach forests as complex adaptive systems as suggested by Messier *et al.* (2013).

Aim 1: Preserving and maintaining the character of the beech-broadleaved forests of the Steigerwald
Strategy:
– No clearfelling
– Single-tree harvest
– Rejuvenation through natural regeneration of native tree species
– Introduction/enrichment of broadleaves and silver fir (planting/seeding) to pure conifer stands and pure beech regeneration
– Conservation of biodiversity by combining set-aside areas and minimal impact management (strict forest reserves, stepping stone habitats)
– Retention of deadwood and habitat trees

→ Work with nature, not against it!

Aim 2: Safeguarding public welfare
Strategy:
– Consequent adherence to the specifications laid out in Article 18 of the Bavarian Forest Law (BayWaldG): protective and recreative functions as well as biodiversity of the forest must be safeguarded and improved, interests of nature and landscape conservation as well as water protection must be considered in all forestry activities and measures, and special functions for public welfare must be provided
– Supporting research and education
– Acquiring funds to finance special functions for public welfare

→ Aim at highest overall benefit for society

Fig. C2.5. Remnants of old beech forests resulting from the changing silvicultural practices in the early nineteenth century can be seen in the strict forest reserve Kleinengelein. The trees reach up to 50 m in height and are around 240 years old. Regeneration of beech established around 1911 during the last shelterwood cut and form the present understorey. There are single relict trees from the previous coppice with standards practice with an age between 330 and 370 years (Photo: Daniel Kraus).

Aim 3: Economic efficiency
Strategy:
– Production and harvest of valuable timber within the framework of close-to-nature forestry
– Biological automation (e.g. reduction of tending effort)
– Consequent reduction of roe deer populations to reduce regeneration costs
– Avoiding timber products with low or negative profit margins
– Increase of income through non-timber forest products

→ Highest added value possible through minimal effort

Aim 4: Resilient and adaptive forest ecosystems in the context of climate change
Strategy:
– Vitality before timber quality
– Increase growing stock
– Increase water retention capacity of stands
– Maintain stable within-stand climate conditions
– Differentiate between forests that serve as sink and as storage
– Browsing reduction to support adaptation of natural regeneration to changing environmental conditions
– Favouring drought resistant tree species (native and to a lesser degree also non-native) (fig. C2.6)

→ Ecosystem services for future generations!

Fig. C2.6. A vision for climate-resilient future forests? Irregular mixed forests of beech *(Fagus sylvatica)* and oak *(Quercus petraea)* with groups of silver fir *(Abies alba)* and the wild service tree *(Sorbus torminalis)* in the northern Steigerwald region (Photos: Daniel Kraus).

Main products and other ecosystem services

The main aim of timber production is to harvest high-quality timber from broadleaves by selecting elite timber trees from a diameter between 20–30 m diameter at breast height (dbh). Competitors of the final elite trees are carefully selected for removal. Removal takes place early enough to enable the elite trees to maintain crown and stem diameter growth, and to reach target diameters rapidly. The final target diameters depend on the species and the final timber quality (table C2.2).

Table C2.2. Target diameters for different species.

	Good quality	Medium quality
Beech	70–80 cm dbh	50–70 cm dbh
Oak	80–100 cm dbh	60–80 cm dbh
Ash, maple, other broadleaves	70–90 cm dbh	50–70 cm dbh

Conifers reach the target diameter between 50–70 m dbh. However, for conifers, quality only plays a minor role (except for emergents of pine and larch with veneer quality from previous tree generations). Excellent quality timber of all tree species is usually marketed through auctions and submission sales (fig. C2.7). During the dimensioning phase mostly fuelwood and to a lesser degree industrial timber can be harvested.

Table C2.3. Typical timber assortments for beech.

High value sawnwood/veneer (A quality)	10 %
Regular sawnwood (B and C quality)	25 %
Industrial timber	5 %
Fuelwood	25 %
Deadwood	35 %

Besides the production of timber, there are several ecosystem services that are provided by designated forest areas (table C2.4).

Table C2.4. Overview of ecosystem services provided by designated forest areas.

Ecosystem Service	Area (ha)
Soil protection	3121.3
Water protection	5631.5
Recreation	4228.3
Climate protection	176.5
Drinking water production	241.2
Special habitat protection (forest)	170.1

Fig. C2.7. High-quality oaks are marketed mostly through submission sales. Veneer quality timber is sold at a price of 1000–3000 €/m³, timber for barrels at a price of 400–600 €/m³ mostly to French customers (Photo: Ulrich Mergner).

Economics

On average, around €6 million are generated by the forest enterprise per year of which 95 % (€5.7 million) come from timber sales. Income from hunting, especially from hunting permits and marketing of game meat, and other businesses contribute only 5 % to the total turnover. The annual costs amount to approximately €5 million of which 56 % (€2.8 million) are for own staff/personnel. On average, an annual profit of approximately €1 million is generated from forest management. Around 67 €/m³ is the average income from timber across all assortments (table C2.5).

Biodiversity concept

The management approach implemented in Ebrach can be described as an integrative approach which strives to ensure biodiversity conservation and timber production over the whole productive forest

Table C2.5. Breakdown of revenue and costs.

Turnover	€6.0 million		
		Timber sales	€5.7 million
		Hunting	€0.1 million
		Other	€0.2 million
Costs	€5.0 million		
		Personnel	€2.8 million
		Contractors	€1.8 million
		Material	€0.4 million
Profit	€1.0 million		

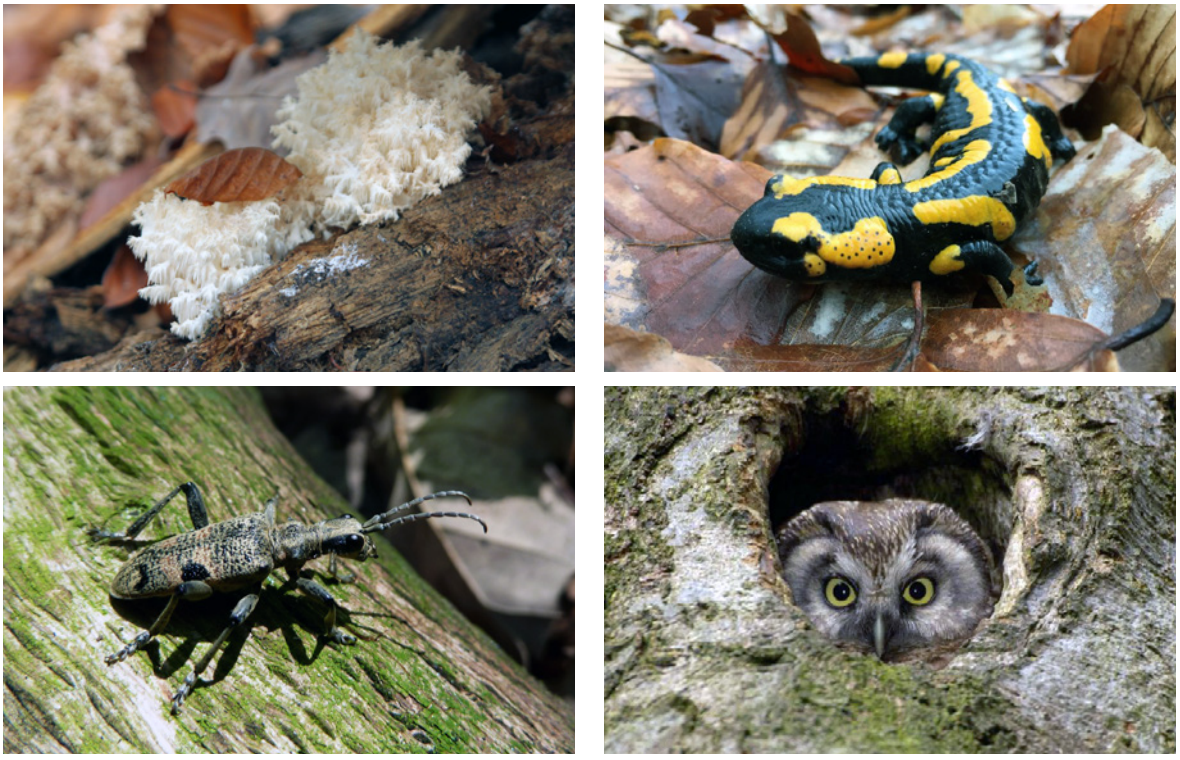


Fig. C2.8. A wide range of species from different groups are benefitting from the biodiversity concept (e.g. *Salamandra salamandra, Hericium coralloides, Rhagium mordax, Aegolius funereus*) (Photos: Daniel Kraus, Ellen Koller).

area (Mergner 2018; Kraus and Krumm 2013). Since most species dependent on old-growth elements and phases have become threatened, conservation of biodiversity in managed forest stands is mainly a question of retention of microhabitat structures (Larrieu *et al.* 2018; Kraus *et al.* 2016; Bauhus *et al.* 2009). To ensure diversity of forest dwelling species, structural diversity and the supply of living wood and deadwood as a resource is crucial (Lassauce *et al.* 2011; Jonsson *et al.* 2005).

A profound understanding of natural processes in forest ecosystems is seen as a prerequisite for implementing the Ebrach biodiversity concept. Altogether 1200 ha (representing 7 % of the productive timber area) are set-aside from forest management in the long term. These set-aside areas serve as the basis for safeguarding of biodiversity by securing survival and reproduction sites for sensitive and highly endangered species (fig. C2.8). In total, six strict reserves and more than 200 additional stepping stone habitats (smaller set-asides with longer habitat histories) are designated as donor areas for temporal colonisation of habitat structures such as habitat trees and deadwood in productive forests. Dispersal-limited and resource-limited species are thus able to spread and establish temporarily also in managed stands from these habitat patches, provided that they are evenly distributed over the entire forest area (Mergner 2018; Jonsson *et al.* 2005; Lassauce *et al.* 2011). Additionally, the strict forest reserves serve as learning sites on how relevant habitat structures develop over long growing cycles. Species assemblages found in these set-aside areas serve as qualitative target definitions of what should be reached on the overall forest area. The extensive research conducted in these living laboratories has produced the guidance for the management principles of the entire forest area.

Another important element of the enterprise's approach is minimal impact of management. This is mainly realised in old stands, or in younger stands with a high number of remnant old trees. This leads to a systematic build-up of habitat trees and deadwood. Currently, minimal impact of forest management activities affects 6400 ha. Positive selection of

Fig. C2.9. Approximately 160 m³/ha of deadwood can be found in the strict forest reserve Waldhaus (Photo: Daniel Kraus).

habitat trees already takes place in thinning phases to ensure that there are sufficient individuals with microhabitat potential in later stages. The selection of elite trees is set to be at 40/ha at most (in beech forest) to leave space for habitat trees to develop. In the case of admixtures with different harvest spans, even more elite trees per ha may be selected. The habitat trees are permanently marked (with a green wavy line) to ensure that these trees are retained. In total, the aim is to retain 155 000 habitat trees (10 trees/ha) in the productive forest area.

Large amounts of wood that is left to decay naturally are seen as crucial in Ebrach for biodiversity and nutrient sustainability (Stokland *et al.* 2012; Müller and Bütler 2010) (fig. C2.9). In later thinning phases and harvest, the Ebrach concept requires trees to be felled away from skidding tracks so that tree crowns remain in the stand. As a rule, the trunk is cut at the first strong branch and only the most valuable section of the stem is removed (fig. C2.10). This helps to reach the aim of increasing the amount of deadwood to 20 m³/ha in forests older than 100 years and 40 m³/ha in forests older than 140 years.

The deadwood concept is not only important for the conservation of forest dwelling species. The latest scientific evidence suggests that retention of wood in the forest is crucial to ensure sustainable nutrient cycling – mainly cations like potassium, calcium, phosphorus, and magnesium are stored in wood and may serve as long-term sources of these nutrients since they are released continuously by large decaying, logs, and are thus made available for plant growth. Additionally, deadwood stores large quantities of water while decaying, or in the form of humus later on. In the light of a changing climate and forecasted prolonged drought periods, this important attribute of deadwood may also be seen as a measure to secure the future of our forests. Furthermore, deadwood probably plays a much more vital role in the composition of forest floors and their functioning as carbon sinks through microbial activity, mostly fungi and bacteria, which is another important reason why it should remain in the forest.

Fig. C2.10. After the tree is felled the trunk is cut at the first strong branch and only the more valuable section is removed. The whole crown remains in the forest to increase large dimensioned deadwood (Photo: Ulrich Mergner).

Table C2.6. Costs of integrative management in Ebrach State Forest Enterprise.

Loss from timber production	Area [ha]	Volume [m³]	Value [€]
6 strict reserves	430	2500	125000
200 Set-asides	760	4500	225000
10 habitat trees/ha (a 50 m²)	780	4600	230000
	1970	11600	580000
Losses from foregone timber revenue		25000	500000
Total loss	1970	36600	1080000

Integrative management: at what cost?

The cost of integrative management can be determined from reduced revenue and additional expenditures. Currently there are 1200 ha set-aside areas and approximately 750 ha additionally that are not available for timber production because they are the location of habitat trees. This amounts to ca. 16500 m³ of timber annually that is not harvested and marketed. When assuming an average timber price of 50 €/m³ for the set-aside areas almost €600000 are foregone annually. Additionally, 25,000 m³ of deadwood from timber harvesting (at an average price of 20 €/m³) amounts to another €500000. Altogether, the cost from reduced revenues is about €1.1 million per year.

On the other hand, the deadwood enrichment strategy by only harvesting sawnwood (and to a minor degree industrial timber) and leaving the complete tree crowns on site seems economically efficient. The total profit from complete processing (sawnwood + industrial timber/fuelwood) is higher, but per m³ it is more profitable to focus on sawnwood only. The average performance of a chainsaw operator in old beech stands is ca. 3.0 m³/hr when processing only sawnwood from the stems. The performance decreases to ca. 2.6 m³/hr with harvesting intensity since the time to produce one cubic metre of timber increases from 20 min/m³ to almost 23 min/m³ when processing the complete tree crown. Thus, it becomes evident that the added value is higher when a more valuable product can be harvested in a shorter time because the working time needed to harvest a certain amount of timber can be reduced; this time could be used for other tasks.

A recent study conducted in Ebrach showed that the Total Economic Value (TEV) provided by all ecosystem services far exceeds the income from timber (Stößel 2020; see Box C1).

Conclusion

Ebrach State Forest Enterprise can serve as a good practice example for integrative forest management where biodiversity conservation, timber production, and many other ecosystem services are managed in an optimised way. From a conservation perspective, it is far more important to focus on strategic planning of conservation instruments rather than on the total protected area. Therefore, habitat requirements and thresholds of target species as representatives of the typical forest community must be considered for the development and cross-linking of conservation instruments. In this context, the current status of the applied silvicultural system should be taken into account since a diversity of silvicultural systems and strategies across the landscape is needed to increase diversity in structures, functions, and biota, and consequently also support a broad range of other ecosystem services.

Hence, the current challenge in Ebrach is to identify the thresholds at which productive functions can be maintained and, at the same time, biodiversity can be protected. To be efficiently assessed, the biodiversity-friendly forest management in Ebrach is constantly surveyed within research programmes (Schauer *et al.* 2018; Zytynska *et al.* 2018; Doerfler *et al.* 2017). Especially species groups which are linked to old-growth structures, deadwood and natural disturbances serve as excellent indicators of the conservation success of the Ebrach integrative management approach.

Considering the new scenarios of increasing pressure on wood resources in Europe because of increasing wood demand, it is crucial to ensure that quality and efficiency of biodiversity conservation in forest management is not diluted by new management goals. The Ebrach biodiversity concept strives to reconcile timber production and biodiversity conservation in an optimal way.

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Box C 1

Economic valuation of biodiversity, water, and climate protection services for the stepping stone concept: Bavarian State Forest Enterprise Ebrach

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In this research a first approximate economic valuation of a variety of forest ecosystems services was generated (biodiversity, water and climate protection). The goal was to increase awareness and integration of indirect use, existence, option, and bequest forest values (Cistulli 2002). The region of northern Franconia in southern Germany is especially affected by climate change – currently resulting in rising mean annual temperatures of up to 2 °C in comparison to the reference period (1970–1999) and significantly decreased precipitation (BDG 2020). In 2019, dying beech trees *(Fagus sylvatica)* were observed on more than 3000 ha of forest areas for the first time in the region.

The estimation of the Total Economic Value (TEV) refers to 1826 ha of set-aside beech and mixed beech forests in the area of the Bavarian State Forest Enterprise Ebrach. Although focusing on forest biodiversity and practicing integrative forest management, the Ebrach enterprise primarily generates income from timber and ancillary uses (e.g. game meat or hunting lease), whilst receiving only a rather small amount of compensation for set-aside areas. An adapted 'benefit transfer' method was used for evaluation of TEV, transferring over 30 selected environmental economic valuations of forest ecosystem services by national and international studies in the last two decades (see list of reports). Overall, the annual TEV was estimated at over €2.4 million, with 43 % provided by biodiversity and related services, 31 % by wood and ancillary use, 16 % by climate protection, and 10 % by water protection services using an adapted benefit transfer.

The values were generated for 1826 ha of set-aside areas, and willingness to pay was calculated with 4.5 potential user households per hectare or approximately 8200 households in total. In Figure 1, the proportions of each service are presented, followed by the estimated annual service value, the annual value per hectare (rounded down), and potential willingness to pay for services per household. Timber and ancillary use displays the potential

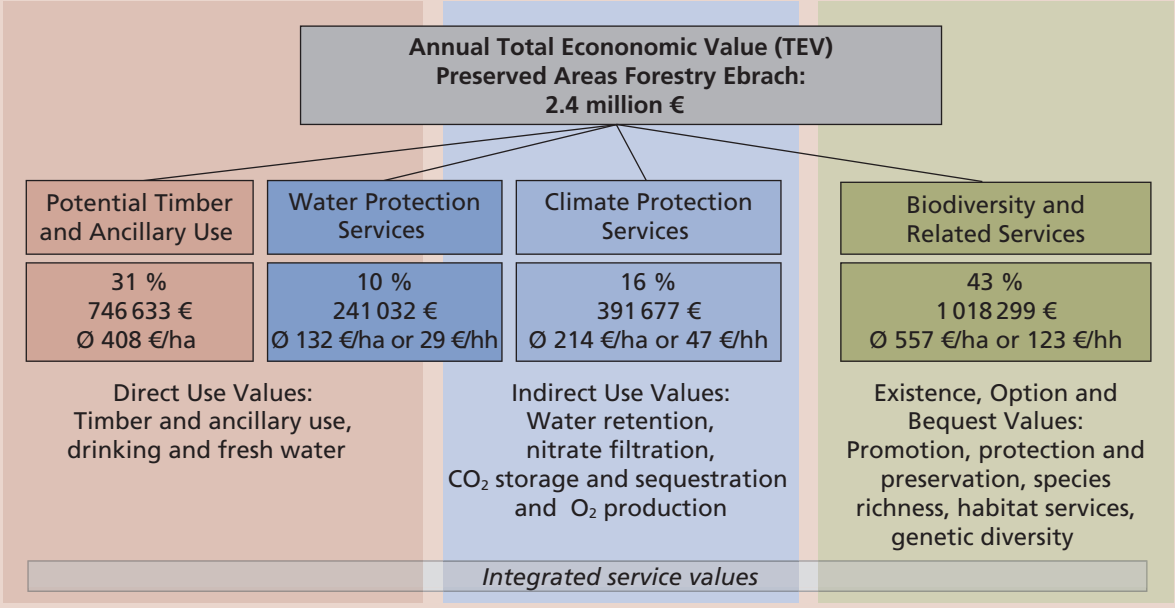

Fig. 1. Annual total economic value of set-aside areas with proportions of services referring to area (ha) or willingness to pay of potential user households (hh).

use value. The boxes also show the general categories of integrated service values included in the assessment. The categorisation was necessary to value the services; however, it should be noted that in practice the placement of the services in one category or another is not always clear-cut (Forest Europe 2016).

With 69 % of the value generated by biodiversity, water and climate protection services, the question arises of how the estimated TEV can be used to develop protection and support for these services, and also to seize future market and product opportunities associated with these services. Increasing amounts of salvage timber, decreasing wood prices, and rising societal awareness for environmental changes in forests are increasing the pressure on forest enterprises. From a local perspective further cooperation between stakeholders and effective financial support for sustainable resource use is needed to preserve and develop estimated values. The listed values can function as a basis for negotiation of local contracts, certificates, and product development. Furthermore, following the concept of 'payment for ecosystem services', the valuation of forest ecosystem services can provide an opportunity to foster existing ecosystems and related services as well as generate new income through public–private cooperation – e.g. with local water management, agriculture, and other societal stakeholders, such as individuals or industry (Barredo *et al.* 2016; Engel 2016; FAO 2018).

In short, the 'benefit transfer' method collects values estimated for a particular service in one area, and then uses, adapts, and transfers those values to another area (Johnston *et al.* 2015). The criteria of ISO 14008:2019 (ISO 2019) were included in the study selection process to increase site comparability of the valuation studies used for the benefit transfer. The standard for monetary valuation of environmental impacts and related environmental aspects was used by defining guiding questions and minimum requirements regarding accuracy, completeness, consistency, credibility, relevance, and transparency. Local ecological similarity was integrated through criteria of relevance to at least match the biome of central European temperate forest. This adaption allowed the selection of studies reaching a minimum requirement in a threescore valuation procedure with 'weak', 'medium' and 'strong' compliance with certain criteria. The studies were identified through searching scientific online platforms and existing literature lists (e.g. Müller *et al.* 2019) for concept-related keywords. As most included studies either referred to annual values for certain areas or potential users, local demographic data in the form of a potential user base including tourists was created to aggregate willingness to pay. The research collected the values of the spectra listed in Figure 1 and created arithmetic means. In practice, an additive approach of values of different services would probably further increase the values of, and willingness to pay for, biodiversity, water, and climate protection services. Although the 'benefit transfer' method is still in development regarding scientific requirements, it has been used to calculate environmental values in the past decade (Johnston *et al.* 2015).

The TEV presented here can be interpreted as a draft of the values of forest ecosystem services and as orientation for future local research, possible cooperation between different stakeholders of forest ecosystem services, and compensation approaches to secure the services (Müller *et al.* 2019). The aggregated economic value of forest ecosystem services must always be one valuation amongst others, and must not be used as a justification to maximise singular services in limited areas at the expense of other services.

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Fig. 2. Values of non-timber forest products play an important role for example in southern Europe. The picture shows a forest area in southern Catalunya (Spain), owned by a monastery allowing for local people to obtain licenses for mushroom picking (Photo: Simon Egli).

Rold Skov – Active measures aiming at integrating nature conservation elements in a multifunctional forest

C3

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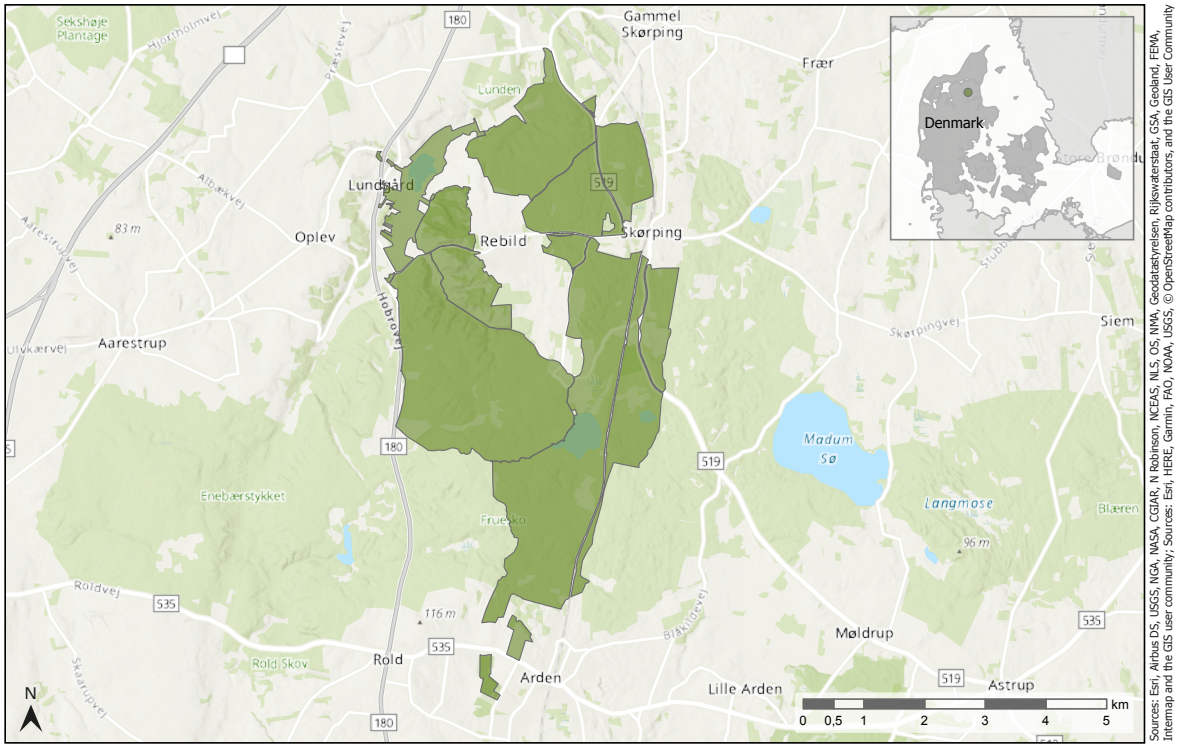
Introduction to the Nature Agency – Himmerland and Rold Skov

The Nature Agency Himmerland is one of the 16 local departments of the Danish Nature Agency (Danish: Naturstyrelsen) and manages a total of 5700 ha of forest and open nature areas. Approximately half is open nature and half is forest.

Rold Skov (Rold Forest) is the largest forest complex in Denmark with a total area of more than 8000 ha. It is located in central Himmerland about 25 km south of the city of Aalborg. The state forest



< Fig. C3.1. Natural regeneration of spruce. The shallow gravel and sandy soils provide very good growth conditions for a variety of both European and Northwest American coniferous tree species (Photo: Karen Poulsen).

Statement

"The developments described for Rold Skov will continue for decades to come. The objective is to develop an ecologically and economically stable forest with a solid base of large old trees in all stands with continuity in forest ecosystem and forest cover and with a variety of recreational forest and nature experiences for the public."

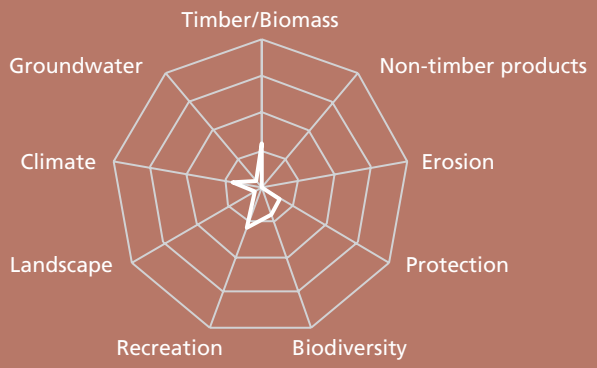


Table C3.1. General information on the forests of the State Forest Rold Skov.

Total state forest area	2300 ha (500 ha is open nature types and 400 ha set-aside forest area; timber production on 1400 ha)
Main management types	Irregular group shelterwood, group and single-tree selection systems
Total volume	230 m³/ha (568.000 m³ in total)
Annual growth	9.7 m³/ha/a (24 000 m³ in total)
Annual cutting rate	8.0 m³/ha
Deadwood	no inventory on forest level
Ownership	State forest
Climate	8.6 °C mean annual temperature, 790 mm mean annual precipitation
Soils	Gravel moraine sandy, well drained, and with a relatively low nutrient content. In the northern part calcareous subsoil is found close to the ground surface.
Protected area	600 ha forest set-aside including open nature types
Natura2000 area	The whole of Rold forest is Natura2000

area covers 2300 ha and is managed by the Danish Nature Agency. Three major private estates own the rest of the forest, the Nørrelund Estate to the west, the Lindenborg Estate on both sides of the state forest area, and the Villstrup Estate to the southeast. Of the 2300 ha which the Nature Agency manages, 1800 ha has forest cover. The following paper focuses on the state-owned part of Rold Skov.

Rold Skov is considered old forestland, which has 'always' been covered with forest. However, documents from 1826, when the state took over the area, state that only a third of the area was covered with forest/trees, most of which was thicket, including beech *(Fagus sylvatica)* thicket and poor beech stands (fig. C3.5), while the rest of the area was open landscape such as heathland and dry grassland. Local farmers had free-ranging livestock grazing the area.

Today, the forest is predominantly the result of the previous 200-year effort to rehabilitate the forest. However, until 2004 most of the forest had been replanted with exotic conifers including Norway spruce *(Picea abies)* and larch *(Larix x eurolepis).* Scots pine *(Pinus sylvestris),* which is the only conifer considered to be a natural part of the vegetation in Denmark, is not common in Rold Skov. Instead North-American conifers have been planted, including, Douglas fir *(Pseudotsuga menziesii),* Grand fir *(Abies grandis),* and Sitka spruce *(Picea sitchensis).* The first Douglas fir to be planted in Denmark was planted in 1849 and can still be found in the forest. Today, large-size Douglas fir timber is sold for special purposes at high prices (fig. C3.3).

The soils in the area are sandy and gravel moraine, well drained, and with a relatively low nutrient content, providing good growth condi-

Fig. C3.2a and b. Beech is common in Rold Skov, though on the northern limit of its European distribution. Beech contributes to two main objectives in the Rold Skov: (1) it is a stabilising element in coniferous dominated production forest, and (2) it constitutes the main species in forest set aside for biodiversity conservation (Photos: Naturstyrelsen).

tions for conifers. In 1998 the tree species distribution was 70 % conifer and 30 % broadleaved tree species. Forest management was very intensive, and these areas were utilised optimally for forest production including draining wet soils for further afforestation. Only very few areas (some meadows, mires, and small lakes) were left open without trees.

The majority of the old beech stands found in the forest in 1826 are still present in the forest today. Rold Skov contains the largest concentration of old (>200 years) beech stands in the state forest. This is one of the reasons why the forest has been designated a Natura 2000 area.

Water and chalk

The northern Rold Skov is dominated by the Lindenborg River, a stream fed by several springs. Unique habitats are associated with these springs and the calcareous soils on the edge of the river valley.

Rifts in the chalk enable very rapid, horizontal, underground water flow towards the steep slopes of the valley. Here the water pushes out near the foot of the steep slope as abundant springs, which are among the largest in Northern Europe.

The calcareous subsoil in the Rold Skov also explains the so-called sinkholes. When rainwater

Fig. C3.3. The first Douglas fir was planted in Denmark in 1849 and such old Douglas fir can still be found in the forest. The forest development type Douglas fir with spruce and beech is an import part of the forest. Today, large-size Douglas fir timber is sold for special purposes at high prices (Photo: Naturstyrelsen).

Fig. C3.4. In 2004, the state began to restore the drained raised bog west of the Great Økssø lake (see the clearing in the bottom of the picture a) from above. A mature stand Sitka spruce (26 ha) was cut down and a dense system of drainage ditches was blocked to retain the water a) from above and b) from the ground (Photos: Naturstyrelsen).

permeates the forest soil, it is acidified by humic acids. The acidified water seeps down through the rifts in the soil and dissolves the chalk. When the chalk is dissolved, holes are formed which may suddenly collapse. Holes of 4–5 m in diameter are common in the Nørreskov forest.

In 2004, the state began restoring the drained raised bog west of the Great Økssø lake. A large area of Sitka spruce was cut down and a dense system of drainage ditches was blocked to retain the water (fig. C3.4).

Fig. C3.5. Part of the very old beech forest was exposed to coppice and grazing more than 200 years ago. The most well-known is also known as the 'troll forest'. The forest is protected set aside forest and is part of northern large set-aside forest see the map figure C3.3 (Photo: Naturstyrelsen).

Biodiversity

Some of the old beech trees are multi-stemmed (fig. C3.5), crooked, and gnarled with cavities caused by cutting and grazing in earlier times. These provide numerous tree microhabitats for insects and fungi as well as for cavity nesters such as tits (Paridae), bats, and a large population of the rare stock dove *(Columba oenas).* The black woodpecker *(Dryocopus martius)* and the stock dove are mostly seen in old broadleaved forest. Other birds present in the forest, and listed in the annexes of the Birds Directive include red kite *(Milvus milvus),* kingfisher *(Alcedo atthis),* honey buzzard *(Pernis apivorus),* woodlark *(Lullula arborea),* and red-backed shrike *(Lanius collurio).*

Also, the old trees host a number of rare epiphytic mosses and lichens including the rare tree lungwort *(Lobaria pulmonaria)* (fig. C3.5). Especially in the centre of the forest (Fællesskov), the level of nutrient discharge from the air is low and there is a favourable environment for mosses and lichens. Fifteen species of lichens found in Rold Skov are classified on the Danish Red List as threatened. Mosses include buxbaumia moss *(Buxbaumia viridis),* leucobryum moss *(Leucobryum glaucum),* and fringed bogmoss *(Sphagnum fimbriatum),* which are listed in the annexes of the Habitats Directive.

Endangered plant species include two orchids: the lady's-slipper orchid *(Cypripedium calceolus),* which is only found at this location in Denmark, and the red helleborine *(Cephalanthera rubra),* is only known from two locations in Denmark

Fig. C3.6. In the centre of the forest (Fællesskov), the level of nutrient discharge from the air is low and there is a favourable environment for mosses and lichens. Fifteen species of lichens found in Rold Skov are classified on the Danish Red List as threatened. Here the rare tree lungwort *(Lobaria pulmonaria)* on beech (Photos: Naturstyrelsen).

(fig. C3.7). Both plants grow on the calcareous soils in the northern part of the forest (Nørreskov). Several rare fungi species are also present here. A total of 48 species of fungi found in Rold Skov are on the Danish Red List and considered as threatened. Most of these species depend on old broadleaved forest growing on calcareous soils or on deadwood for their habitat.

Out of the 17 Danish species of bats, eight are found in Rold Skov. The forest is attractive to bats because of the combination of watercourses and lakes in the forest (which provide good opportuni-

Fig. C3.7. Endangered plant species include two orchids: the lady's-slipper orchid *(Cypripedium calceolus)* (a), which is only found at this location in Denmark, and the red helleborine *(Cephalanthera rubra)* (b), which is only known from two locations in Denmark. Both plants grow on the calcareous soils in the northern part of the forest (Photos: Naturstyrelsen).

ties for food), and the hibernation sites in the Thingbæk limestone mines near the forest, as well as the numerous tree cavities. The bat species in Rold Skov include: serotines *(Eptesicus serotinus),* noctules *(Nyctalus noctula),* long-eared bats *(Plecotus auritus),* pond bats *(Myotis dasycneme),* Daubenton's bats *(M. daubentonii),* Natterer's bats *(M. nattereri),* Brandt's bats *(M. brandtii),* and pipistrelles *(Pipistrellus pygmaeus).*

Other mammals include one of the oldest races of Danish red deer *(Cervus elaphus).* The forests red deer population is estimated at 900 animals. Also, the otter *(Lutra lutra)* and pine marten *(Martes martes)* are found in Rold Skov.

Multipurpose and close-to-nature forestry

Since the 1990s, the multifunctional forest concept came increasingly into focus because of a new national forest law, the Rio Convention on the Conservation of Biodiversity (1992), and the subsequent introduction of the sustainability concept.

Close-to-nature forest management

The frequency of storms with severe impact on Danish forests have increased during the last 50 years. In 1967, 1982, 1999, 2005 and 2013 more than one mill. m³ of wood has fallen at each of these storms. The worst hurricane struck in 1999 (3.4 mill. m³ fell) and was a so-called once in a 100 years event. This event highlighted the need for a more robust and resilient forest development. Thus, the decision to implement close-to-nature forest management was seen as a long-term strategy towards achieving these aims. The decision was part of the first national forest programme (Skov- og Naturstyrelsen 2002). In 2005 an action plan was launched to apply close-to-nature forest management principles in all state forests. This was a radical change from previous state forest management. A transformation over the next 100 years was envisioned.

The management concept of the Nature Agency changed from a classical 'high forest, mono-species, and even-aged management system with clear felling to a close-to-nature forest management concept with no clear felling and characterised by more single tree and group management, incorporating and supporting natural regeneration and structural differentiation as well as more integration of biodiversity and outdoor recreation. For a more comprehensive description of the concept, see Larsen (2012).

Rold Skov was hit by another storm in 2005. It flattened 120 ha of spruce stands and damaged a further 340 ha in the state forest part of the forest. This again highlighted the vulnerability of the uniform stands to wind throw and potentially other calamities. It was decided to turn this calamity for wood production into a positive beginning for the new forest management regime.

A new management plan was made for the forest. Open nature types were restored on substantial parts of the cleared forestland. Furthermore, new management targets were defined for the forested area, laying out new forest development types (FDT) based on local growth conditions and soil mapping. In accordance with the management plan, forest areas have been converted from spruce to broadleaved tree species, to increase the coverage of broadleaved tree species; in particular, beech was planted in cleared patches. In addition, the area of open habitat has increased and contribute to more diverse habitats in the forest including areas with more light and transition zones between open and closed forest. Figure 3.8. shows the change in area distribution over the last 30 years.

In Rold Skov, where the beech is naturally present and conifers grow and regenerate profusely, the FDTs are mainly targeted at beech mixed with broadleaved tree species (on the better soils) or beech mixed with conifers to a greater or lesser extend (on more sandy soils). The beech generally has a stabilising function while the conifers constitute the primary forest production. Table C3.2 provides an overview of the FDTs used. The title of the FDT indicate the main species mix, though more tree species are included in all FDTs. An important feature of the Danish concept is the integration of FDTs with nature conservation as the primary objective. FDT 91, 92, 93, and 94 all focus on nature conservation and they are an integral part of the forest matrix. Coppice and forest with grazing also include an element of preserving cultural and historic management methods. Figure C3.9 shows the distribution of the FDT in Rold Skov.

Table C3.2. Forest Development Types (FDT) in the Danish State forests.

FDT No.	Forest type	FDT No.	Forest type
11	Beech *(Fagus sylvatica)*	52	Sitka spruce *(Picea sitchensis)* and pine (*Pinus sylvestris* and *P. contorta*) with broadleaved trees
12	Beech with ash *(Fraxinus excelsior)* and sycamore *(Acer pseudoplatanus)*	61	Douglas fir, Norway spruce *(Picea abies)* and beech
13	Beech with Douglas fir *(Pseudotsuga menziesii)* and larch *(Larix x eurolepis)*	71	Silver fir *(Abies alba)* and beech
14	Beech with spruce (*Picea* spp.)	81	Scots pine, birch and Norway spruce
21	Oak *(Quercus robur)* with ash and hornbeam *(Carpinus betulus)*	82	Mountain pine *(Pinus mugo)*
22	Oak with lime *(Tilia cordata)* and beech	91	Coppice
23	Oak with Scots pine and larch	92	Forest with grazing
31	Ash and alder *(Alnus glutinosa)*	93	Forest meadow
41	Birch *(Betula pendula, B. pubescens)* with Scots pine *(Pinus sylvestris)* and spruce	94	Set-aside forest – strict reserve
51	Spruce with beech and sycamore		

Note: FDTs no. 92, 93 and 94, are all forest development types set aside for nature conservation.

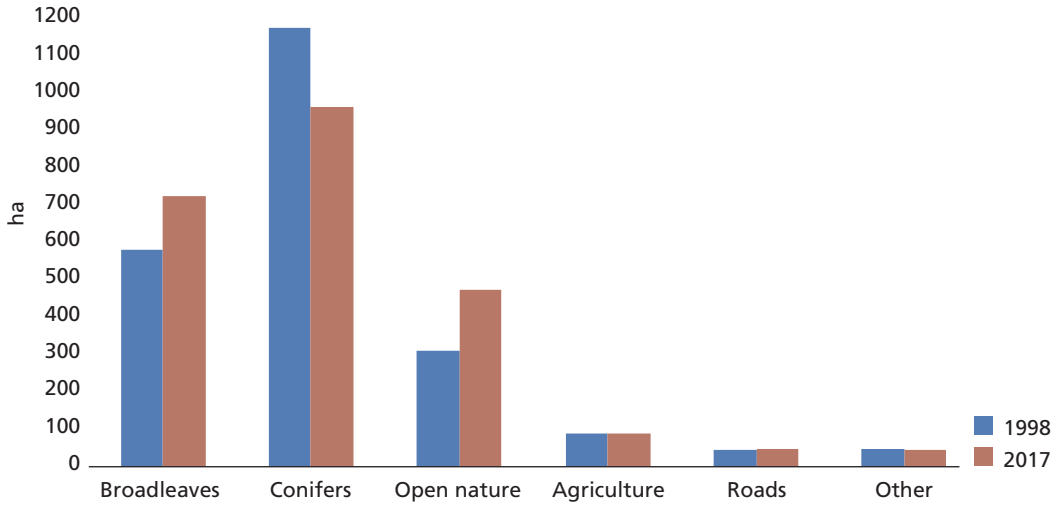


Fig. C3.8. Changed area distribution (ha) from 1998 to 2017.

Activities integrating nature conservation element over the past 15 to 20 years

Integrating nature conservation elements in the production forest matrix

- In 2015, the area with domestic broadleaved tree species as main tree species had increased by 25 % and the area of conifers as the main tree species had decreased by 18 %.
- An increase in variation of mixed stands has taken place. Either with two or more tree species or two or more forest layers by: (1) planting under an older canopy, (2) group plantings, and (3) by natural regeneration.
- Retention of high stumps, single dead trees and scattered wind felled trees in the forest matrix, to increase the amount of deadwood.
- Retention of LifeTrees (habitat trees) and veteran trees in all stands to increase long-lived and large trees, natural tree death, and decay. A minimum of five trees per hectare are retained over time.

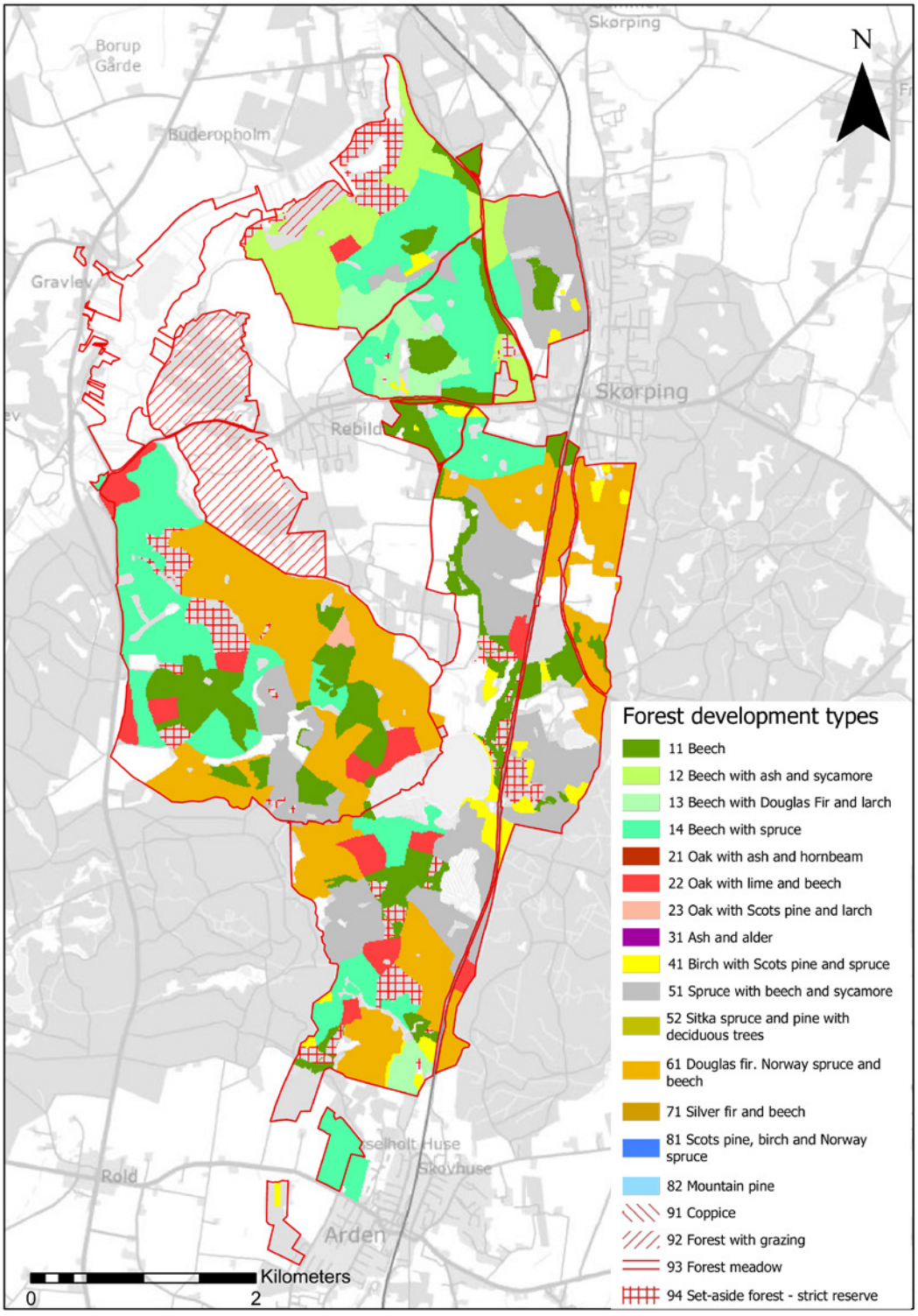


Fig. C3.9. Map of the planned forest development types in Rold Skov. See table C3.2 for an explanation of the numbers on the FDTs used in the legend of the map.

- Trees with woodpecker holes or nests made by birds of prey are painted with a big F for bird tree (Danish: fugletræ) to prevent the trees being felled by accident.
- Uncommon or rarer tree species are retained to increase variation and secure microhabitats for species living on these trees: willow species (*Salix* spp.), aspen *(Populus tremula),* oak *(Q. robur),* Norway maple *(Acer platanoides),* mountain ash *(Sorbus aucuparia)* and crab apple *(Malus sylvestris),* etc.

Integration of set-aside areas for new habitats in the production forest matrix

- 50 new small lakes and ponds have been established
- A large number of draining ditches have been closed to restore the natural hydrology.
- The total area of open areas in the forest including inner forest edges and transition zones have increased from 300 ha to 470 ha. This area is mainly meadows and restored mires.
- 404 ha of forest area have been set aside for nature conservation (strict protection) mainly divided in two large areas (22 % of the forest cover). Selection is based on the presence of threatened red list species and old beech forest patches.
- More than 180 prehistoric sites such as burial mounds, burial chambers, rocks, and dykes are managed as small open areas in the forest and contribute to a varied forest structure.

Set-aside forest for nature conservation

Segregated forest areas for nature conservation is an integral part of the multipurpose forest in the state forests. Since 1995 107 ha of old-growth forest has been set aside for nature conservation in the state forest of Rold Skov and mainly consist of smaller old beech stands spread all over the forest (6 % of the forest cover). Selection of areas was part of the first national effort for forest biodiversity conservation and linked to the Danish adoption of the UN Convention of Biodiversity agreed in Rio 1992.

In 2016, a further 297 ha was set aside in two major areas, Nørreskov and Fællesskov. Nørreskov to the north is predominantly an old beech forest on calcareous soils. Very rare species of fungi and orchids are found here and are associated with these soils (see Biodiversity section). Also, sixteen rare species living on deadwood are found in these two forest areas as well as rare insects associated with open forest meadows (Buchwald 2018).

The new set-aside areas bring the total forest area for nature conservation up to 380 ha, equal to 22 % of the forest cover. This was part of a government decision called the 'Nature Package'. See details in Box B3. The newly selected areas for conservation will undergo forest restoration. Measures include restoration of previously drained water systems; artificially promoting microhabitats on trees and increasing the amount of deadwood. Harvest of trees will take place with the aim of, reducing or even eradicating non-native tree species and may include clear felling promoting open areas for natural succession. These actions will increase the structural variation in the forest.

Parts of the forests set aside for nature conservation are already open habitats (e.g. forest meadows and wet habitats). Some of these open areas (including some of the areas to be clear felled) are to remain open as they host rare species and play an important role creating transition zones between the closed shaded forest and open sunny habitat. To prevent the transition of open habitats into forest, some of these areas are grazed with domestic animals e.g. cattle and horses. Restoration of natural water regimes will increase the area of shallow wet soils and is another strategy to prevent open habitats from growing into forest. Figure C3.10 shows a map of the selected areas to be set aside and their distribution of forest cover and open habitat.

The new set-aside areas cover a total area of 380 ha. The areas include patches of previously set-aside forest already set aside in 1995 as part of the first national strategy to set a side forest for biodiversity: Untouched forest (60.4 ha), forest with grazing (21.6 ha) and 0.4 ha of coppice. The new set-aside areas add 257 ha forest, 15.9 ha protected open habitat covers, and other open areas cover 24.7 ha. The forest area is mainly composed of beech (110.3 ha), oak (42.3 ha), Norway spruce (47 ha), and non-native species (mainly Douglas fir, grand fir, and Sitka spruce) (36.8 ha). The protected open habitat consists of bogs (5.9 ha), meadows (6.4 ha), semi-natural grasslands (2.5 ha), and lakes (and other water) (1.1 ha). Other open areas consist of grassland (14.9 ha), forest roads (7.5 ha), agriculture (0.2 ha), and unplanted areas (2.1 ha).

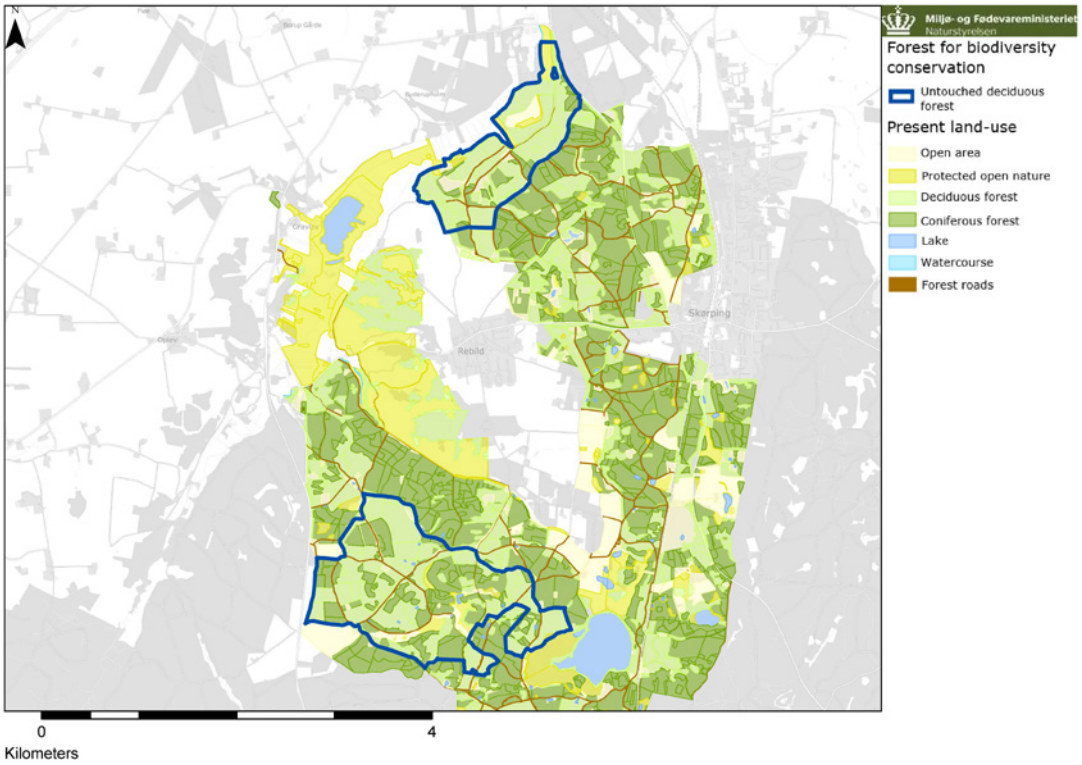


Fig. C3.10. Present land use in the new set-aside areas (marked by the dark blue line). Open areas are divided into: (i) protected natural areas and (ii) other open areas.

Outdoor recreation and tourism

Rold Skov attracts visitors all year round for outdoor recreation. Hiking and running is possible on 60 km of marked routes, though not restricted to the tracks. Access is open all over the publicly owned forest. Other rules apply in the privately owned part of Rold Skov. Horses and dogs are also welcome in the forest. Horse riding is unrestricted in the northern part of the forest and restricted to marked bridleways in the southern part. In general, dogs must be kept on a leash in the forest. The two off-leash dog parks are very popular among dog owners. The undulating terrain is very popular with mountain bike enthusiasts. Since 2004 one of Denmark's most comprehensive networks of mountain bike routes has been developed here. There are now three routes including Denmark's longest downhill track. The tracks are established and maintained in close collaboration with volunteers from the local mountain bike club. The recreational opportunities do not only attract locals, but also visitors from Aalborg, which is the third largest city in Denmark and beyond. There are varied options for accommodation for visitors, including hostels, 'bed and breakfasts', and hotels in the area and these provide easy access to the forest. Some of these specialise in sports and active holydays and arrange tours and renting out of mountain bikes, etc.

Conclusion

Site-adapted silviculture with multispecies and multilayer forest provide the basis for dynamic forest development and diversifying the risks from climate change and calamities. Thus, ensuring continuous forest growth even when calamities occur. Integration of segregated set-aside forest for biodiversity in the forest matrix is part of multifunctional strategy. The forest management aims have changed over time according to the changing needs of society – from production of timber, to

Fig. C3.11. Rold Skov has one of Denmark's most comprehensive networks of mountain bike routes (Photo: Mads Krabbe).

multifunctional forest services, to set-aside for biodiversity or carbon storage. Thus, it is vital for the forest management applied to be able to adjust to changing circumstances such as climate change and changing objectives required by society. This also ensures more options for future generations as they may have other priorities for the forest.

Over the last 25 years, the management of the state-owned part of Rold Skov has worked intensely to develop the forest away from the intensive production that had been practiced during the previous 150 years, towards a stable forest with a high level of integration of biodiversity and outdoor recreation, though still with a high annual growth and thus high carbon sequestration. About 22 % of the forest will have biodiversity as the primary objective, while the rest of the forest will develop further under close-to-nature forest management, thus integrating numerous small key habitats and single elements with high value for biodiversity within the forest matrix. As a whole, the forest will promote multiple services, including timber production, biodiversity, cultural heritage, landscape, protection of groundwater sources, and also, the latest very highly prioritised objective, to store carbon in the forest.

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Box C2

Forest set-aside for biodiversity conservation – the Danish Nature Package and beyond

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In 2016, the Danish government launched the 'Nature Package' (MFVM 2016). A significant element in the package was a decision to increase biodiversity in Danish forests, with the aim of improving the conditions for a number of animal, plant, and fungi species. The government thus made an agreement to set aside 13 300 ha of state forest. With this agreement, the total areal of forest with the aim of conserving biodiversity on state forest areas increased to 22 300 ha or approximately 20 % of the state forest area.

The specific allocation of forest areas to be set aside resulted in the selection of 45 state forests or forest sites for biodiversity conservation. An imported selection criterion was the selection of large connected areas, in contrast to small and scattered 'hot spots'. Thus, the newly selected forests include not only high value forest for biodiversity, but also younger stands planted within the last decades, stands of exotic tree species, as well as open habitat types such as forest meadows and swamps as natural elements in the forest. These open biotopes, such as meadows and small wetlands, benefit a diversity of species not found in the closed forest.

Selection of sites was carried out based on scientific analyses including a national evaluation of the status and preferences of threatened species and data on their presence in the state forests and nationally (Buchwald 2018).

'Untouched' forest is here defined as forest with no forestry activity, meaning no commercial felling of trees, so as, to become 'minimum intervention' reserves. The selected sites will after a restoration period be left to develop naturally. Grazing and other nature restoration activities may be applied for the benefit of biodiversity. In addition, management activities may be applied for the benefit of outdoor recreation as well as for preservation of pre-historic sites. Sold wood from the restoration period partly finances the effort (changed in 2020 – see below).

An up to 10-year nature restoration period is applied in the broadleaved forest region, and up to 50 years in the conifer plantation region. Restoration activities will thus end in 2026 in broadleaved forests and in 2066 for the plantation forests. After the transition period minimum-intervention untouched forest applies. However, trees assessed to be a danger to forest visitors or assessed problematic in relation to pre-historic sites or biodiversity e.g. invasive alien species may be felled after 2026. Cut trees must be left in the forest as deadwood.

Most of the forest set aside for nature conservation has been planted within the last 200 years. This means these forests consist of mostly even-aged stands with one main tree species. The transition period makes it possible to prepare the forest with the aim of transforming even-aged stands to less homogeneous stands, reducing or even eradicating exotic tree species, promoting less common native tree species, and thus increasing the structural variation in the forest.

The other part of the effort under the Nature Package is the designation of 'other forest for biodiversity'. This forest is primarily broadleaved forests where the concern for biodiversity is combined with continuing, but reduced, forestry activity. A minimum of 15 habitat trees are left per hectare.

Table 1. Political 2016 area targets and final selection of Danish state forests for biodiversity conservation.

	Protection type	Forest region/type	Nature package area targets (ha)	Final selection (ha)
Nature package New selections	Untouched forest	Broadleaved forest	6 700	6 900
		Conifer plantation region	3 300	3 300
	Other forest for biodiversity	Primarily broadleaved forest	3 300	3 600
		Total	13 300	13 800

'Other forest for biodiversity' includes forest areas that benefit from some level of forestry activity e.g. old oak (*Quercus robur* and *Q. petraea*) forest in competition with beech *(Fagus sylvatica).*

Management guidelines have been developed to make sure management efforts across the country and over time is applied within the same framework for the benefit of biodiversity. For example, the guidelines provide instruction on how to fell trees in the transition period, and prioritise use of native European tree species rather than exotic tree species. The guidelines also include advice on management for specific biodiversity elements.

An important part of the package is the development of a transparent management plan for each forest with involvement of local stakeholder groups and public hearing of the proposed management plan. The process includes public forest walks. The plans include e.g. details on nature restoration and removal of exotic tree species.

Changing management conditions – a new political agreement

In 2019 a new Danish Government took office. At the same time, there was growing debate and criticism about the felling of trees for up to 50 years in the selected set-aside forests. Especially the option to cut some of the native tree species and sell them as part of the transition period has been criticised.

In June 2020 the new government launched a new political agreement changing some of the conditions stated in the Nature Package described above (MFVM 2020). Also, it was decided to set aside an additional 6000 ha of untouched forest for biodiversity conservation.

The new agreement includes; all commercial forestry stopping immediately in the sites planned for untouched forest and the transition period only allowing nature restoration activities to take place. Non-native tree species must be removed and invasive species combated in order to create space for native species. Open habitats and natural succession are promoted. Native trees are only to be felled for a specific conservation objective and the wood may not be sold but must instead increase the deadwood pool. Some trees must be 'veteranised', (veteranisation is the process whereby younger trees are deliberately damaged – e.g. by ringbarking) in order to promote standing deadwood. Only wood from non-native trees may be extracted and sold. This income is used for nature restoration including rewilding selected sites with large-scale fenced naturalistic all-year grazing. In Denmark almost all of the used broadleaved tree species are deemed native (except *Acer pseudoplatanus*) while all conifers are deemed non-native except Scots Pine *(Pinus sylvestris).*

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Kottenforst – The Regional Forest District Office Rhein-Sieg-Erft: forestry, nature conservation and recreation in urban areas

C 4

U. Schölmerich[1], K. Striepen[2]

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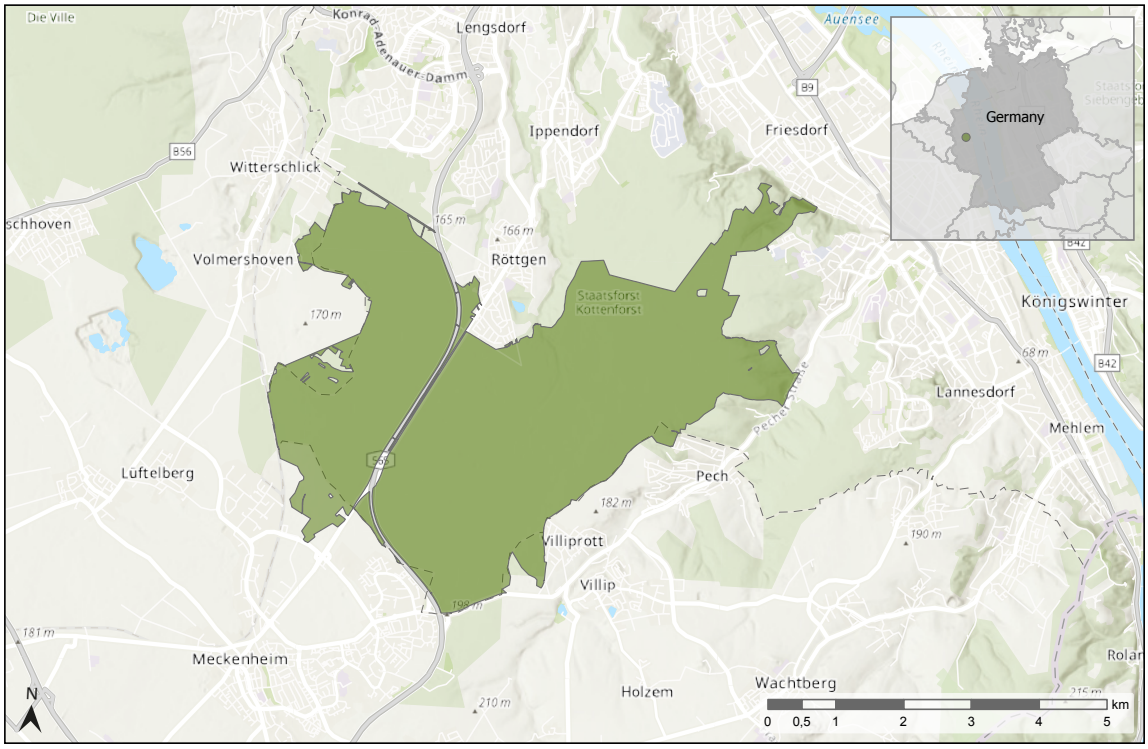
Aims of the enterprise

The aim of our forest management is to increase forest resilience against climate change impacts in order to guarantee all relevant forest ecosystem services for society in the long term. Recreation, nature conservation and wood production are always considered but may be given different priorities depending on the geographic location of the forest area.



< Fig. C4.1. The Kottenforst in the foreground and the city of Bonn with the high tower in the background shows the interface between forest, landscape and densely settled area in the 'Rhein-Sieg Erft' close to Bonn and Cologne (Photo: Klaus Striepen).

Statement

"Combining forestry, nature conservation and recreation in urban areas."

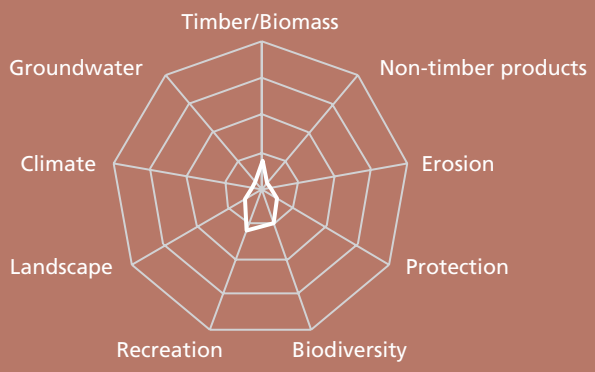


Table C4.1. Key figures: Regional Forest District Office Rhein-Sieg-Erft (state forest).

Forest community	Mixed oak – beech forest in both lowlands and low mountain ranges
Total forest area	Forested area 211 km²/non-wooded areas 20 km²
Main management types	94 % high forest; 1 % coppice with standards, 5 % without management
Total volume	206 m³ under bark/ha (4 339 459 m³ under bark)
Annual growth	7.6 m³ under bark/ha (159 692 m³ under bark)
Annual use	4 m³ under bark/ha (85 000 m³ under bark) according to the latest forest management plan
Altitude	100 to 400 a.s.l.
Ownership	State of North Rhine-Westphalia
Geology	Right bank of the Rhine: Rhenish Slate Mountains Left bank of the Rhine: Lower, Mid and High Rhine Terraces
Protected area (total)	144 km²
Nature protection area (Natura 2000)	106 km²
Protective function	Protection forests: against noise and emissions

Background

The Rhineland in the west of North Rhine-Westphalia is one of the most populous regions in Germany. The area of the Forest District Office includes the cities Cologne and Bonn as well as the counties 'Rhein-Sieg' and 'Rhein-Erft'. Altogether 2.4 million inhabitants live in cities and counties corresponding to about 40 people for each hectare of forest. The Forest District Office manages all forests owned by the state of North Rhine-Westphalia and offers services to both private and municipal forest owners. It implements tasks as set out by the forestry authority.

Two types of landscapes are typical for the region. In the west, the terraced landscape of the Rhine Valley lies at an altitude of between 100 and 200 m above sea level. It is characterised by varying, small-scale site conditions. The mild sub-Atlantic climate with an average annual temperature of about 10 °C displays slightly continental characteristics with low annual precipitation of 600 mm. Mixed oak (*Quercus* spp.) forests (fig. C4.2), lowland beech *(Fagus sylvatica)* forests and mixed coniferous and broadleaved forests with Norway spruce *(Picea abies)* and Douglas fir *(Pseudotsuga menziesii)* prevail depending on edaphic conditions. In the northwest there are also extensive areas that have been afforested following extensive brown coal mining.

East of the Rhine, the Rhenish slate mountains dominate. The altitude rises rapidly to 400 m. In weather exposed areas, annual precipitation can reach up to 1000 mm, while the average annual

Fig. C4.2. Mixed oak forest in the Rhein-Sieg-Erft Regional Forest District Office (Kottenforst near Bonn) (Photo: Klaus Striepen).

temperature drops to 8 °C. Soils are alkaline and nutrient poor and thus characterised by beech with a few sessile oaks *(Luzulo-Fagetum)* and extensive spruce forests.

In the Rhine Valley, human influence has shaped the landscape especially around metropolitan areas. The main challenges include not only the fragmentation of forests and their intensive use for recreation, but also the increasingly critical attitude of the urban population towards the wood use.

Portrait

Ownership structure

The total forest area in the forest district is 620 km². The highest proportion is private forest (43 %), followed by state forest (38 %), municipal forests (14 %), and federal forest (5 %). The high proportion of small private forest properties is characteristic of the ownership in the region, and 53 % of the forests are less than 20 ha. The private forest owners are organised into 16 Forest Management Associations, and in 2018 14 of these associations (representing about 4000 forest owners) were serviced by the foresters of the Rhein-Sieg-Erft Regional Forest District Office.

Table C4.2. Tree species distribution in the Rhein-Sieg-Erft Regional Forest District Office (state forest).

Tree species	ha
Oak *(Quercus robur, Q. petraea)*	4625.0
Beech *(Fagus sylvatica)*	4229.4
Poplar (*Populus* spp.)	634.0
Other broadleaves	4193.6
Norway spruce *(Picea abies)*	4400.4
Scots pine *(Pinus sylvestris)*	1725.7
Douglas fir *(Pseudotsuga menziesii)*	692.3
Larch *(Larix decidua)*	767.0

Forest history and cultural heritage

The oldest settlements in the Rhine Valley date back 7000 years to the Neolithic era, and the region has been continuously inhabited since Roman times. Throughout the centuries, people have worked and shaped the forests according to their needs. From the Middle Ages to the Napoleonic period, many woodlands were owned by the

church, such as the Kottenforst to the west of Bonn or the Königsforst on the outskirts of Cologne. Owing to the importance of forests for supplying timber to these cities and serving as the hunting grounds of the 'Electorate of Cologne', the forests have preserved their characteristics over the centuries and are characterised by a high level of habitat continuity. The special cultural and historical significance of this forest is documented in the redesign of the Kottenforst as a 'par force' (the ritualised hunting of game by the nobility) hunting area by Clemens August of Bavaria (Archbishop-Elector of Cologne) in the middle of the eighteenth century. The star-shaped network of forest roads is preserved to this day.

Nature conservation

About 62 % of the state forest managed by the Regional Forest District Office Rhein-Sieg-Erft is protected either as nature reserves or Natura 2000 areas, and thus the area has a crucial role in protecting biodiversity in the region. Protected areas of European significance include: (i) the old beech forests in the 'Siebengebirge' near Bonn, (ii) Atlantic heaths and oak forests on sand dunes in the 'Wahner Heide' and (iii) mixed oak forests in the 'Villewälder' between Cologne and Bonn. Management of protected forest areas is based on Natura 2000 management plans. This includes the promotion of natural forest communities and the safeguarding of old trees and deadwood in managed forest stands. To promote natural forest development, the harvesting and extraction of wood is completely banned in an area of 1862 ha (wilderness development areas, strict forest reserves). The oldest forest areas in which natural development processes are protected were already set aside in 1970.

The conservation of old trees and deadwood is also carried out outside protected areas to safeguard biological diversity. This is implemented by the Forest Service of North Rhine-Westphalia (Wald und Holz NRW) based on the Tree-Biotope-Concept 'Xylobius'. An aim of management is either a total deadwood volume of 40 m³/ha or 10 biotope or habitat trees/ha in all forest stands with near-natural tree species composition and an age of above 120 years (for oak forests above 140 years). Biotope wood is defined as trees with cavities or nests, as standing or lying deadwood, or trees displaying (potential) habitat features as well as ancient/monumental trees.

The Regional Forest District Office is the initiator and partner in large-scale nature conservation projects, such as: the European LIFE+ project 'Ville Forests – LIFE forests and waterworlds' and the Federal project 'Chance 7' funded by the Federal Programme for Biological Diversity.

Population and recreation

About 2.4 million people live in the Cologne/Bonn region, and forests represent important retreats from the rush and noise of the cities. The 'peace and quiet' of the forests has been shown to have a positive effect on people's health. Good access to forests makes them a prime location for recreational sports. The near-natural of these forests also offer visitors the chance to experience nature and thus counteract the alienation of the urban population from nature. The number of forest visitors is high, especially at weekends. However, their demands vary considerably. They range from the desire for an undisturbed nature experience to the demand for well-developed and accessible forests for family outings and sports activities. Such intensive leisure time use can lead to possible conflicts with conservation objectives, and in turn can lead to questions concerning the type and intensity of forest management. To address such conflicts, the Regional Forest District Office pursues various approaches, ranging from public relations work throughout the whole region to a wide range of forest related educational services and activities. The office cooperates with three information centres, namely 'Haus der Natur' in Bonn, 'Steinhaus' in Bergisch-Gladbach, and the exhibition of the 'Verschönerungsverein für das Siebengebirge' in Königswinter. New educational tools, so-called 'outdoor forest classrooms', or Marteloscopes, are also applied for public outreach.

Economy

The State Forest Enterprise in North Rhine-Westphalia derives about 70 % of its income from wood products (fig. C 4.3), and 30 % from non-wood products such as rentals, leasing, hunting, fishing, transfer revenues, eco-points, and the sale of seeds. The total revenue of the enterprise is in the magnitude of 20–50 €/ha. A number of ecosystem services can be only partially marketed in Germany. For example, owing to the free right of

Fig. C4.3. High-quality timber is marketed mainly through submission sales (i.e. the public announcement of timber for sale and the offers for the timber) (Photo: Klaus Striepen).

access to forests, visitors are not charged for recreation.

Integrated management often leads to good results. It can, however, cause lower revenues and additional costs as for example, by preserving old trees and leaving large amounts of deadwood in the forest. Additional costs can also arise when applying, for example, more expensive timber harvesting methods to support soil protection. One of the benefits of such approaches is that they help to improve public acceptance for forestry measures, in this timber extraction.

The Rhein-Sieg-Erft Forest District Office benefits from easy access to high-quality seed stands and seed plantations, which is a unique situation for North Rhine-Westphalia. The favourable location also makes the sale of firewood to the end consumer an important source of income.

The proportion of spruce in the state forest will decline drastically in future as a consequence of the predicted increase in the frequency and severity of storms, heatwaves, drought, and bark beetle infestations. Such developments will have negative effects on income, as coniferous wood currently contributes considerably more to the overall revenue as compared to its area share. This is due to a generally low prices for hardwood and the high proportion of non-marketable assortments.

Example Kottenforst near Bonn – Finding the balance

In forests close to cities, wood production, nature conservation and recreation need to be adequately considered. Each forest area poses its own challenges, making it necessary to apply tailored solutions. This is illustrated by an example from the Kottenforst forest area near Bonn. The following statements refer only to the Kottenforst state forest situated in the Rhein-Sieg-Erft Forest District Office (fig. C4.7)

The Kottenforst is one of the most important oak forests in North Rhine-Westphalia. Oak and beech are up to 250 years old. The forest is located at the gates of the city of Bonn and covers an area of about 4000 ha. The altitude is approximately 170 m a.s.l., with an annual average temperature of 9.4 °C and annual precipitation of 670 mm. The dominant soil type is moderately base-rich, heavily

waterlogged pseudogley derived from Löß overlaying glacial terrace gravel of the Rhine. As the occurrence of oak-hornbeam forests on temporarily wet sites is of Europe-wide significance, the core area has been protected as a Natura 2000 site since 1999. The Kottenforst is habitat for protected species of European interest including the middle spotted woodpecker *(Dendrocoptes medius)* (fig. C4.5a), the Bechstein's bat *(Myotis bechsteinii)* (fig. C4.5b), the stag beetle *(Lucanus cervus),* and the wildcat *(Felis silvestris).* At the same time, it is one of the most important areas for amphibians in North Rhine-Westphalia with occurrences of agile frog *(Rana dalmatina)* and crested newt *(Triturus cristatus).*

The main management aim in Kottenforst is the production of high-quality oak timber along with the integration of nature conservation aspects. The structural diversity of these oak forests and their large amounts of old trees and deadwood are decisive factors that safeguard species diversity under this management scheme.

Table C4.3. Key figures of the forest district Kottenforst near Bonn (state forest).

Forest community	Oak-hornbeam *(Quercus robur-Carpinus betulus)* forest admixed with small-leaved lime *(Tilia cordata)* and beech *(Fagus sylvatica)* on waterlogged soil
Total forest area	3900 ha
State forest area	2400 ha
Main management types	89 % high forest; 1 % coppice with standards; 10 % no management
Total volume	225 m³/ha
Annual growth	7.9 m³/ha
Annual use	4.1 m³/ha
Nature protection area (Natura 2000)	2456 ha

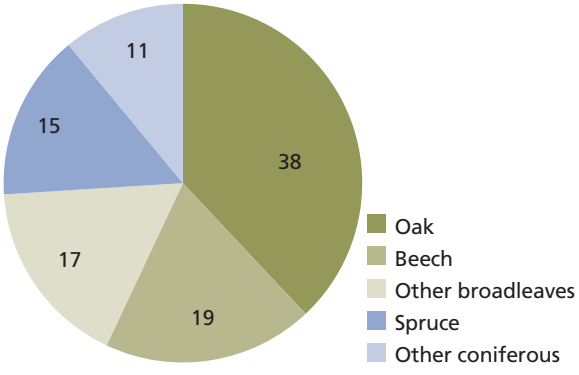


Fig. C4.4. Tree species composition of the state forest area of Kottenforst (in %).

Preserving old trees and deadwood

Combining unmanaged and near-natural forest stands serves as the basis for preserving old trees and standing and lying deadwood. Timber removal is banned on 235 ha of ecologically valuable forest areas. These areas are left to develop freely without human intervention and serve as a retreat for animal, plant, and fungal species, that are closely linked to old-growth and decay phases. Further they act as so-called donor stands for enhancing the spread of such species to neighbouring commercially managed forests.

Managed forests of oak and beech are enriched with old trees (fig. C4.6.) and deadwood once they reach an age of 100 years. For this purpose, 10 habitat trees per hectare are selected and marked. These trees are left to develop without intervention and will not be harvested. The distribution of these habitat trees is not uniform in all stands but takes into account both their ecological importance in terms of the occurrence of protected animal and plant species and their economic value.

A number of additional protective elements have also been applied. Particularly valuable old forest stands larger than one hectare have been protected as so-called 'wood island biotopes' or 'stepping stones'. Interventions directed at the conservation of ecologically valuable old oak trees under competition from beech and hornbeam are allowed. If such measures are no longer acceptable for reasons of worker safety the stand is temporarily left for free development until the old trees in the stand are well into the decay phase. To locally increase the amount of deadwood, cohorts of 10 to 15 trees have been identified as so-called 'biotope tree groups'. These groups were mostly clumped around already designated habitat trees. The groups were established mainly in stands with low wood quality and sufficiently far from frequently used hiking trails to ensure public safety. Particular attention was given to protecting valuable tree microhabitat structures such as tree cavities or severe tree damage (e.g. crown breakage, cankers), standing large deadwood, and veteran/ancient trees.

Fig. C4.5. The middle spotted woodpecker on an old oak tree and on the left a Bechstein's bat in a hollow oak (Photos a: Klaus Striepen and b: Martin Koch).

Expanding natural forest communities

The state of North Rhine-Westphalia aims at increasing the proportion natural forest communities to meet the conservation goals of the Natura 2000 areas in the long term. At present, the proportion of coniferous forest e.g. in Kottenforst is still at 26 %. This relatively high proportion is because of the large pure Norway spruce stands, which have often been planted on unsuitable waterlogged soils. These stands are being converted towards more climate-stable mixed oak stands. Dying spruce stands are regenerated with pedunculate oak *(Quercus robur)* and other suitable tree species. This will help to achieve the protection objectives of promoting oak forest habitat types and better adaptation of forests to the effects of climate change. Managing those stands towards high-quality oak assortments will also create a favourable economic return in the long term.

Minimising human disturbance

Anthropogenic impacts on forest sites are being reduced e.g. by dismantling old drainage ditches. The competitiveness of pedunculate oak is thus improved as beech is more sensitive to waterlogging. Measures like these, support the conservation of protected forest habitats. The removal of ditches also reduces surface runoff after heavy rainfall and improves water supply of forest stands during dry summers, yet another contribution to the adaptation of forests to the consequences of climate change.

Fig. C4.6. Large tree cavities such as the one found on this 180-year-old oak are rare as they require many decades to develop and are thus of particular ecological importance (Photo: Klaus Striepen).

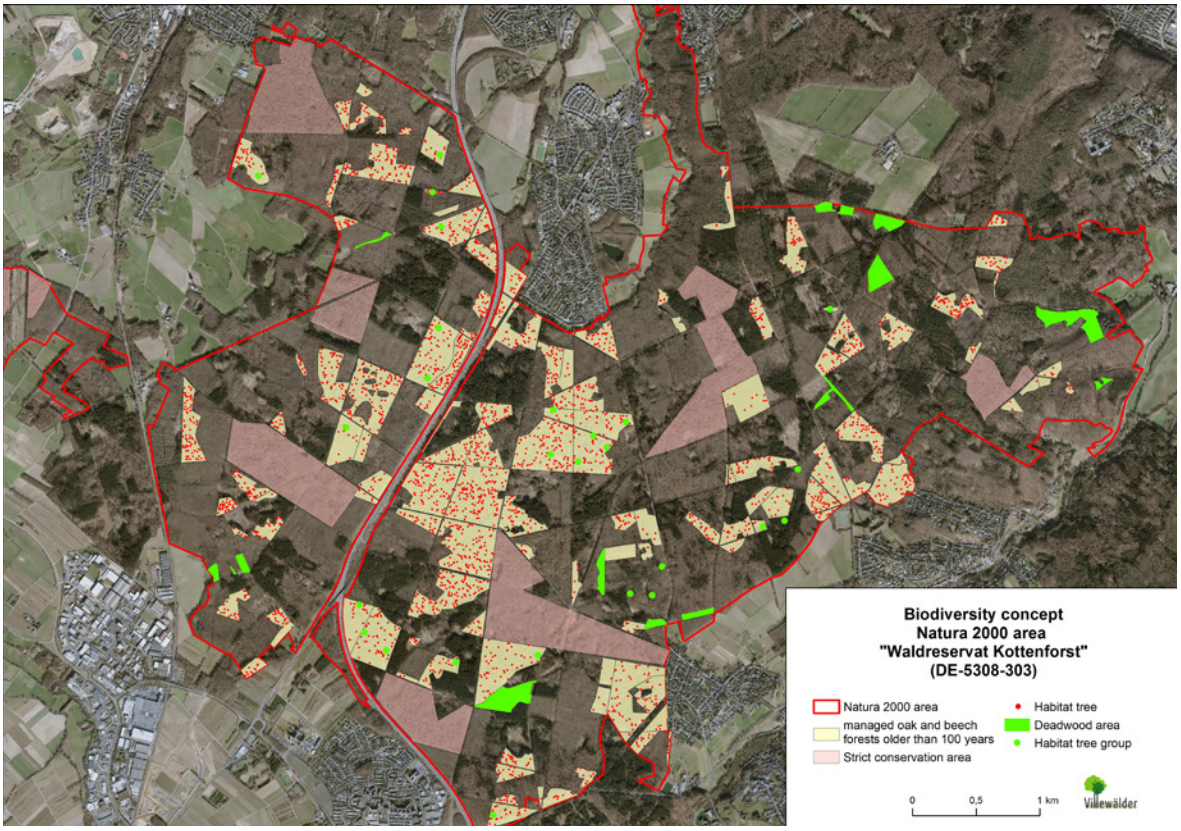


Fig. C4.7. Biodiversity concept for the Natura 2000 area 'Forest Reserve Kottenforst'.

Promoting coppice with standards

Coppice with standards is a traditional form of forest use in Kottenforst. It was abandoned in the middle of the nineteenth century. Today, only a few oak and beech trees remind us of this traditional form of forest management. Owing to the importance of open, sunlit forests for many plant, animal, and fungal species, selected stands have been transformed to coppice forests. Such stands allow visitors to experience this traditional form of forest management and the biodiversity associated with it.

Safeguarding forest habitats

An important component of the protection concept is the conservation and promotion of small-scale habitats within forests. Examples are the maintenance of small water bodies serving as habitats for amphibians, dragonflies, and water dwellers, and the extensive use of species-rich forest meadows. The forest meadows include such species as tall oat-grass *(Arrhenatherum elatius),* bristle mat-grass *(Nardus stricta)* and moor grass *(Molinia caerulea)* meadows with occurrence of Arnica *(Arnica montana),* Devil's-bit *(Succisa pratensis),* and various orchid species.

Informing forest visitors

The forest area is located about 10 km from the city centre of Bonn and serves as a local recreation area of outstanding importance. To sensitise visitors to the vulnerability of forest ecosystems and their numerous habitats, the Rhein-Sieg-Erft Regional Forest District Office engages in comprehensive public relations work. Jointly with the City of Bonn the Regional Forest District Office operates the forest information centre 'Haus der Natur' (House of Nature). In addition to the permanent exhibition 'Großstadtwald' (city forests), the forest information centre offers guided tours and workshops (fig. C4.8).

Fig. C4.8. Guided excursion in the Kottenforst, where interested visitors learn about tree microhabitats (Photo: Klaus Striepen).

European funding helps

The nature conservation concept has been implemented between 2014 and 2020 as part of the LIFE+ nature conservation project 'Ville Forests – LIFE forests and waterworlds'. The project is coordinated by the Rhein-Sieg-Erft Regional Forest District Office in cooperation with the conservation organisation Biologische Station Bonn/Rhein-Erft e.V. The project budget is € 3.3 million, half of which is financed by North Rhine-Westphalia Ministry of the Environment. The remaining funds are provided by the European Union.

For more information

www.wald-und-holz.nrw.de/ueber-uns/einrichtungen/regionalforstaemter/rhein-sieg-erft
www.wald-und-holz.nrw.de/naturschutz/xylobius-lebensraum-bewahren
www.villewaelder.de
www.chance7.org

Box C3

Water – A forest service, an example from the Hardwald (Switzerland)

U. Meier

Forestry Office of Canton Basel-Stadt and
the Canton Basel-Landschaft

The Hardwald, in the vicinity of the city of Basel in northwestern Switzerland, spans an area of about 268 ha and is of very high importance for the greater region as a drinking water retention area. It is a showcase for a multifunctional forest, but also for an area that has experienced drastic changes in management and use within the last five centuries. In the seventeenth century the forest served as a grazing area for pigs. At that time the so-called 'Wytweide' (forest pasture) with coppice and standards was a widely used management scheme for forests in Switzerland (see case B9 in this book); the scheme favoured light-demanding species, especially oak (*Quercus robur* and *Q. petraea*). This changed in the nineteenth century when beech *(Fagus sylvatica)* was promoted and the forest management was transformed into a high forest system. Consequently, the forest floor got darker, and the flora and fauna adapted accordingly, with a shift from light-demanding species to shade-tolerant species. Close to the Rhine, the soils are dominated by gravel and dry out quickly as the water storage capacity is low. After World War II, there were several dry years (in particular, 1947 was a very dry year) and many beech saplings died. The need to provide essential goods for the survival of people and the dry summer 1947 revealed a need to secure the increased demand for drinking water in the growing city of Basel. After establishing a company that serves the provision of drinking

Fig. 1. Systematic water retention in the Hardwald. Water is directed from the Rhine and percolates through the forest ground in a system of water channels (Photo: Ueli Meier).

water, since the 1950s water from the Rhine has been redirected into the Hardwald; the water runs through water channels with gravel beds and percolates through the forest soils (fig. 1). The water is then collected and distributed around the city. To secure clean and high-quality drinking water, the forest soil depends on the growing stock of trees and other plants. The most important forest function in the Hardwald is to secure drinking water (fig. 1). Forest management is planned and implemented according to this priority function. However, important transportation routes cut through the forest, and the forest also serves as an important recreation area for the people of Basel.

The dry years 2018/2019 and 2020 have had serious impacts on this forest, causing many trees to die, or parts of large trees to dry out and break off (fig. 2). Parts of the forests were temporarily closed to the public and big trees, mainly beech, were felled for safety reasons. The thin humus layer and the gravel soils with poor water retention capability, means that the trees are at their limits and the forest is sensitive to dry conditions.

Fig. 2. Aerial photograph of the Hardwald and the Rhine. The damage caused by the drought in 2018 are well shown in this photo (the brown patches are dead or dying beech trees). The photo gives a good impression of the dimensions of this forest area (Photo: Christian Kleiber, Bürgergemeinde der Stadt Basel).

Lessons learned

The crucial question for all stakeholders is how the forest services can be maintained in the future. Wooden products might be substituted by other regions; however, the provision of clean and high-quality drinking water is a very sensitive issue that many people take for granted. The case of the Hardwald shows the vulnerability of logistics and infrastructure and the importance of retention areas especially in urban areas where the demand for water is much higher than in rural areas where water is often not limited.

Not far away from the Hardwald, but still within the limits of the urban area of the city of Basel, another case shows how the Hardwald could develop. The 'Lange Erlen', a small area on the border of Germany and Switzerland is a former floodplain forest. As the urban area developed, water from the River Wiese (originating in the Black Forest in Germany), was diverted into canals built to serve industrial/urban developments. As a consequence, the typical alluvial flora of the River Wiese was changed drastically as the area lost its reliable water supply; the water runoff in the area also became faster. Consequently, the area was planted with a variety of deeper-rooting species which can access water deeper in the soil. Also here, the provision of high-quality drinking water is the most important forest service and it may serve as an example of a sustained forest service under changing conditions. The lesson for the Hardwald might be that beech is probably not well suited to the conditions at this site anymore. Considering ongoing climatic changes and the expected drier conditions, and because of the sensitivity of beech to sunburn and heat, consideration should be given to planting oak species.

Kandern City Forest – A traditional multifunctional community forest

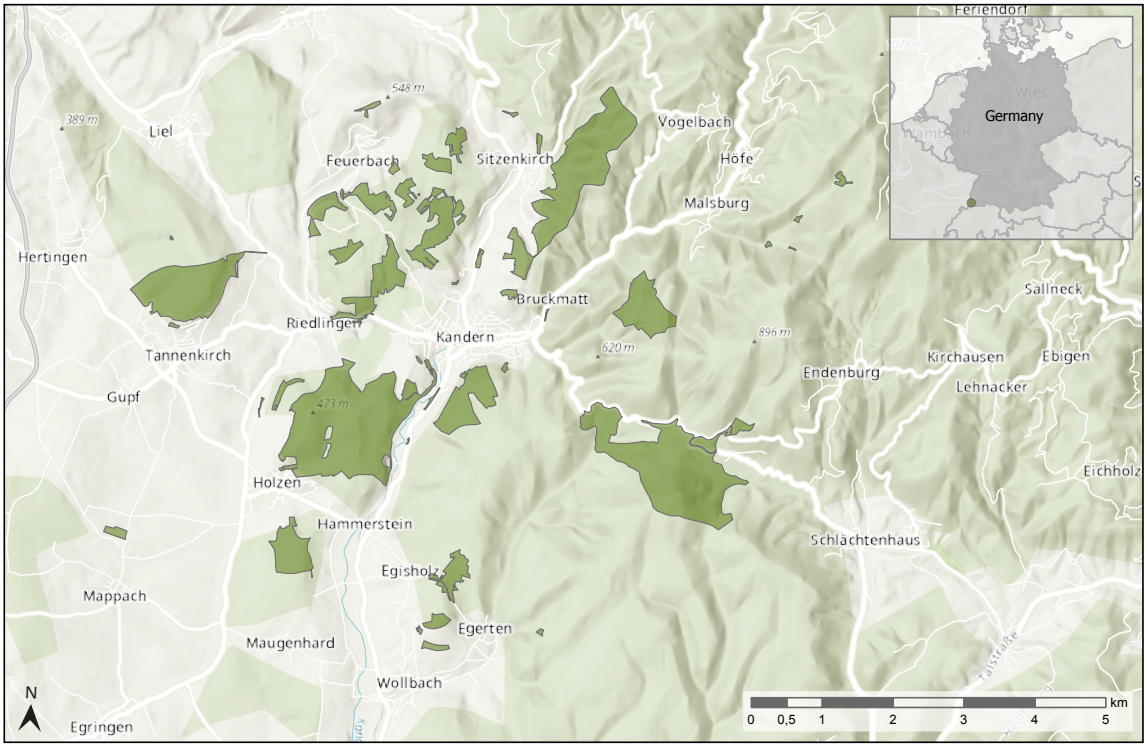
C5

R. Dickele

Forest Enterprise, City of Kandern, Germany

Context, legal frame, and ownership structure

The city forest of Kandern is located in Baden-Württemberg in southwest Germany, not far from the Swiss and French border. The forest enterprise of Kandern has a long tradition of forest management and has produced valuable timber in a selective management system for many decades. Favourable conditions and a heterogeneous topography support the existence of a diverse forest with many different tree species, but also the production of



< Fig. C5.1. Varying landscape with the small city of Kandern in the background and its associated villages between forests and agricultural land. The forests are dominated by oak and beech in the lowland areas at the bottom of the photograph, whereas there is a higher proportion of conifers (silver fir, Douglas fir, and Norway spruce) in the forests in the more upland areas at the top (Photo: City of Kandern).

Statement

"The forest provides a steady and sustainable flow of resources over time. Forest products should be used accordingly!"

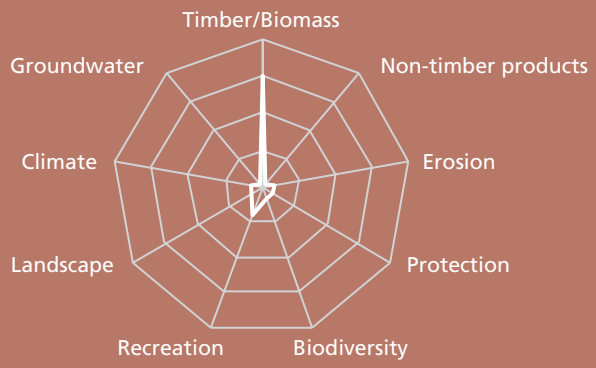


Table C5.1. General information on the city forest of Kandern.

Forest community	Mixed mountain forests and beech / oak forests in the lower parts
Total forest area	887 ha
Main management types	Selection cutting system/'Femel-cuttings' and small-scale gap clearcuts < 0.6 ha (oak management)
Total volume	371 m³/ha
Annual growth	8.7 m³/ha
Annual use	8.5 m³/ha
Deadwood (standing and lying)	18.2 m³/ha
Altitude	350–711 m
ownership	Community forest
Geology	Black Forest bedrock (sandstone – on 200 ha); Rest 'Markgräfler hills' (clayish soil types – fine clay, little clay or marl soils)
Nature protection area (including Natura 2000)	295 ha
Forests with protective function	887 ha. The whole area has a protective function. Some parts of the forest have multiple protective functions (water and habitats)
Climate protection service per year	7.170 to CO_2-equivalent by storage in the forest, in long-lived forest products and substitution effects

valuable timber. The long tradition of forest management and the high forest productivity lead to the production of high-quality timber – mainly oaks (*Quercus robur* and *Q. petraea*) and Douglas fir *(Pseudotsuga menziesii).* Although the Swiss city of Basel is very close (about 23 km), the identification of the area with forestry and its products is still at a very high level.

The forest enterprise is owned by the city of Kandern with about 10000 inhabitants and eight attached villages. The political decision-making body is a council with 14 members and the mayor. The forest area is embedded within a patch of state forest areas and small-scale private forests. The infrastructure, market, and sociological aspects are therefore closely linked to each other. Some services are provided by the Baden-Württemberg state forest administration.

Forest history and cultural heritage

For many centuries oaks (*Quercus robur* and *Q. petraea*) and other broadleaved species (e.g. beech–*Fagus sylvatica;* ash–*Fraxinus excelsior;* or sycamore–*Acer pseudoplatanus*) have been an integral part of forest management in this area. There are some old oaks trees with an age of about 400 years. The long tradition and connection to oak forests are hinted at in the names of areas and roads ('Eichholen' or 'Eichwald'), and also in nursery rhymes, songs, and stories.

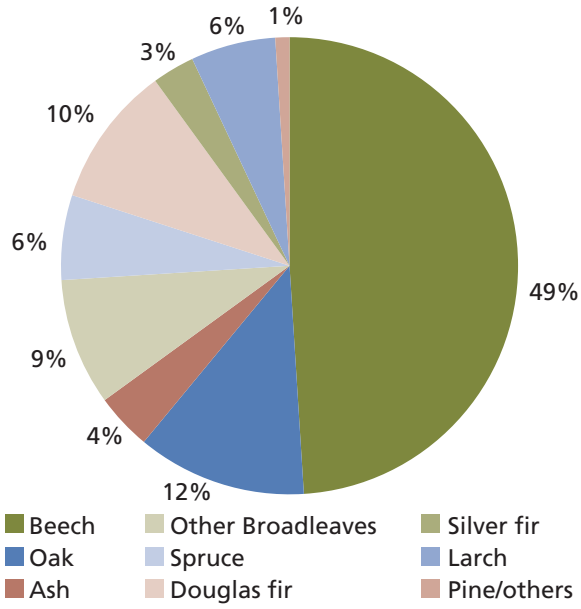


Fig. C5.2. Tree species distribution in the community forest of Kandern.

Recently, there have been several re-organisations of the forest administration and structural changes that have led to the current situation with one responsible forester for the complete city forest area. The area managed by this forester has increased several fold within the last few decades. As a kind of compensation, the state forest agency has taken over some tasks and has reduced the workload and responsibility of the remaining forester. For instance, marketing of the timber is now handled by the local state forest agency.

Thirty years ago, the average price of a solid metre of timber in the city forest was about 75 €/m³. This covered the cost of a forestry worker for about five hours. Today, the timber price is the same as in 1989, but this covers only two hours of work.

Historically, the timber produced by the enterprise has been supplied to a few local clients. Today, there are many wood buyers who have diverse sorting quantity and delivery requirements. Without its own well-trained forest workers, it is very difficult to be flexible and successful on the timber market.

Recent windstorm events as Vivian and Wiebke (1990) and Lothar (1999) have caused structural changes. Severe damage of about 15000 m³ of windthrown timber in the city forest have resulted in a drop in hardwood prices and the enterprise slipped into a deficit. There were two possibilities: (1) reduce personnel costs, which was not possible in the short term; or (2) develop new sources of income with new fields of activity. For this, the city offered to 'rent out' some of the employees in winter to work in other forests, and thus keeping them employed in winter while also carrying out forest management tasks in the city. Thus, it has been possible to run the forest enterprise with its own forest workers. Throughout the years, the model has been adapted and further developed. Looking back, this was a crucial decision for the successful approach as it allowed for a high degree of flexibility.

The main forest types are mixed mountain stands dominated by beech *(Fagus sylvatica),* admixed with Douglas fir and oak. The applied management system is a selection rotation system with a high return frequency (every stand is assessed, at least once every 8–10 years, and silvicultural operations are carried out). The natural forest composition is dominated by beech and a broad range of broadleaved species as cherry *(Prunus avium),* oak, ash, sycamore, linden *(Tilia cordata),* and alder *(Alnus glutinosa).* Oak occurs on about 15 % of the total forest area and has partly been planted and needs a high management intensity. In gaps up to 0.6 ha, oaks are planted and protected against browsing damage and favoured against competing vegetation. This intensive management to promote valuable oak is rather specific and has a long tradition in this forest. Valuable oak timber is, however, the economic and ecological backbone of the enterprise. About 34 % of the forests are designated as Natura 2000 areas, though they are not treated differently. Valuable beech, silver fir *(Abies alba),* Douglas fir and European larch *(Larix decidua)* trees are also part of the production and are produced in a single-tree selection system with increasing gap sizes over time (Badischer Femelschlag). The 887 ha in city forest enterprise all have a protection and recovery function. In addition, some areas have multiple protective functions and protects water restoration or protection of habitats (Natura 2000) at the same time.

Aims of the enterprise

As an economic objective, a surplus is very important. Without a surplus, the forest is a recipient of subsidies and thus more dependent on political decisions. The net yields should flow evenly. Fluctu-

ations in the operating results give rise to mistrust. In good times, which correspond to periods with an economic surplus from forestry, the community has always approved investments in the forest (e.g. forest roads, forest purchases, or recreational facilities). Essential expectations of the population should be met: firewood supply (industrial wood is secondary to firewood); good forest roads and a good forest condition; no major damage caused by forest management operations. Difficult decisions should be communicated properly and with sensitivity. The city is the forest owner and principal. If the city disagrees with something, the forester has to convince them; otherwise, a loss of confidence will be the undesired and mid-term consequence.

Economy

During the period from 1998 to 2009 the enterprise had an annual surplus of about € 120 000, or 138 €/ha. This is about 20 times more than other broadleaved-dominated forests in southwest Germany. From 2010 to 2016, the annual average operating surplus was € 140 000 and 164 €/ha. The total income for that period was about € 4.5 million. Expenses were approximately € 3.5 million. The costs included, for example, more than 30 000 plants that were planted during this period.

Fig. C 5.3. Typical and important economical product in the City Forest Kandern. Example: Douglas fir as 'cash cow' (Photo: Reiner Dickele).

The balance of the enterprise in the last decades is a success story and there are several reasons for this sustainable positive economic result:
- Favourable site conditions;
- Very good work of the pre-accessors; resulting in a good and maintained infrastructure and sustainable management;
- Successful marketing strategy – submissions three times/year;
- Important decision 120 years ago to import and plant Douglas fir;
- Trust in the decisions of the forester;
- Wide range of tree species and own forest workers enables quick reaction to fluctuations in the market and storm damage.

Ownership structure

The City Forest Kandern is a communal forest, though embedded in a network of state forest areas and small-scale private forest patches. This situation is specific, and over the centuries the local inhabitants have identified closely with their forests and forestry. The right to collect and use wood for fuel and construction is important and a basis for the close identification with the forest.

Most important service/product

The main product of the city forest is high-quality timber, mainly from oaks, but also from Douglas fir (fig. C 5.3). However, the value of the forests with respect to recreation and as cultural heritage for the local people is difficult to quantify. Without doubt, this is a very important forest service. The habitats for a multitude of species is connected with this argument. Hunting is another important service.

Fig. C5.4. Special forest biotope (Schonwald), the so-called 'Wolfsschlucht' with calcareous rock formations and very rare species (*Lunaria rediviva* and *Carex pilosa*). The forest has a high touristic value. It also serves as the setting for a theatre production for one show in the summer (Photo: Frank Krumm).

Fig. C5.5. Mixed oak/beech forest including old-growth elements and a carpet of early flowering wood anemone *(Anemone nemorosa)* (Photo: Frank Krumm).

Specialities and rarities

The area is made up of diverse forest habitats, including some rare habitats that are home to a number of rare plant and animal species. There are small patches with forest reserves ('Schonwald' as a special protection format) and protected areas are dispersed across the entire forest area. Rare species – such as the moss *Neckera crispa,* the liverwort *Metzgeria conjugata,* and the sedge *Carex pilosa* – are found in canyon vegetation types with moist conditions and calcareous bedrock formations (fig. C5.1 and C5.4). Also, there are rare species of birds, bats, and other mammals which depend on old-growth forests.

Nature conservation

The state forest administration has introduced the AuT- concept (Alt- und Totholz Konzept; Old and Deadwood concept) (ForstBW, 2016). About 20–30 ha of small stands and tree cohorts with nature protection value are preserved within the managed forest areas. There is a possibility to designate these areas as 'ecopoints' and to get some compensation (paid by the state) for this. Also managed forests without any protection status are of high value for nature conservation because of the large proportion of old-growth structures (fig. C5.5) and higher probabilities to develop habitats for particular species (fig. C5.6).

Fig. C5.6. Old oaks in a managed forest area providing valuable timer and habitat structures (Photo: Frank Krumm).

Population and recreation

The local population identifies strongly with the forest, as traditionally local people have bought and sold firewood in at least four firewood auctions per year. The city provides incentives for local private forest owners to harvest and sell firewood assortments from young stands of broadleaved species (about 35 % of the harvested wood in the region is sold as firewood). There has also been close contact between the municipality and the local population through initiatives such as the forest adventure trail (established in 2003). Since 2003, several features have been added or are planned: 'Kletterwald' (2010), the 'sound path' (2016), and a water station (2020). Further, water has a specific value in the mountainous forests as it is very poor in minerals and in high demand by local beer brewers and distillers. Figure C5.7 shows a fountain built and maintained by the community forest that is frequently used and provides a basis for local products of high value.

Fig. C5.7. Fountain in the middle of the forest. The spring water in the area is well known. This fountain is used as a water source by local distillers and craft beer brewers (Photo: Frank Krumm).

Fig. C5.8. Planted and protected oak regeneration on a small clearcut area (less than 1 ha) as a basis for successful oak management (Photo: Frank Krumm).

Conclusions – Strengths and weaknesses

Management: The presented approach, based on valuable timber production and a high level of understanding in the society for management, depends on local people and the forester identifying strongly with the region and the applied management concept, including small clearcut areas (fig. C5.8). This might change over time as the forester will retire soon and immigration into the region is currently high.

Policy: This type of ownership and the local and small-scale policy allows for more flexibility while making decisions. This depends on the continuing support of the council. Currently it is considered to be a clear strength.

Communication is very basic and local, but is tailored to the aims of the enterprise.

Nature conservation is partly embedded in the daily routine of the forester and depends on his personal understanding. Production and protection are long-term management aims and seem to work well in this case. As oak is one of the main tree species, management of the forest area targets production and nature conservation as dual aims. There are many rarities present and a high share of the area is under protection and under additional survey from nature protection agencies. The tools to maintain multifunctional forests are used and are sufficient. However, successful implementation strongly depends on the managers and also on the control agencies (i.e. the city council and the state agencies) as presented in this case.

Portrait

Our mission is to manage forests for humans needs and wellbeing as a long-term task. We aim to produce valuable timber and maintain the close connection of local people with the forest.

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Box C4

Marteloscopes – a key instrument for fact-based learning, understanding, and the exchange of knowledge on forests and their management

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What are marteloscopes?

The concept of 'marteloscopes' was developed in France. The name is derived from the French term for tree selection ('martelage') and the Greek 'scopein' (look). So, the purpose is to have forest sites that literally allow 'having a closer look' at tree selections. At first marteloscopes were applied in private forests. However, their potential for field-based training and education for both forestry professionals and students was already recognised in the 1990s (Bruciamacchie *et al.* 2005). Marteloscopes were then continuously established also in other European countries. Initiated in Integrate+ (2013–2017) and continued in other projects such as Informar (2017–2020), Marteloscopes have found increased interest as training and educational tools.

To date, more than 100 marteloscope sites dispersed over 16 European countries have been established within the scope of these projects, and the number continues to grow1. Most of them are located in public forests, but there are also marteloscopes on community, church, and private forest land. They cover a broad range of forest types, altitudinal gradients, site conditions, and management regimes. There are also a few sites in unmanaged forests, which are especially interesting when it comes to learning about natural forest development processes and biodiversity.

Marteloscope sites are usually 1 ha in size. Within these sites all trees above an agreed breast height diameter (usually 7.5 cm) are measured and numbered. The recorded tree data includes tree species, tree location, tree status (dead/alive), breast height diameter, tree and crown base height, tree-related microhabitats and an estimation of timber quality (Schuck *et al.* 2015). This results in a comprehensive set of data for each recorded tree and includes the assignment of both an economic and a habitat value (Kraus *et al.* 2018). Economic value is derived by visual estimation of wood quality sections for each tree to which local timber prices are then assigned. Tree-related microhabitats are assessed using a designated list of tree microhabitat structures (Larrieu *et al.* 2018; Kraus *et al.* 2016).

Fact-based learning in marteloscopes

Because of the versatility of marteloscope applications, they are not only of interest for forest practitioners, but also for stakeholders from nature conservation associations, environmental organisations, universities, schools, and society at large. As environmental, political, and societal demands and needs change constantly, as do scientific findings, it is crucial to ensure for continuous exchange, understanding, and learning amongst all actors. How to best convey such changes and their multi-layered effects when it comes to practical implantation is a major challenge. Marteloscopes allow communication of different concepts related to forest ecology, silviculture, forest management, and conservation within the framework of flexible training courses. Furthermore, they can help visualise often complex decision-making processes in forest management and support a better understanding of forests between often conflicting interests.

An evaluation and simulation software was developed for conducting training exercises in the marteloscopes. Running on hand-held devices, the software allows the results of a virtual intervention to be displayed immediately, and are thus available for discussions amongst exercise participants (fig. 1). Marteloscopes and the software can be applied for a variety of educational aims and participants.

The main focus is usually on providing insight to stand structures and stand dynamics while at the same time evaluating individual trees in terms of wood quality, and economic and nature conservation value. A typical example was to investigate the

[1] http://iplus.efi.int/marteloscopes-data.html

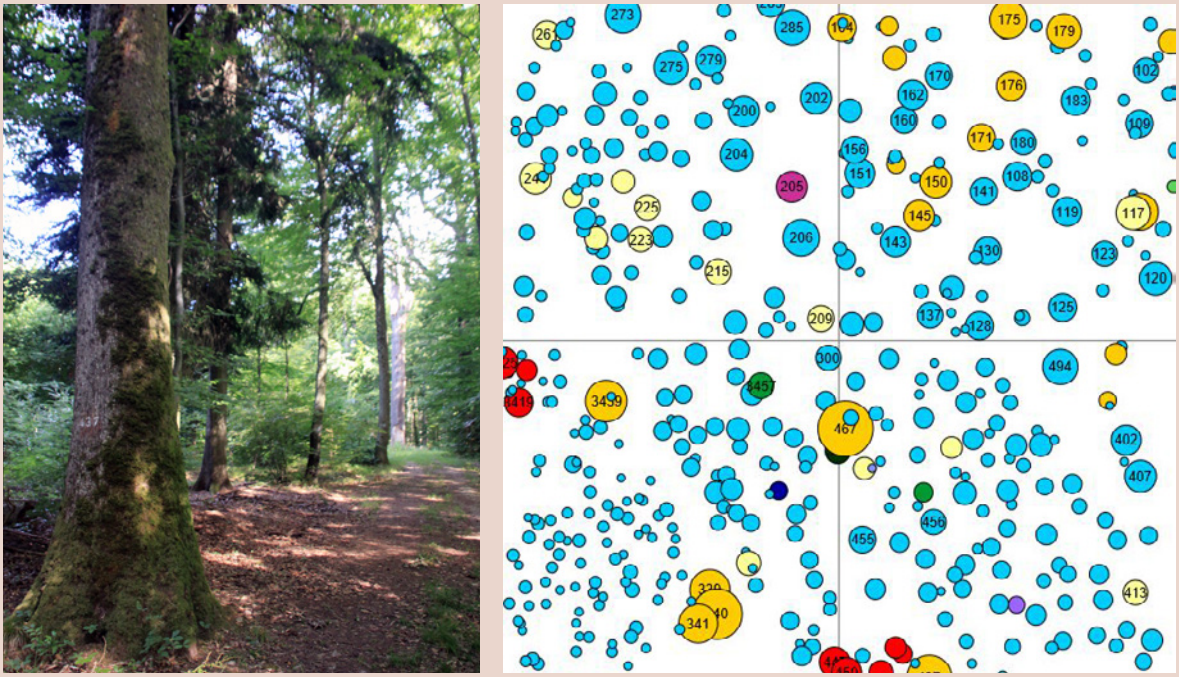

Fig. 1. Martelscope 'Behleneiche' in the forest district Kandern, Baden-Württemberg, Germany (Photo: Frank Krumm). Tree base map of the Behleneiche site (right).

development of habitat values against that of achievable revenues. However, aims can easily be tailored to other topics.

An exercise can focus on one individual aspect or combine several topics. This is decided by the field course teacher when planning the exercise for a particular target group (some examples).

- Silviculture: thinning regimes (thinning from above/below, stand conversion); stand regeneration/stability …
- Economy: maximum economic return; high quality timber removal/accumulation; elite tree selection …
- Nature conservation: selection of habitat/future habitat trees; deadwood accumulation …
- Other: wood volume and basal area estimations, identifying trees/tree traits (microhabitats, wood quality); work safety; recreation …)

Training events involving marteloscopes have been continuously increasing. The main audiences are forest and nature conservation professionals, university students, but also policy makers, school students, and the interested public.

Example training event (October 2018): Marteloscope 'Falkenberg' (Vosges Nord/Lorraine; Forêt de Bitche, France)

The training brought together 40 foresters from public and private forests. First an introduction was given to different tree-related microhabitats, their importance for forest dwelling species and how to identify them. The introduction was followed by a training in the Falkenberg marteloscope where the participants applied their newly gained knowledge in the course of virtual tree selection exercises. The exercise outcomes of all groups were then jointly evaluated and discussed (fig. 2).

Fig. 2. Lively discussion between conservation managers, forest owners, and forest workers following a training exercise in the Marteloscope 'Falkenberg' (Photo: Andreas Schuck).

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Fig. 3. Tablet computers allow interested people to simulate management operations with relevance for biodiversity in forests (Photo: Andreas Rigling).

Pahernik Forest – A case from Slovenia

C6

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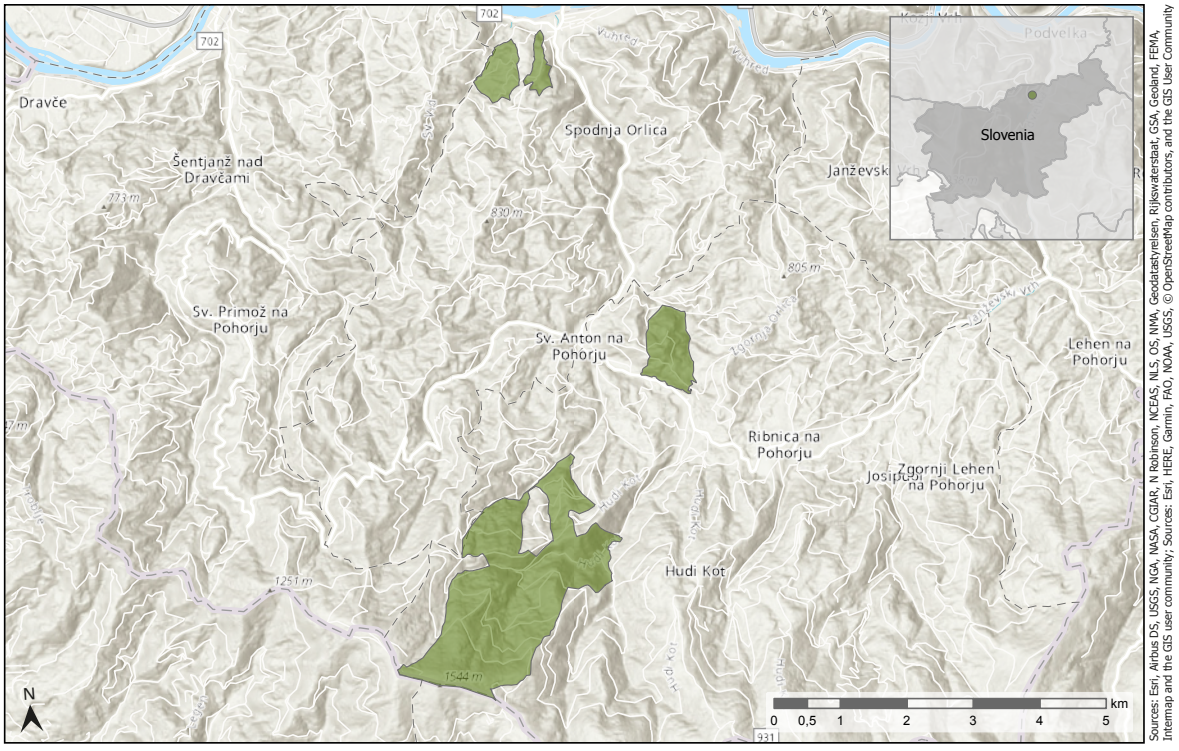
About Pahernik forest

The Pahernik forest (fig. C6.1) is situated on the northern slopes of the Pohorje mountain chain in northern Slovenia. Forest stretches from the foothills of the mountain Pohorje (370 m a.s.l.) to its highest peaks (1542 m a.s.l.). It is a part of a forested landscape interwoven with individual farms up to an altitude of 1000 m. The Pahernik forest covers an area of 570 ha and is located on very productive forest sites (*Luzulo–Fagetum* and *Galio rotundifolii–Abietetum*). It is a mixed forest of Nor-



< Fig. C6.1. Pahernik forest is located in the Pohorje region in Northern Slovenia within a landscape with long traditions in forest management (Photo: Jurij Diaci).

Statement

"In Pahernik forest the coexistence of natural values, culture, history, education, and timber production has a long tradition."

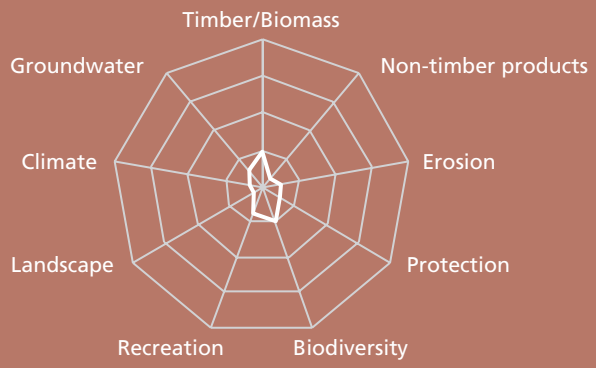


Table C6.1. Basic information of Pahernik forest according to the last forest management plan (2014–2023).

Forest community	– Beech forest with white wood-rush *Luzulo–Fagetum* (66 %) – Fir forest with round-leaved bedstraw *Galio rotundifolii–Abietetum* (23 %) – Spruce forest with wavy hairgrass *Avenello flexuosae–Piceetum* (3.5 %) – Spruce forest with great wood-rush *Luzulo sylvaticae–Piceetum* (3 %) – Beech forest with hard fern *Blechno–Fagetum* (3 %) – Forests of valuable broadleaved trees on non-carbonate bedrock *Dryopterido affinis–Aceretum pseudoplatani* (1 %) on ravines and slopes – Fir forest with Long-Leaved Fork-Moss *Paraleucobryo–Abietetum* (0.3 %) – Grey alder forest with balm-leaved archangel *Lamio orvalae–Alnetum incanae* (0.2 %)
Total forest area	570 ha
Main management types	Freestyle silvicultural system following natural principles (from single and group selection to irregular shelterwood)
Total volume	453 m³/ha
Annual growth	10.8 m³/ha
Annual use	8 m³/ha
Deadwood (standing and lying)	11.6 m³/ha
Altitude	Between 370–1542 m
Ownership	Pahernik Foundation
Geology	Lower part: metamorphic stones (gneiss, phyllite) Upper part: magmatic stones (tonalite, dacite) Soils are mostly acid brown soils (district cambisol)
Protected area	14.3 ha are ecocells
Nature protection area (Natura 2000)	331 ha
Main function – biodiversity conservation	73 ha
Main function – Protective (protection of forest stands and soil)	311 ha
Main function – social	Protection: protection of forest roads Hudi kot – Kralj and road on Pungart Aesthetic: around chapels and church, Pahernik spruce and stone sculptures Educational: on paths leading through educational objects (forest)

way spruce *(Picea abies),* European beech *(Fagus sylvatica)* and silver fir *(Abies alba)* (fig. C6.2) with a high average growing stock and wood quality. Most of the forest is multi-layered, uneven-aged, with small areas of single-tree selection stands and pure even-aged spruce forest stands.

The growing stock of the Pahernik forest has increased significantly over the last 50 years. The steady increase was interrupted during the silver fir decline in 1970, which was a consequence of several factors. The silver fir is very sensitive to the polluted atmosphere, so it decreased sharply during times of high emissions of sulphur oxides. However, this type of pollution in the world has significantly decreased and at least the younger population of silver fir has recovered well. The last forest management plan (2014–2023) estimated the average growing stock as 453 m³/ha, annual increment of 10.8 m³/ha, and approved a highest possible felling rate of 8 m³/ha (table C6.1), which is usually fully realised.

The majority of forest stands (53 %) lie on steep slopes (20–30°), and the rest are on very steep slopes (>30°). Precipitation ranges from 1100 mm to 1500 mm, and the mean yearly temperature ranges from 3 °C to 8 °C. The most rainfall falls during the vegetation period. At lower altitudes, the geology is composed of metamorphic stones (gneiss, phyllite), while at upper altitudes magmatic stones prevail (tonalite, dacite). Soils are mostly acid brown soils (district cambisol).

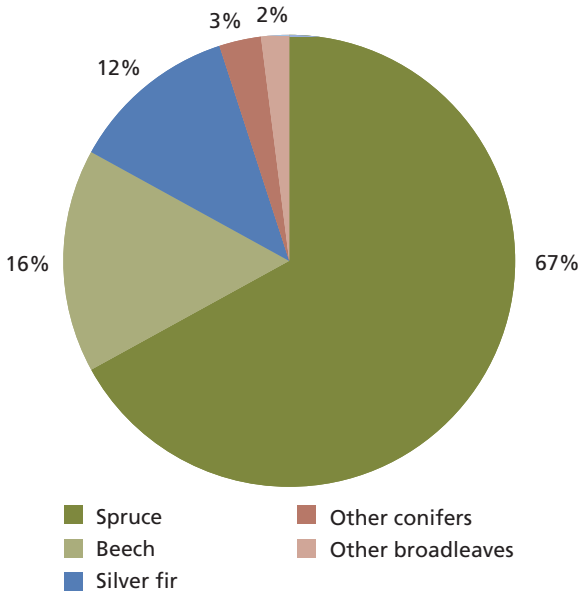


Fig. C6.2. The most common tree species in Pahernik forest.

History and ownership

Franjo Pahernik (fig. C6.3) (1882–1976), and his family, have played an important role in the historical and cultural aspects of Slovenian forestry. Franjo Pahernik was a forestry engineer and one of the pioneers of applying close-to-nature forest management principles in Slovenia. He ensured that natural development processes were taken into account in forest management during a time when clear-cutting and planting of monocultures of Norway spruce were common and seen as the most profitable form of forestry. Since the early twentieth century, a gradual transformation of pure Norway spruce stands towards a more natural species composition has taken place. Degraded pastures and meadows have been reforested with native tree species. The main silvicultural tools were planting, tending, and selection cutting. Slovenia, therefore, has a long history in applying close-to-nature forest management with some of its best examples found in the Pahernik forest. After World War II, the property was taken from the Pahernik family and nationalised. Only later, in 1999, was the property returned to the family. For most of the period when property was owned by the state, Franjo Pahernik was involved in the management of this forest.

Fig. C6.3. Forestry engineer Franjo Pahernik (Photo: Digital Library of Slovenia).

Later, his daughter Vida Ribnikar inherited the Pahernik forest. She was aware of the love her father had for this forest and of the importance of maintaining it for close-to-nature forestry practice, and so she established the Pahernik Foundation, which is now the legal owner. The purpose of the foundation is to manage the forest based on close-to-nature principles, and with the profits from its activities to provide scholarships for forestry students at the Biotechnical Faculty of the University of Ljubljana.

Management and multi-purpose forest

The growth conditions and the state of the forest enable sustainable wood production, which represents an economic basis for all other activities and the mission of the owner – Pahernik Foundation. Wood production is a main function and emphasised on 96 % of the forest area. Management is based on close-to-nature forestry techniques with freestyle silviculture, following natural principles. The aim of forest management is to find a balance between ecological and socio-economic functions based on sustainability criteria. Ecosystem conservation, the protection of soils, social functions, and timber production are equally important.

Special attention is given to continuous forest cover, gradual transformation of the remaining Norway spruce plantations (approximately 60 ha) into more natural structures (fig. C6.4), and to consistent verification of the management success with the control method. To ensure the continuous forest cover and balance between functions, only a part of the growing stock has been cut – 18 % of the growing stock or 75 % of the increment. The forest stands are approaching optimal growing stock. Thus, natural regeneration (fig. C6.5) and indirect tending are fully implemented. Most stands are mixed and uneven-aged. The remaining stands include younger even-aged stands created by planting on abandoned agricultural areas; these need to be gradually converted to structurally diverse stands. To strengthen the overall stability of the stands, the emphasis is on maintaining high growing stock and increment, while simultaneously favouring a complex stand structure and regeneration on the entire area of the holding.

A well-developed forest infrastructure (36.8 m/ha of forest roads and 117 m/ha of skidding tracks) guarantees that timber can be extracted efficiently and with a low impact on other forest functions. Logging is done manually by chainsaw while timber is moved by cable to forest roads. In the case of logging and harvesting, the possibility of damaging trees must also be considered. In Pahernik forest the tree damage estimations ranges from 6.5 to 9 %. Damage most frequently occurs on the tree trunk and roots. In the last 10 years, 328 m³ (average volume per tree of 2 m³) was harvested as a result of damage connected to forest work.

When planning forest work, time is a very important factor in Pahernik forest:

- In the higher altitude parts of the estate, because of the nature conservation restrictions, work can begin only after the end of June. Capercaillie *(Tetrao urogallus)* breeding takes place from the beginning of March to the end of June.
- Harvesting and skidding are prohibited in the lower part of the estate in the early spring months because of the wet terrain and reduced load capacity of the roads. Hunting is a main aim of management in 1.2 ha. These are non-forest areas that are functionally linked to the forest and are important for feeding and as quiet zones for wildlife.

Economic aspect

Close-to-nature management in Pahernik forest assures continuous economic returns. With continuous tending of individual high-quality crop trees (pruning, light increment) the economic returns are expected to increase even more in the near future. Within the last decade the annual economic surplus was about 190 €/ha. The logs are sold to the local sawmill which is also equipped with a band saw suitable for sawing larger diameter logs. A high economic return is a result of 98 % natural regeneration, indirect tending because of the long regeneration periods, and involvement of the Slovenia Forest Service with preparation of forest management plans and tree marking. The average annual investment in regeneration, forest tending, and protection is about 1 hour per ha (table C6.2). In some areas game browsing is a problem, and therefore regeneration of silver fir and noble broadleaves is only possible with fencing or protection of individual trees.

Fig. C6.4. Gradual transformation of Norway spruce to a more natural structure (Photo: Jurij Diaci).

Fig. C6.5. Pahernik Forest – fir and spruce regeneration (Photo: Jurij Diaci).

Table C6.2. Annual investments in forest tending and forest protection in the period 2011–2014.

	Total hours	Hours per ha
Regeneration	26	0.04
Tending of stands	390	0.68
Tending of biotopes	68	0.12
Forest protection	87	0.15
Total	571	1.00

The mission of the Pahernik Foundation encourages young people to study forestry and supports research activities in the field of forestry. For this purpose, the foundation grants scholarships for students and funds for research activities every year, starting from 2011 onwards. For eight years about 40 000 € per year has been granted as scholarships and tuition fees for forestry students at the Master and PhD levels and 35 000 € per year for research and other activities connected to close-to-nature forestry. This money is provided by careful and planned management of the Pahernik forest.

Ecological aspect

Besides the production function of this forest (production of quality timber and economic return), other forest functions are also considered as important (fig. C6.10).

Conservation of biodiversity is considered important in Pahernik forest. This is reflected by half of the area (331 ha) being designated as Natura 2000 and around 14 ha of old forest as set-aside areas, allowing free development of the stand. Diverse habitats – e.g. streams (fig. C6.6) and rare and protected species are found in this area – e.g. the capercaillie. Targeted management measures are applied to improve capercaillie habitat.

The average amount of deadwood is 11.6 m³/ha. The deadwood is mainly thin, standing dead trees (class A: 10–29 cm diameter at breast height, dbh). However, there is a lack of larger trees (>30 cm dbh) and lying deadwood. One of the reasons is the threat of bark beetle (*Ips typographus* and *Pityogenes chalcographus*) for the forest, which requires consistent sanitary cutting. In addition, in managed forest deadwood and habitat trees are often removed, because of their low quality, a traditional view of the 'clean' forest and also for reasons of worker and visitor safety. In the case of Pahernik forest, the owner allows local people to collect the wood left on the ground and use it as firewood; this can also be partly the reason for the low amount of lying deadwood.

Even though the focus is on close-to-nature management, it is quite a challenge to increase the quantity of deadwood and old habitat trees. They are an important indicator for forest biodiversity since an important share of biodiversity is dependent on these features. With intensive forest management, it is even more important to include the deadwood conservation in forest management plans. Nevertheless, planned non-intervention and the long-term change of tree species composition will allow a gradual increase of habitat trees, logs, and snags (fig. C6.7).

Social aspect

Pahernik forest is frequently used for research and serves a wide community from science and forest practice for conducting training courses and excursions (fig. C6.8 and C6.9). The Pahernik Foundation provides financial support in the form of scholarships and grants to students and scientists for implementing research activities. The Pahernik Foundation helps to maintain several joint research plots for the University of Ljubljana and the Slovenian Forestry Institute. Every year, several graduate theses are accomplished with data from Pahernik forest. Further, this forest is important from historical and cultural points of view, since it is a good practice good example of close-to-nature forestry practice, which was applied in the twentieth century by the former owner Franjo Pahernik. As such, this forest is also included in the network of ProSilva Europe. The forest is visited every year by more than a dozen excursions of scientists, students, and forest practitioners from Slovenia and abroad. In September 2019, the participants of the 30th anniversary conference of ProSilva visited Pahernik forest.

In this forest there are some outstanding large and old trees, such as the Pahernik spruce. This spruce is one of the biggest in Slovenia and is a tree of national importance. Its height is 48 m and it has a circumference of 420 cm. The age is assessed at about 250 years.

Fig. C6.6. Streams in Pahernik forest are important from the view of habitat diversity (Photo: Anica Simčič).

Resilience

Recently in Slovenia we have faced many natural disturbances – from ice and snow to strong winds causing tree crown damage, stem breakage, and uprooting on extensive areas. Natural, uneven-aged, and mixed forests should have higher resistance to natural disturbances than even-aged monocultures. In parts of the Pahernik property, pure even-aged spruce stands still remain as a result of planting and natural succession on abandoned agricultural lands. The principal goal for adapting forest to the challenges of the future is a gradual reduction of the share of spruce over the property linked to an increase in the share of silver fir and in the lower altitude parts of the property, in increase in broadleaved species, especially oak (*Quercus petraea* and *Quercus robur*). In addition to the emphasis on improving the forest mixture, the emphasis is also on promoting a small-scale variability of forest structure and on favouring natural regeneration.

Fig. C6.7. Retention of snags in a stand (Photo: Anica Simčič).

Fig. C6.8. Many educational paths are located in Pahernik forest (Photo: Jurij Diaci).

Fig. C6.9. Educational and recreational role of Pahernik forest (Photo: Anica Simčič).

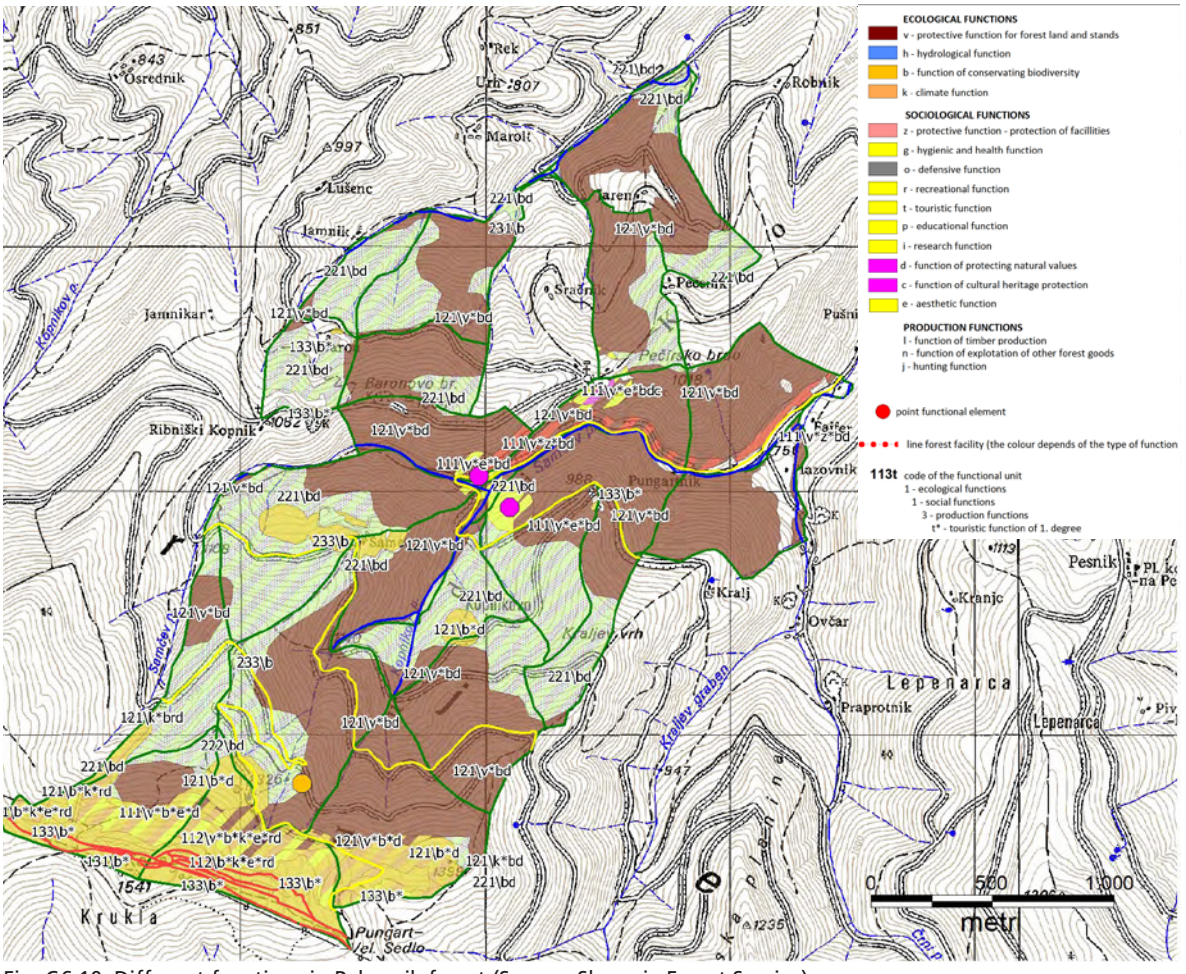


Fig. C6.10. Different functions in Pahernik forest (Source: Slovenia Forest Service).

The close-to-nature forestry system and selection principle will contribute to a high level of biodiversity of species and habitats, which leads to a natural and preserved forest.

Statement

The Pahernik forest has a special value for us foresters. In this forest, natural values, culture, history, education as well as timber production, coexist. There are so many different functions in one place, which are successfully coordinated with the help of the Slovenia Forestry Service. In Slovenia, sustainable, close-to-nature, multi-purpose, and sustainable forest management is determined by law. Forests like this are good practice examples and, therefore, need to be preserved for future generations.

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Box C 5

CO_2 certificates – an approach to save time and space for biodiversity and climate change

L. Friedli

Wald-Klimaschutz Schweiz

Background

Climate change is a global challenge and Switzerland has promised to reduce CO_2 emissions by 50 % (relative to 1990 levels) by the year 2030. The Federal Office of the Environment (FOEN), 'WaldSchweiz' (the federal level forest owner association), and the community and forest owner association of the Canton Solothurn (BWSo) have initiated a climate protection project. Following the innovative approach of the OAK Schwyz (see Box C 7 in this book), FOEN, WaldSchweiz and BWSo have started a project in cooperation with communities and private forest owners with the aim to use forests as temporary CO_2 sinks.

Rationale of the project

One of the main principles of the project is the promotion of the continued use of wood. The consumption of Swiss wood and the support of local value chains is promoted explicitly instead of importing wood and wooden products from other regions of the world. This means that this approach will lower the local timber harvest, but only to a small extent as the utilisation of wood is indispensable to maintain a wood producing and processing industry. By doing this, sustainable and healthy forests with suitable structures will be promoted, realising the maximum growth with optimal stock levels and, therefore, sequestering more CO_2. This will then result in an increased sink capacity with optimised timber production. At the same time, while a number of trees will get older, also habitats relevant for biodiversity conservation will be promoted.

The idea

In different projects oriented and tailored to specific local conditions, the concept is to sell certificates in managed forests for purposefully increased wood stock per hectare. The quantity of certificates generated by a project is calculated by comparing current stock levels (baseline) and the respective goals in the forest management plan with the (higher) goals set through a project. In another model, certificates are generated in forest reserves that remain untouched for at least 50 years, where biomass is accumulated naturally over time. The goal of the projects is to reach climate neutrality by compensating unavoidable CO_2 emissions in a certain place with CO_2 sequestration somewhere else. The project methodology was developed as a climate protection project in accordance with ISO 14064:2 (which specifies principles and requirements for quantification, monitoring and reporting of activities intended to cause greenhouse gas emission reductions) and certified by TÜV NORD. The Forest Climate Protection Switzerland Association keeps the project register and is the contact partner.

Bucheggberg Project

The Bucheggberg Forest Enterprise developed the initial project. It will run for 30 years on an area of about 1236 ha (2016–2046). During this time span more than 112 000 tons (3737 t/yr) of CO_2 will be stored in this forest area. The project planning has been carried out over the entire managed forest and obliges the operation over the duration of the project not to fully utilise the legal and silvicultural wood utilisation potential. The difference between the possible target stock of wood per hectare and the agreed, higher project stock will result in the annual amount to be marketed in the form of CO_2 certificates. Regular validations (every two years) ensure control and reliability.

The public forest owners represented by the Bucheggberg Forest Enterprise have decided, independently of the CO_2 project, to keep the proceeds generated by the sale of CO_2 certificates in a retention fund. The proceeds are thus only used for measures relating to climate change and nature conservation; they are thus once again used for near-natural and sustainable forestry. All related forest areas are certified according to Forest Stewardship Council (FSC) standards.

Homattflue-Goldbach Project (and its social impact)

In another project, the community of private owners of the Homattflue-Goldbach area in the Emmental, Canton of Berne, set up a forest reserve in which they refrain from any use of wood for

Fig. 1 Sequestration of CO_2 in trees depends on growth processes. Dendrometers can measure tree growth on a high resolution and allow measurements of carbon allocation (Photo: Andreas Rigling).

50 years. This will considerably increase the biomass stock. On the 27 ha of the reserve, around 10 000 t of CO_2 will thus be additionally stored in the biomass of the living trees. About the same amount will additionally be stored in the soil, (but this will not be counted), and larger amounts of carbon will be stored in deadwood. The area is an official reserve, in the canton of Berne. The total forest reserve provides habitat for a variety of protected and endangered animal and plant species.

In this rural area with very steep slopes, an economic forest and agricultural management are difficult to achieve, owing to expensive, but necessary logging methods. Thus, the community has given up logging entirely in favour of a state forest reserve contract. However, the state compensation payment was deemed to be insufficient to ensure the long-term upkeep of a traditional farmhouse on the property. Therefore, other solutions had to be identified. The now available option of a CO_2 project in combination with a reserve revived the previous plans. Contracts for the climate project were signed prior to the state instalment of the reserve, which followed shortly after. It is expected, that thanks to this solution, the property can be managed by its current owners for at least another 30 years.

Conclusion

These projects can make a small contribution to reducing the amount of CO_2 in the atmosphere is envisaged; such approaches can be used to gain time to reduce dependency on fossil fuels and the overall societal carbon footprint as well as to find sustainable and long-lasting solutions to sequester CO_2. This also allows preservation of other ecosystem service function of forests for the future, especially biodiversity conservation.

The approach is based on a calculation of emissions resulting in a climate balance where emitted CO_2 is quantified and set against sequestered CO_2. It is clear that this method will not solve the overall climatic crisis. However, it is an approach that can generate revenues for a forest ecosystem service that has hitherto not been compensated. It certainly depends on the age of the forest and on the conditions, but since old-growth forests are widely lacking, or at least rare, not only CO_2 sinks can be promoted by ageing forests, but also structures for biodiversity conservation can be supported. Though it is not always clear which species may benefit and which may not, it is undoubted that conditions for higher species diversity will increase with the age and size of trees.

Piwniczna – Multifunctional mountain forests: an example from southern Poland

C7

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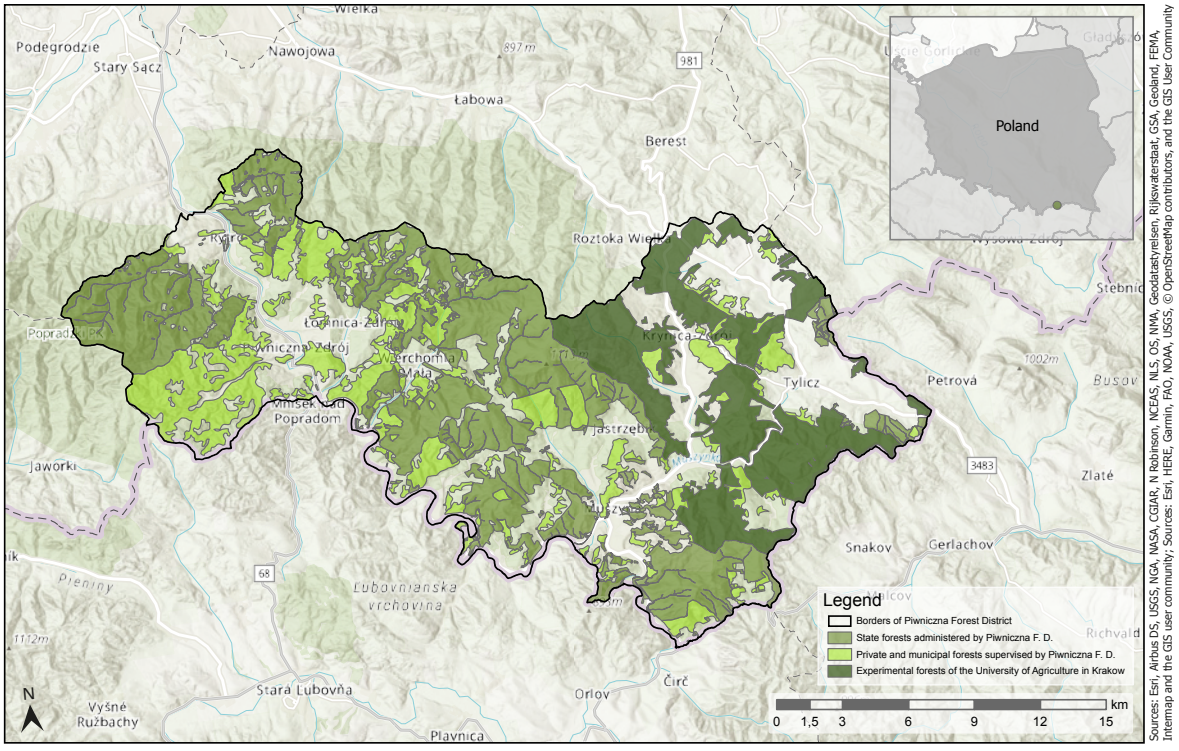
Context, legal frame, and ownership structure

Piwniczna Forest District (Piwniczna FD) is located in the Western Carpathians, in an area characterised by diverse topography and climatic conditions (fig. C7.1); the diverse conditions are reflected in the high diversity of plants and animals. Forests of the Piwniczna FD are home to all the large mammal predators (wolf, *Canis lupus;* brown bear, *Ursus arctos;* and lynx, *Lynx lynx*) of central Europe. There are 20 tree species, although only five of them are



< Fig. C7.1. General view of the Piwniczna Forest District – a typical landscape of the northern part of the Western Carpathians (Photo: Krzysztof Tomasiak).

Statement

"Our mission is the protection and development of forest resources along with the provision of various forms of recreation to the people and the production of high quality timber. An important part of our mission is forest education, realised using a well-developed educational infrastructure."

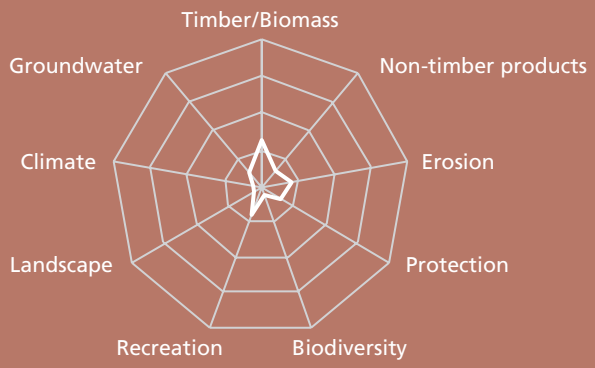


Table C7.1. General information on the forests of Piwniczna FD.

Forest community	Mostly fertile beech *(Fagus sylvatica)* forests, smaller areas occupied by silver fir *(Abies alba)* forests
Total forest area:	13 275 ha
Main management types:	Complex cutting systems, mostly irregular shelterwood system
Total volume	343 m³/ha
Annual growth	9.1 m³/ha
Annual use	7.75 m³/ha
Deadwood (standing and lying)	Total – 20.8 m³/ha (standing – 7.4 m³/ha, lying – 13.4 m³/ha)
Altitude	336 m – 1265 m
Ownership	State Forests
Geology	Carpathian Flysch – a mix of sandstones and shales
Protected area (total)	Nature reserves – 430 ha; landscape park covers 99 % of the area of Piwniczna FD
Nature protection area (Natura 2000)	Special area of conservation (SAC; PLH120019) – 13 099 ha Special protection area (SPA; PLB180002) – 174 ha; in total 99 % of the Piwniczna FD
Protective function	98 % of the Piwniczna FD has the status of 'protection forests'

abundant enough to play a significant role in the forest economy. The mean age of tree stands is 81 years. Forest management is very much focused upon the protective functions of the forest, and this is especially the case in the forest stands surrounding several spa resorts located in this region.

The entire Piwniczna FD is included in the Natura 2000 system. There are seven nature reserves, a dense network of hiking and bicycle trails, and several ski resorts. The administration of the Piwniczna FD supervises forest management in the private and municipal forests of the region.

Forest history and cultural heritage

The oldest tree stands in Piwniczna FD are about 175 years old, and there are individual trees older than 220 years old. Old stands and old trees are usually in nature reserves, but there are also some in parts of the managed forest (fig. C7.2 and C7.3). From the end of the thirteenth century until the end of the eighteenth century, large parts of these forests (about 3000 ha) were owned by the Catholic Church as the so-called 'Religious Fund'. When Poland lost its independence at the end of eighteenth century, these forests were taken by the government of the Habsburg Empire.

At first forest exploitation was based on large clearcuts, but later it was replaced by complex cut-

Fig. C7.2. Mature beech–silver fir stands are the main source of income for the Piwniczna FD (Photo: Krzysztof Tomasiak).

Fig. C7.3. A stand dominated by silver fir *(Abies alba)* with abundant regeneration of beech *(Fagus sylvatica)* (Photo: Krzysztof Tomasiak).

ting systems, with the clearcuts restricted to tree stands of poor quality or affected by disturbances. The owners of the forests have changed frequently. The last private owner of these forests was the Count Adam Stadnicki (1882–1982), himself a well-educated forester (Jaworski and Skrzyszewski 2016). At the beginning of the twentieth century Stadnicki established several forest reserves in his property; these were among the first protected areas in the Western Carpathians (Staszkiewicz 2000). That approach to forest management was very unusual at that time (Szwagrzyk and Bodziarczyk 2016). After 1945, the large forest owners were expelled by the communist government and the forests were nationalised; small forest farms and municipal forests were not nationalised. The area of national forests was expanded by almost 4000 ha by afforestation of the former arable lands and pastures. Former agricultural lands were mostly planted with Scots pine *(Pinus sylvestris),* and no tending was applied in the early age of those plantations because of the lack of labour.

In the years 1945–1951, the intensity of management was very low; the annual timber cut was less than 16000 m³, and cutting was mostly confined to removing dying trees. In the year 1951 the national forests were re-organised, and the Piwniczna FD in its current shape was created by merging three smaller forest districts. After 1951, forest management was based upon 10-years forest plans, although in the beginning the plans were rather simple; over time, they became more elaborate, putting more emphasis on adjusting the composition of forest stands to the local habitat conditions. In the 1950s and 1960s attempts to regenerate stands naturally were largely unsuccessful, and so planting of seedlings was widely applied. In the following decades, the silvicultural methods evolved, with natural regeneration becoming more dominant as the favoured form of regeneration, and consequently a change towards a more natural species composition of forest stands.

An important step forward in changing forest management in Piwniczna FD towards a close-to-nature silviculture was the establishment in 2004 of the Promotional Forest Complex Forests of the Beskid Sądecki Range, encompassing Piwniczna FD, the Experimental Forests of the University of Agriculture, and (since 2011) also the Nawojowa FD, bordering Piwniczna in the north. The Promotional Forest Complexes in Poland are expected to promote the sustainable forest management and to conduct forest education. In December 2008, almost all forests of the Piwniczna FD were included in the Natura 2000 system.

Aims of the enterprise

The aim of the Piwniczna FD is balancing timber production with provision of a wide range of ecosystem services. Protective functions and providing ecosystem services are priority aims. As a part of the Polish National Forest Holding, each forest district can be supported financially from the national Forest Fund to allow the districts to provide these protective and ecosystem services in cases where the income from selling timber is not enough to cover the costs of forest management.

Economy

The mean annual income of the Piwniczna FD from selling timber during the period 2016–2018 amounted to 11891262 PLN (2765401 €); the income from other sources was equal to 635669 PLN (147830 €), and so the total yearly income was about 12526931 PLN (2913240 €). Total annual costs amounted to 16218878 PLN (3771832 €), higher than the annual income, and so the difference is covered by the central Forest Fund. The highest share of the total costs (37 %) were the costs of cutting and extracting timber, which was done by contracted companies. Costs of maintaining the forest administration (employee salaries) amounted to 34.7 % of total costs, and 18.9 % is spent on maintaining and developing the infrastructure, especially forest roads. The costs of planting seedlings are about 3 %, and the costs of tending young stands are about 2.2 %. Another 3 % is spent on the protection of forest stands. Almost all forest districts in mountain areas are supported by the Forest Fund because of the higher costs of forest operations in the rough terrain; however, over 90 % of national forests in Poland are in lowland areas and they contribute to the Forest Fund.

In the next decade (2019–2028), timber cutting in Piwniczna FD will increase by 21 %. The area of planting will decline by 43 %, so the costs of planting and tending will go down. The costs of timber cutting and timber extraction are expected to

Fig. C7.4. Springs and mountain streams are important for the economy of the region (Photo: Krzysztof Tomasiak).

increase, as is the income from selling timber. However, the future relation between costs and income is difficult to predict.

Ownership structure

Piwniczna FD is a part of the National Forest Holding, and the forests belong to the state. Administration of the Piwniczna FD supervises the forests belonging to other owners; that supervision is based upon the agreement with the local administration. The area of supervised forests is about 6846 ha; they are scattered over the entire area of Piwniczna FD (see fig. C7.2). About 731 ha of forests belonging to Piwniczna FD have been excluded from timber production; these are mostly the forests immediately surrounding the spa resorts.

Most important services and products

The main product of Piwniczna FD, is high quality timber, mostly beech, silver fir, Norway spruce *(Picea abies),* and European larch *(Larix decidua).* The mean annual timber cut during the period 2016–2018 was 59 365 m³. The average value of timber is 200.3 PLN/m³ (46.6 €/m³). Another source of income is hunting; each year on average 126 red deer *(Cervus elaphus),* 50 roe deer *(Capreolus capreolus),* and 110 wild boar *(Sus scrofa)* are killed by hunters in the forests of Piwniczna FD. The total income from hunting is 200 000 PLN (46 511 €). Another important forest product is honey; there are about 200 beekeepers in the area of Piwniczna FD, and the annual production of honey is about 8 litres per bee-hive. The total value of honey produced annually in the forests of Piwniczna FD is 640 000 PLN (148 837 €). Of the ecosystem services provided by the forests of Piwniczna FD, the most important one is drinking water, including various kinds of mineral water from numerous springs (fig. C7.4). The other important ecosystem services are biodiversity protection and recreation. There has been valuation of these services.

Specialities/Rarities

The area is characterised by the presence of many rare plant and animal species, as well as rare habitat types. With respect to plants, there are 53 plant

Fig. C7.5. Steep scree slopes with rocky outcrops are the typical habitats of sycamore forests (*9180-2 Natura 2000) (Photo: Jan Bodziarczyk).

species present in Piwniczna FD that are legally protected in Poland, and 10 of those are included in the Polish Red List of Plants (Kaźmierczakowa *et al.* 2014).

Among the 36 protected species of animals occurring in Piwniczna FD, 14 are in the Red List of Animal Species (Głowaciński 2001). The most interesting habitat type is the sycamore *(Acer pseudoplatanus)* forests on steep slopes (*9180 Natura 2000). It occurs in areas with numerous rocky outcrops, frequently affected by landslides and rockfall, typically on north-facing slopes characterised by cool and humid microclimates (fig. C7.5). Patches are small, and they cover in total 5.3 ha; all are excluded from regular timber production. Typical species associated with this habitat include the Hart's tongue fern *(Phyllitis scolopendrium)* (fig. C7.6) (Bodziarczyk and Szwagrzyk 1995; Bodziarczyk 2012). In small river valleys there are patches of riparian forests representing the Alno-Ulmion alliance (*91E0 – Natura 2000), covering in total 21.7 ha. A rare specialty of Piwniczna FD is the submontane broadleaved forest dominated by small-leaved linden *(Tilia cordata)* (fig. C7.7), with individual trees over 200 years old, with a maximum height of 45 m and a maximum diameter at breast height (dbh) of 138 cm. The mean standing volume is 549 m³/ha, and in one compartment it reaches 757 m³/ha. This forest is a nature reserve, covering 113 ha.

An important specialty of Piwniczna FD is also the occurrence of all central European large mammal predators: wolf *(Canis lupus),* lynx *(Lynx lynx)* (fig. C7.8), and brown bear *(Ursus arctos)* (Okarma 2000). Wolves and lynx breed regularly in local forests; brown bear dens are found occasionally. Among protected bats in Piwniczna FD the most common are: Bechstein's bat *(Myotis bechsteinii),* Geoffroy's bat *(Myotis emarginatus),* greater mouse-eared bat *(Myotis myotis),* and lesser horseshoe bat *(Rhinolophus hipposideros).* Rare bird species include the golden eagle *(Aquila chrysaetos),* lesser spotted eagle *(Aquila pomarina),* Ural owl *(Strix uralensis)* (fig. C7.9), black stork *(Ciconia nigra),* European green woodpecker *(Picus viridis),* white-backed woodpecker *(Dendrocopos leucotos),* three-toed woodpecker *(Picoides tridactylus),* and red-breasted flycatcher *(Ficedula parva).* There are

Fig. C7.6. Hart's tongue *(Phyllitis scolopendrium),* a rare species typical of the sycamore forests, protected in most European countries. In Piwniczna FD, the sycamore forests are excluded from timber production (Photo: Jan Bodziarczyk).

Fig. C7.7. Las Lipowy Obrożyska forest reserve, established in 1919 as one of the first reserves in the Western Carpathians, protects an old-growth stand dominated by *Tilia cordata* (Photo: Krzysztof Tomasiak).

Fig. C7.8. Eurasian lynx *(Lynx lynx)* – a rare and protected species, finds good habitats in the forests of Piwniczna FD. There is a high density of potential prey, especially roe deer. Inaccessible ravines and steep slopes with rocky outcrops provide safe sites for breeding (Photo: Automatic camera/Archives of Piwniczna FD).

Fig. C7.9. Old beech–fir stands are inhabited by the Ural owl *(Strix uralensis)* – a strictly protected species, also listed in the Bern Convention (Photo: Krzysztof Tomasiak).

Fig. C7.10. Łabowiec Reserve – the most natural forests are protected as nature reserves. These areas are home to many species typical of old-growth stands (Photo: Krzysztof Tomasiak).

also capercaillie *(Tetrao urogallus)* and eagle owls *(Bubo bubo);* a quite common bird in mountain meadows is the corncrake *(Crex crex)* (Wilk *et al.* 2016). Among the rare insect species, the most interesting ones are *Carabus variolosus* and *Rosalia alpina.*

Nature conservation

Piwniczna FD is 99 % covered by Natura 2000 – SAC PLH120019 (13 099 ha) and SPA PLB180002 – (174 ha), as well as by the Popradzki Landscape Park. There are seven nature reserves with a total area of 430 ha. Six of them protect old-growth forests (fig. C7.10), and one is a landscape reserve located in the area of high historic value. Eight habitat types (including six forest habitats) are listed in the Natura 200 Habitats Directive; among them are the fertile beech forests, acidophilous beech forests, montane spruce-fir forests, sycamore forests, mixed broadleaved forests, and riparian forests, as well as *Molinio-Arrhenetheretea* meadows and matgrass pastures *(Nardetalia),* characterised by the presence of *Nardus stricta.*

Population/Recreation

The local population is still strongly dependent on the forests of the region, especially with respect to use of wood from local sources. Apart from fuelwood, the local inhabitants also buy construction wood (on average 4500 m³ annually, i.e. 7 % of all timber cut in Piwniczna FD). The picking of berries, mushrooms, and medicinal herbs in the forest are also important for local people. The well-developed ski resorts and dense networks of hiking and biking trails attract a lot of visitors and are an important part of the local economy. Kayaking on the Poprad River is also becoming a major tourist attraction. Infrastructure supporting tourism is well developed, and so are the local spa resorts, and some of them have been in continuous operation since the middle of the nineteenth century. Recently, the number of domestic and foreign tourists visiting the spa resorts of Krynica Zdrój, Muszyna, Żegiestów, and Piwniczna amounted to one million per year.

Strengths and weaknesses

Management: An important advantage of the management of state forests is the scale of the enterprise (almost 80 % of all forests in Poland belong to the National Forest Holding). That allows for subsidisation of some of the 430 forest districts from the national Forest Fund. Forest districts that are subsidised are either working in difficult conditions (for example, in industrial areas with extensive needs for forest restoration) or in areas of high natural value, where the intensity of timber production is lower because of the nature conservation priorities. This is the case for the Piwniczna FD. Other strengths are: well-educated staff, well-developed infrastructure, and a functional information system.

Policy: The involvement of state forests in supervising forest management in private and municipal forests is also considered an advantage. Piwniczna FD cooperates with the local forest owners in developing and maintaining the network of forest roads, as well as in developing hiking and biking trails.

Among the weaknesses is the ongoing argument with the local communities concerning the further development of ski areas. Apart from the existing modern ski resorts, some local businesses plan to develop several new ones, which could be a threat to nature conservation, for example to the populations of capercaillie and the large predators.

Fig. C7.11. Nature education conducted by the local Piwniczna FD foresters is one of the benefits to local children and visitors (Photo: Mieczysław Karwala).

On the other hand, there is potential for the future development of nature-oriented tourism (e.g. bird watching or wildlife tracking) in Piwniczna FD.

Science: Scientific exploration of this area dates back to the beginning of the twentieth century.

The early studies were focused upon the mineral springs and opportunities to use the local waters for activities related to human health (Rajchel *et al.* 1999, Porwisz *et al.* 2011). Early botanical and phytosociological studies (Staszkiewicz 1972) led to the establishment of a network of nature reserves in this area. Recently, there have been numerous studies focused upon monitoring of the populations of rare plants and animals; these studies have been associated with the implementation of the Natura 2000 system.

Communication: Extensive education about nature and forestry is one of the strengths of the Piwniczna FD (fig. C7.11). That education is focused on children, but recently it has also increasingly been targeted towards adults. During the last decade, the employees of Piwniczna FD have conducted 1349 field classes and workshops, and these were attended by 190 600 people of all ages. Among them were international groups from Germany, France, Italy, Hungary, and Slovakia. Other advantages include: good relations with the local media, active Facebook page of the Piwniczna FD, and participation in many local cultural events. The weak point is the increasing criticism of timber cutting that has been increasing in the Polish society, especially in metropolitan areas. To a large extent this has been triggered by the strong controversy concerning the Białowieża Forest in the years 2016–2017.

Nature conservation: In Piwniczna FD the controversies between timber cutting and nature conservation are still marginal, and cooperation between foresters and administrators of protected areas (RDOŚ, Regionalna Dyrekcja Ochrony Środowiska; Regional Directorate for Environmental Protection) is very good. In many cases the foresters have initiated the efforts to establish new nature reserves or to enlarge the existing ones. Another area of cooperation between foresters and nature conservationists are the efforts to stop the expansion of ski resorts, which nowadays represent the major threat

to nature in this region. Apart from that, the attitude of local communities towards nature conservation is positive, as the inhabitants of the region recognise the economic benefits of tourism associated with well preserved, close-to-natural forests.

Conclusion

Piwniczna FD is a good example of mixing timber production with the conservation of nature. Maintaining that balance is not easy; not all forest districts within the National Forest Holding are doing equally well in that respect. Having a good organisation and a sound financial system is a prerequisite for attaining this delicate balance. However, keeping it for a longer time needs a lot of effort and strongly depends on the people involved in that process.

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Nyon-St-Cergue – a case from western Switzerland

C8

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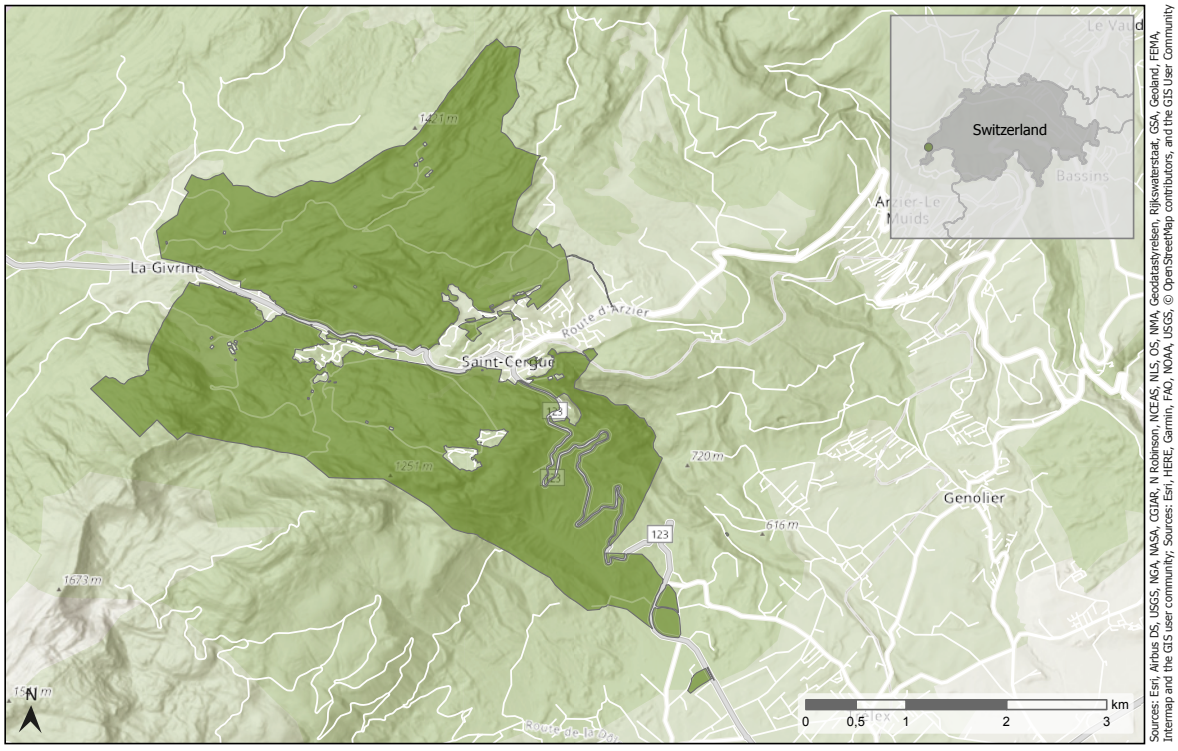
Portrait of the enterprise – important numbers and figures

Our objective is to reconcile, in a sustainable and efficient way, the production of high-quality wood, the conservation of wooded pasture landscapes, and the protection of animal and plant species identified as a priority at the Swiss level.



< Fig. C8.1. Wooded pastures in the Swiss Jura mountains have a long history. In addition to traditional summer livestock farming and timber production, the Jura is becoming increasingly important for summer and winter tourism thanks to its scenic beauty. Our management must therefore take many aspects into account at the same time (Photo: Alain Perusset).

Statement

"Our activity aims at implementing multi-functional forestry."

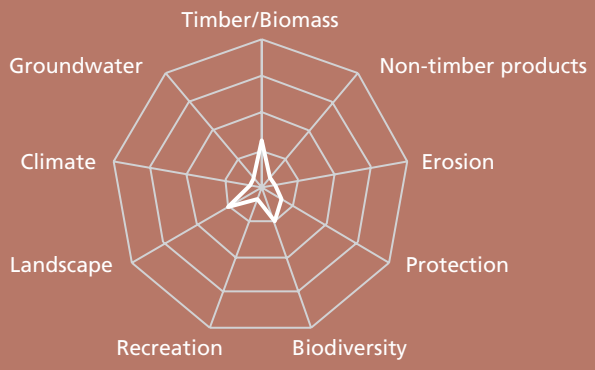


Table C8.1. General information on the forests of Nyon-St-Cergue.

Forest community	Côte du Jura: mixed beech *(Fagus sylvatica),* and silver fir *(Abies alba).* Mountain forests: mixed Norway spruce *(Picea abies),* silver fir, and beech
Total forest area	1391 ha
Main management types	Progressive shelterwood cutting (coupe d'abri cuttings) (Côte du Jura) and selection cutting system (mountain forests)
Total volume	250 m³/ha (Côte du Jura), 340 m³/ha (mountain forests)
Annual growth	6.2 m³/ha (Côte du Jura), 5.4 m³/ha (mountain forests)
Annual use	4.3 m³/ha (1977–2016: 3273 m³ by Nyon and 2650 m³ by St-Cergue)
Deadwood (standing and lying)	12–15 m³/ha
Altitude	600–1500 m
Ownership	Community forest
Geology	Hard limestone (Malm era), often outcropping with different karst forms (lapiez); marly limestone; Quaternary moraine on the Jura slopes
Forest reserves	70 ha (in progress)
Old-growth islands	32 ha (in progress)
Habitat trees	150 (in progress)
Protective function	43 ha

Landscape context, site, and important functions

The forest enterprise Nyon-St-Cergue manages forests between 600 and 1500 m a.s.l. in the western part of the Jura Mountains, northwest of the city of Nyon. These forests cover the first Jura slope overlooking Lake Geneva, extending as far as the Haut-Jura, the highest part of the Jura. They are located at the interface between a region with high population growth (Lausanne–Geneva agglomeration) and the large wild spaces of the Haut-Jura. The forest enterprise is thus both within the perimeter of the Regional Nature Park 'Jura Vaudois' and the perimeter of the Greater Geneva urban area.

The forests extend over 1391 ha including 318 ha of wooded pastures (866 ha belonging to the Commune of Nyon and 525 ha belonging to the Commune of St-Cergue); the vast majority of the land is publicly owned. The main plant associations are different beech *(Fagus sylvatica)* forest associations below about 900 m a.s.l., and mixed beech–spruce–fir *(Fagus sylvatica–Picea abies–Abies alba)* forests at higher altitudes.

We distinguish three different management units, each with specific main functions (fig. C8.2a–c):

(a) Regular productive forests on the first slope of the Jura overlooking the Lake of Geneva (about 315 ha): the main functions are wood production and landscape protection.

Fig. C8.2a. Regular productive forests (Photos: © CNES, Spot Image, swisstopo, left; Alain Perusset, right).

Fig. C8.2b. Irregular forests in the Haut-Jura, not used by livestock (Photos: © CNES, Spot Image, swisstopo, left; Jean Rosset, right).

Fig. C8.2c. Wooded pastures and forests used by livestock (Photos: © CNES, Spot Image, swisstopo, left, Jean Rosset (right).

(b) Irregular forests in the Haut-Jura, not used by livestock (about 758 ha): the main functions are wood production, biological protection, and, locally, protection against natural hazards (above roads and railways).

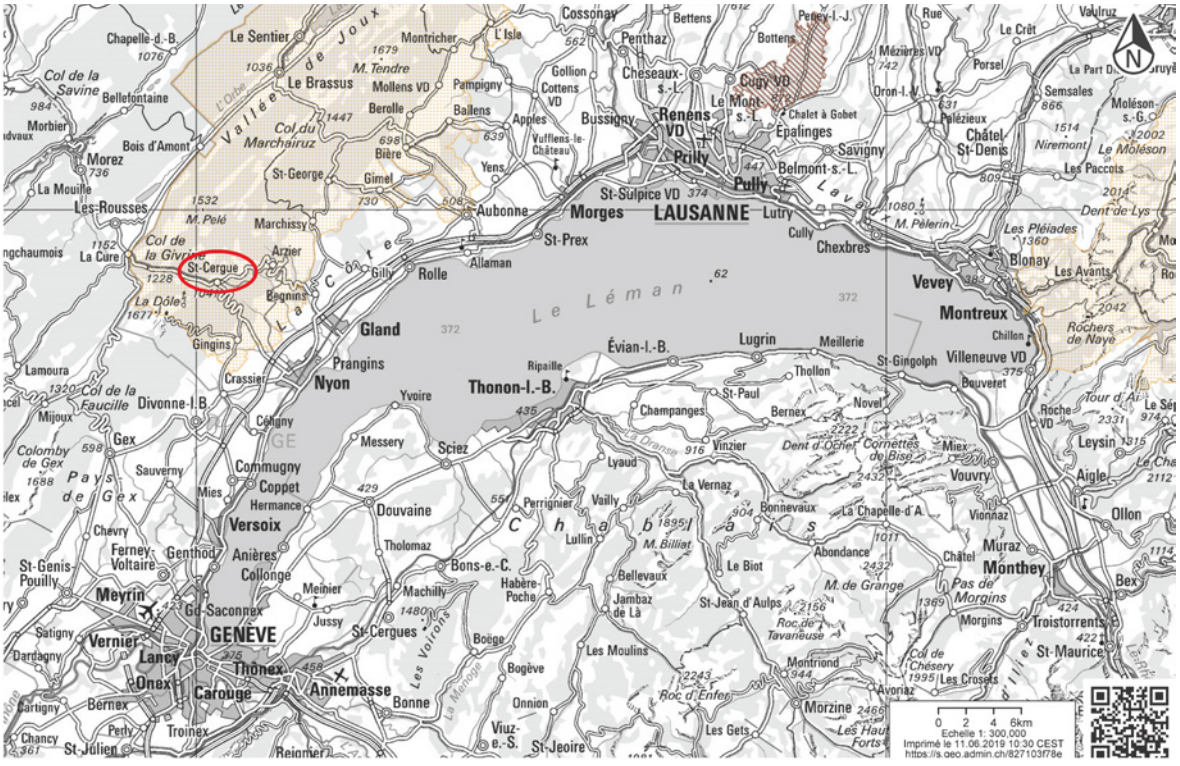
(c) Wooded pastures and forests used by livestock (318 ha): the main functions are production of wood, milk, and meat (pasture), landscape protection, and biological protection.

Forest history and cultural heritage

Viewed from Lake Geneva (fig. C8.3), the Jura Mountains seem almost completely covered by forests. Once on the ridges, however, the traveller notices that the forests are part of a mosaic with pastures and wooded pastures. Indeed, our ancestors exploited these mountain forests, opened the valleys to put their cattle there, and unintentionally created a beautiful landscape made of large sunny valleys, narrow, more intimate valleys, and vast forests like at the end of the world. The characteristics of the Nyon-St-Cergue forest enterprise are closely linked to the history of this region. Therefore, to understand the current management challenges it is necessary to provide a brief historical overview.

Evidence of pre-Roman settlements in the Jura is weak, but it is very likely that people already used the forests and created pastures. From the Middle Ages to the twelfth century, the Jura was colonised by monasteries. The monks encouraged the clearing of forests. In the twelfth century most of the pastures were grazed by sheep reared for wool. From 1250, cows regularly appeared on the mountain pastures and cheese was produced. People were also allowed to graze livestock in the forest. Therefore, at the end of the sixteenth century and during the whole of the seventeenth century, the pressure on forests had increased sharply and the forests were overexploited. There was a huge demand for wood for construction, heating, blast furnaces, and glass factories. A large quantity of wood was transported down to the plains to be used as fuelwood and for stakes in vineyards. In the eighteenth century, the forests of the Vaud region seemed to be in very poor condition, and those of Nyon-St-Cergue were completely ruined.

In 1806, the new canton of Vaud created a forest administration, and in 1810 it enacted its first forestry law: forest management became mandatory, slopes could no longer be cleared, logging was limited to annual increases, and regeneration was encouraged. The second law in 1835 went fur-


Le Léman
LAUSANNE
Morges
Nyon
Thonon-l.-B.
Évian-l.-B.
Gland
Rolle
St-Prex
Aubonne
St-Cergue
Vevey
Montreux
Villeneuve VD
Monthey
Bex
Aigle
Leysin
Ollon
Versoix
GENÈVE
Meyrin
Vernier
Lancy
Onex
Thônex
Carouge
Annemasse
Bons-e.-C.
Douvaine
Sciez
Yvoire
Prangins
Gingins
Arzier
Le Brassus
Col de la Savine
Col de la Faucille
Col du Marchairuz
Col de la Givrine
Dent d'Oche
Dent de Lys
Pays de Gex
Vallée de Joux
Lac de Joux
Lac de Bret
Les Voirons
Roc d'Enfer
Roc de Tavanesse
Les Diablerets
Les Rochers de Naye
Les Pléiades
Les Avants
Les Paccots
Le Moléson
Châtel-St-Denis
Semsales
Oron-l.-V.
Puidoux
Chexbres
Cully
Lutry
Pully
Prilly
Renens VD
Crissier
Ecublens VD
Chavannes-près-Renens
Bussigny
Cheseaux-s.-L.
Penthaz
Cossonay
Penthalaz
Chapelle-d.-B.
Le Sentier
Montricher
L'Isle
Bettens
Penthalaz
Gollion
Cottens VD
Pampigny
Mollens VD
Berolle
Ballens
Apples
Vufflens-le-Château
Yens
Gimel
St-George
Bière
Morez
Bois d'Amont
Morbier
Bellefontaine
La Mouille
Les Rousses
La Cure
Marchissy
Begnins
Gilly
Allaman
Lavaux
Epalinges
Savigny
Belmont-s.-L.
St-Sulpice VD
Lausanne
Chalet à Gobet
Le Mont s.-L.
Cugy VD
Mézières VD
Porsel
Le Crêt
Vaulruz
Semsales
Pelézieux
Châtel-St-Denis
Les Paccots
Le Moléson
Niremont
Blonay
Chillon
Villeneuve VD
St-Gingolph
Bouveret
Tour d'Aï
Roche VD
Vouvry
Vionnaz
Muraz
Monthey
Pas de Morgins
Troistorrents
St-Maurice
Col de Chésery
Les Crosets
Morgins
Avoriaz
Morzine
Les Gets
Les Hauts Forts
Onnion
Viuz-e.-S.
St-Jeoire
Reignier
Bogève
Les Moulins
Boëge
Habère-Poche
Machilly
Jussy
Meinier
Gd-Saconnex
Satigny
Dardagny
Russin
Aire-la-Ville
Bernex
Cartigny
Chancy
Petit-Lancy
Troinex
St-Julien
Genthod
Bellevue
Collonge
Anières
Hermance
Coppet
Commugny
Céligny
Mies
Sauverny
Gex
Messery
Tholomaz
Perrignier
Lullin
Vailly
Lyaud
Vinzier
Champanges
St-Paul
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Lugrin
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Yvoire
Divonne-l.-B.
Lamoura
Mijoux
Colomby de Gex
Chevry
Ferney-Voltaire
St-Genis-Pouilly
Pougny
Chancy
Bonnevaux
La Chapelle-d'A.
Abondance
Le Biot
Bellevaux
Jambaz de Là
St-Jean d'Aulps
M. de Grange
M. Billiat
M. Pelé
M. Tendre
M. Pélerin
Dent d'Oche
Cornettes de Bise
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Leysin
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Onnion
Viuz-e.-S.
St-Jeoire
Reignier
Bonne
Annemasse
Thônex
Onex
Carouge
Lancy
Vernier
Meyrin

Fig. C8.4. Spruce is the tree species generating the most income (Photo: LFI/WSL).

ther by imposing training on foresters, restricting the movement of goats and cattle, and further limiting theft and smuggling of wood. The industrialisation of the plain caused a rural exodus and a decrease in the need for resources from the Jura Mountains. Some pastures were abandoned or concentrated on the best soils, while others were used for the summer grazing of livestock from the plain. As a result, the forests slowly recovered.

Forest inspectors played a major role in guiding forest restoration. The first movement was that of caution in trying to capitalise, allowing as many trees as possible to grow to recreate a dense and rich forest. Around 1930, however, forestry took a new turn with the introduction of selection cuttings ('jardinage'). The aim of this type of exploitation is to obtain and maintain, through silvicultural measures, an irregular forest structure with all age groups represented and regeneration ensured in a continuous and natural way.

Yet several recent problems are likely to have a major influence on forest management in the coming decades.

Aims of the enterprise and management

The management objectives and measures differ between the three management units. Different silvicultural techniques practiced at a fine scale vary from progressive to selection cutting.

a) In regular production forests:
The main objective is to enhance the value of wood production in regular forests (fig. C8.2), particularly those with ideal stable conditions (soil, slope, orientation, etc.), while preserving the landscape and the quality and tranquillity of the natural environment. The silvicultural system aims to mainly produce high-quality sawn timber, while preserving particular microsites (rocky and dry areas, wetlands, etc.).

In particular, we:
- promote natural regeneration and limit planting to possible supplements;
- apply differentiated cultural care to reduce costs: (i) moderate care in most young stands, (ii) traditional

care in areas where exceptional wood quality can be expected, and (iii) minimal care in areas where only mass production is expected;
– take the necessary measures to prevent game damage only in areas where high-quality timber can be expected.

b) In irregular forests in the Haut-Jura (not frequented by livestock):

The main objective is to manage forests in an integrated manner, taking into account the production of high-quality wood and the conservation of priority animal and plant species at the Swiss level, such as capercaillie *(Tetrao urogallus)* or species depending on old trees and deadwood.

In particular, we:
– aim at and permanently preserve an irregular mosaic forest of different age groups, with preferably a horizontal structure in groups of 0.02–0.1 ha;
– reduce the growing stock to 250–280 m³/ha, including a volume of 10–20 m³/ha of broadleaved trees;
– aim for a coverage of the main stand of 50 % to 70 % to obtain an open and clear structure (ideal for capercaillie);
– promote the natural regeneration of coniferous tree species in groups;
– fight against the invasion of beech on hills, small flats, and blueberry *(Vaccinium myrtillus)* areas (important for capercaillie);
– favour softwood species, shrubs, bushes, and berry bushes, especially blueberries and raspberries *(Rubus idaeus);*
– preserve branchy trees that can be used as dormitories and pantry for capercaillie (firs and some beeches and sycamore, *Acer pseudoplatanus*);
– select, mark, and protect habitat trees until they collapse completely, and keep standing dead trees.

c) In wooded pastures and forests used by livestock:

The main objective is to pursue sustained silvicultural and pastoral management to enable the conservation of landscape and biological values. The forest service and grazing farmers must coordinate to work towards the same aims: find a balance to prevent woodlands from becoming too dense and pastures from losing isolated trees. The forestry service must thin the woodlands to ensure that there is enough light in the pastures to maintain grassland production. On the other hand, grazing farmers should not cut down all young spruces and other shrubs in the pastures to ensure the regeneration of trees.

In particular, we:
– harvest trees to revitalise areas abandoned by livestock;
– intervene on young stems invading pastures (clearing) during logging operations;
– plant small tree groups and protect existing ones from livestock to renew isolated trees in pastures.

Challenges

Nowadays, local landscape managers are looking for ways to reconcile agricultural, silvicultural, touristic, and ecological interests in wooded pastures. The aim is to strike a balance between wood production, the conservation of threatened animal and plant species, the landscape protection of wooded pastures with their exceptional biodiversity values, and leisure activities. In order to prepare for the future, numerous challenges must be met.

1. Reduce the loss of landscape and biological diversity

The productionist policy that prevailed in the 1950s to 1970s led the forester Edouard Rieben (1957) to advocate a clear separation between forests and pastures. The purpose of silvicultural and pastoral development at that time was to define one activity per area (either forestry or agriculture) to facilitate management of the land and increase the economic productivity of both agriculture and forestry. As a consequence, the forest density and growing stocks became higher. Slowly but surely, this sectorisation led, in some areas, to the intensification and concentration of pastoral activity, in parallel with the extensification of wooded areas followed by scrub encroachment and forest growth in large areas of pastureland (fig. C8.5). While this development has advantages for forests, its drawbacks are the loss of biological and landscape diversity represented by wooded pastures. More intensive graz-

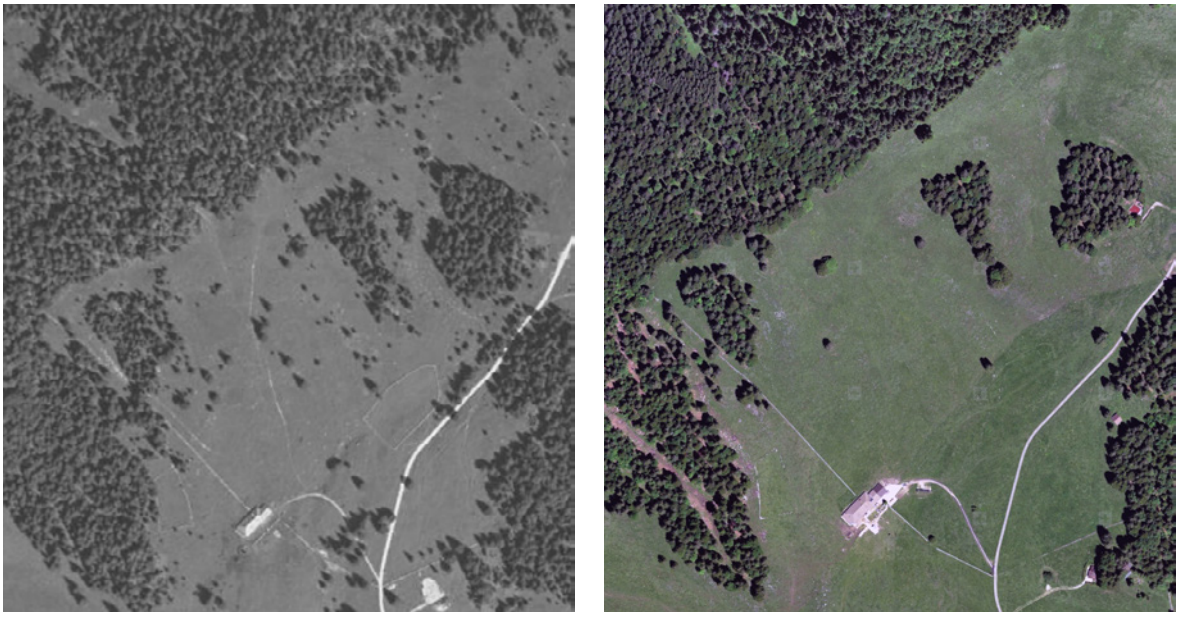

Fig. C8.5. Wooded pasture landscape 1933 (left) and today (right). Pastures and forest areas are less interwoven today than earlier, with forests became denser and single pasture trees becoming less common (Photos: © swisstopo, left; © CNES, Spot Image, swisstopo, right).

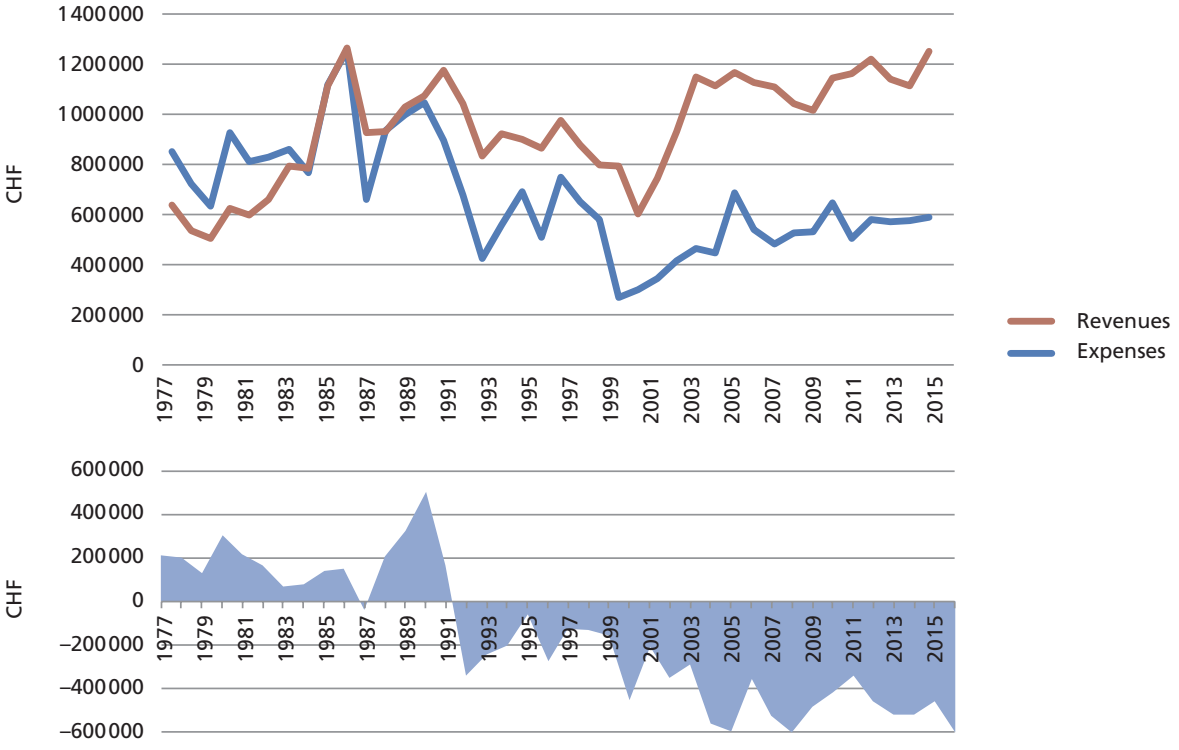

Fig. C8.6. Revenues and expenses (above) and yearly results (below) of the forest enterprise since 1977 (Result with public subsidies).

ing has a negative impact on biodiversity in wooded pastures, while denser forests harbour less thermophilic and edge species than loose woodland pastures. To slow down and maybe reverse the landscape and biodiversity loss, a close collaboration between the forest enterprise and agricultural enterprises is necessary: more intensive logging to reduce growing stocks in certain areas, but better preserving a fragile environment with shallow soils on karst, and dry and low-fertility pastures sensitive to both the passage of machinery and application of fertiliser.

2. Economic sustainability

There was a time when forests were the wealth of communes. Since the mid-1980s, however, timber exploitation has been in deficit, since revenues from the wood sale are decreasing, while wages are rising. Government subsidies have not changed this situation much, although they have reduced the deficit a little (fig. C8.6). In addition to the active forest-pasture separation, reduced wood harvesting contributed to the densification of forests discussed before, with its negative impact on biodiversity. The forest enterprise's challenge is to find a balance between revenues and expenses.

3. Find a balance within measures for different aspects of biodiversity

Wooded pastures and the irregular forests of the Haut-Jura are a cultural ecosystem of tremendous ecological and landscape value. They provide shelter for a great diversity of species, including the emblematic capercaillie *(Tetrao urogallus).* Present in coniferous forests since the last ice age, capercaillie has become a synanthropic[1] species (follower of civilisation) since the Middle Ages: overexploited at that time, the forests became clear and well structured, offering ideal conditions for capercaillies. In addition to intensive logging, forest grazing and litter use contributed to creating an ideal habitat for this species. However, the closed forest conditions of recent decades has been unsuitable for capercaillies. For a decade, biodiversity measures have mainly focused on improving the capercaillie habitat. One of the measures is the systematic cutting of old beech trees to prevent excessive regeneration, thought to be an impediment for capercaillies. While this measure probably favours the capercaillie, it nevertheless disadvantages saproxylic[2] species and secondary cavity nesters, such as the Tengmalm's owl *(Aegolius funereus).* As a whole, measures in favour of capercaillie populations are costly and entail multiple constraints. In addition, the future of capercaillie in the Jura mountain is uncertain because of climate change and increasing human pressure. Thus, we have to rethink the balance between the means deployed for this emblematic species and the probability of conserving it in the future. The main issue is how to find a sound balance between specific measures in favour of capercaillie and measures for other species or species groups, such as saproxylic species. Recently, therefore, measures have become more varied, with particular emphasis on retaining habitat trees and creating forest reserves and old-growth islands to promote natural processes and saproxylic species. Currently, forest reserves extend over 70 ha and old-growth islands over 32 ha. In addition, 150 habitat trees have been retained (with this number increasing). Public subsidies have facilitated the implementation of such measures.

4. Define the future status of beech

Beech is a naturally occurring species at all altitudes in the forest enterprise. However, because of the past overexploitation of this excellent firewood, the species had declined sharply. Grazing in the forest also limited its regeneration. Today, nothing prevents its growth, and after each wood felling it takes the opportunity to invade the openings and thus shades spruce seedlings. Fostered by climate change, it is expected that beech will become even more competitive. Nowadays forest managers try to contain it, although at great expense, because of its low economic interest. The question arises as to what status beech will have or should have in the future.

5. Game management and forest regeneration

[1] A synanthropic species (from the Greek syn-, "together with"and anthropos, "man") is a wild animal or plant species that lives near, and benefits from, an association with humans and the somewhat artificial habitats that humans create around themselves.

[2] A saproxylic species is a species depending, at least during a part of its life cycle, on veteran trees or deadwood, or on other species that are themselves dependent on deadwood.

An important issue for the past two decades has been the high density of game, especially red deer *(Cervus elaphus).* After its complete disappearance from the Jura Mountains at the beginning of the last century, red deer have gradually and naturally recolonised the Jura Vaud for around 20 years. The absence of natural predators has, so far, led to a difficult situation today. The pressure on regeneration from browsing of broadleaf species and fir is high in some parts of the forest area. Therefore, it is becoming more and more problematic to regenerate the forest with adequate tree species, especially fir, mountain maple, and other broadleaf species. The lack of sufficient regeneration of adapted tree species might become problematic in the coming decades with the expected climate changes. The challenge is to get a sound game management in this region.

6. Management of leisure activities and social aspects

St-Cergue is a small summer (walking, mountain biking, etc.) and winter tourism resort (snowshoeing, cross-country and alpine skiing, ski touring, dog sledding, etc.). As in all 'natural' regions close to urban areas, the silvo-pastoral mountain area must increasingly fulfil a new role: welcoming the public. Every year more people come to get some fresh air, walk, ski, cycle, picnic, etc., in the Jura Mountains. Pastures and forests must, therefore, offer the desired calm and beauty; wooded pastures particularly fulfil this role.

Therefore, it is important to practice an integrative management, which must regularly adapt to changes both in terms of the expectations of the population and the protection needs of the natural environment. In addition to the traditional management plan, we need a strong guiding planning document to frame and guide forest management and silviculture. The forest master-plan is currently in preparation at the scale of the 32 000 ha of forests in the Jura Mountains in the western part of the Canton of Vaud.

Resilience

For about a decade, we (the forest service) have encouraged the public forest owners to create an ecological infrastructure in the form of a network of forest reserves, old-growth islands, and habitat trees, covering 10 % and 3 % of the forested area with the aim to support and increase the resilience of the ecosystem.

Conclusion

This example shows a case of complex management of a cultural landscape with a long history. The fine-scale and adaptive silviculture, which is necessary to meet multiple objectives, including ecological and landscape objectives, is costly. The participation of society, through public subsidies, is essential in a context where other forest services (water protection, recreation, biodiversity conservation, etc.) are not part of a financial market.

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Box C6

The conservation of forest biodiversity in multiple-use landscapes of central Europe based on tree-related micro-habitats

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Integrative conservation practices that include the retention of structural elements such as habitat trees are used in managed temperate forests to conserve forest biodiversity (Gustafsson *et al.* 2019). Such practices are often called variable retention forestry or retention forestry (Martínez Pastur *et al.* 2020). The search for such integrative solutions has led to an increased attention in recent scientific projects, including several large-scale projects that focus on the retention of structural elements. One of these recent large projects is 'Conservation of forest biodiversity in multiple-use landscapes of Central Europe' (ConFoBi) (Storch *et al.* 2020). The research design of ConFoBi comprises 135 one-hectare plots in mountain forests (≥500 m a.s.l.) along two environmental gradients in the southern Black Forest in southwest Germany: (1) fragmentation (measured as the percentage of forest in the surrounding 25 km²); and (2) stand structural diversity (measured as the amount of standing deadwood visible in aerial images). Determination of the gradients for each plot is based on GIS data. Within the project, plot-based information on bats, birds, insects, epiphytes, and ground vegetation has been collected. The interdisciplinary project also investigated economic and social aspects related to retention forestry. One of the approaches that has been used in close-to-nature forest management to value and select habitat trees for retention are tree-related microhabitats (TreMs) (e.g. Forstamt Thurgau 2017; ForstBW 2015). Larrieu *et al.* (2018) define a TreM as "a distinct, well delineated structure occurring on living or standing dead trees, that constitute a particular and essential substrate or life site for species or species communities during at least a part of their life cycle to develop, feed, shelter or breed".

Within the framework of the ConFoBi project, it has become clear that forests at higher altitudes provide a greater abundance of TreMs in central European mountains compared to those at lower altitudes (Asbeck *et al.* 2019). This might be related to factors such as increasing rock fall or soil movement or other factors such as tree swaying that may lead to stronger development of buttresses at higher altitudes. Other factors that might contribute to this finding is a difference in management regimes at lower altitudes compared to higher altitudes. The results imply that neither tree size nor forest type show a significant interaction with altitude.

A second interesting result is related to forest management intensity. In the plots of the ConFoBi project, management type (uneven-aged or even-aged) did not influence TreM abundance and diversity (Asbeck *et al.* 2019). Other predictors besides management categories could provide more information on the influence of forest management on TreMs. Therefore, a preliminary analysis of the relationship between forest management intensity, expressed as a continuous index (ForMI) (Kahl and Bauhus 2014), and TreMs was carried out. The ForMI index includes three single indicators: (a) the proportion of harvested tree volume to the theoretical maximum; (b) the proportion of tree species that are not part of the natural forest community compared to the potential natural vegetation; and (c) the proportion of deadwood showing signs of saw cuts versus deadwood without these signs (Kahl and Bauhus 2014). For each of these parts a value between 0 (no management influence) and 1 (strong management intensity) was assigned; the sum of values for each indicator presents a single index value between 0 and 3. The explorative analysis on this issue showed a close and significant correlation between forest management intensity and TreM abundance and richness per plot (fig. 1). In this analysis, the richness was based on the occurrence of groups of TreMs (out of 15 possible groups) as described in Larrieu *et al.* (2018).

TreMs were more abundant in the less intensively managed areas, indicating that the concept of TreMs as biodiversity indicators might have some relevance for the conservation of forest biodiversity in integrative approaches. Considering these preliminary results, it is obvious that the value for biodiversity conservation of forest stands strongly depends on the management history. In an earlier

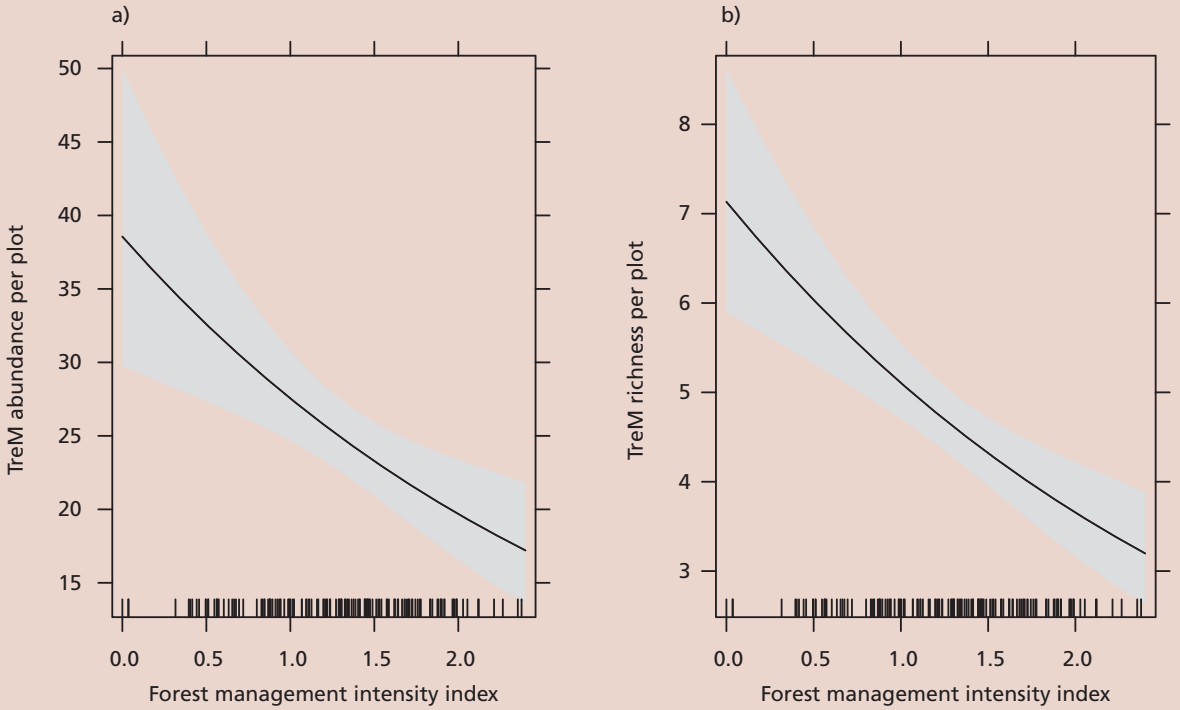

Fig. 1. Effect plots from a generalised linear model for the predicted abundance (a) and richness (b) per plot of TreMs that responded significantly to forest management intensity. The grey area indicates the 95 % confidence interval and the rug plot at the bottom the marginal distribution of the numeric predictor. From Asbeck (2019).

study, TreMs were more abundant in small-scale private forests than in municipal or state-owned forests (Johann and Schaich 2016). This is reflected by different approaches towards retention forestry as described for private and public landowners for different regions of Europe, where continuous-cover forestry is practised (Gustafsson *et al.* 2019). Motivations for different types of owners differ. For instance, private forest owners might be compensated for retention of structural elements on their lands by the private sector as compensation measures for larger projects such as windmills for energy production (cf. Gustafsson *et al.* 2019). On the other hand, state foresters might be obliged to retain structural elements in their forests to fulfil legal requirements of habitat and species conservation (e.g. ForstBW 2015).

In addition to these results with a focus towards site conditions and management, it has become clear that the concept of TreMs is especially beneficial for the conservation of three species groups in temperate mountain forests of central Europe (Basile *et al.* 2020). The abundance of certain taxonomic groups (particularly bats and insects, and to a lesser extent birds) is positively correlated with the abundance of specific TreMs (fig. 2). For instance, rot holes were identified as key structures for the conservation of bats and insects, and fresh exudates (i.e. sap runs or heavy resinosis), which are often caused by bark beetle outbreaks that provide additional food sources for birds, are positively correlated with bird abundance. Hence, managers could address this in the selection of habitat trees that provide these features in case their goal is the conservation of one of these taxonomic groups.

The results of ConFoBi indicate that flexible approaches to the retention of structural elements are needed based on the diversity of requirements of species from different taxonomic groups. While some TreMs are more important than others, a certain diversity of TreMs needs to be provided to support a wide range of taxa. The relationship between

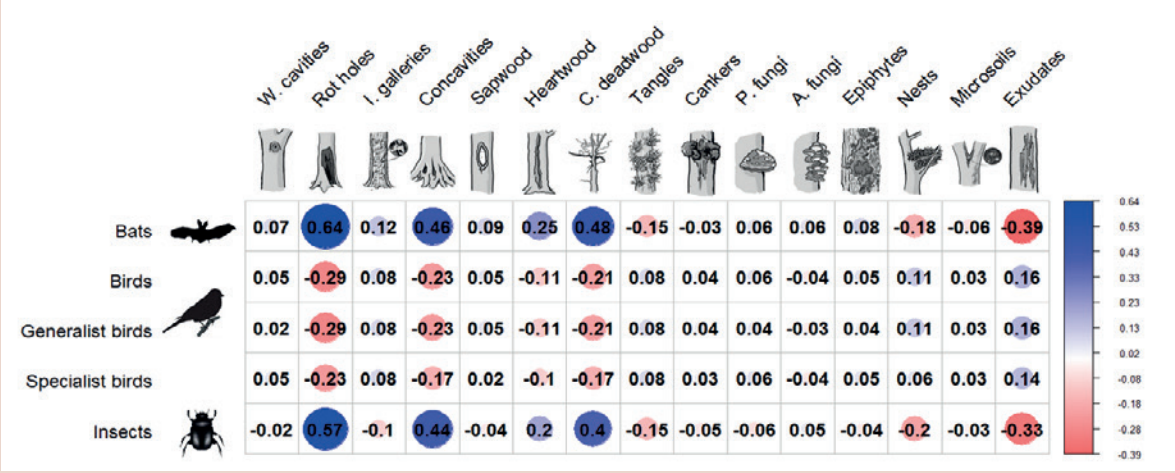

Fig. 2. Correlation matrix between different taxonomic groups and different types of TreMs. W. cavities=woodpecker cavities; I. galleries=insect galleries; C. deadwood=crown deadwood; P. fungi=perennial fungi; and A. fungi=annual fungi. Blue circles show positive correlations while red circles show negative correlations. The number in the circles indicates the correlation coefficient. From Basile *et al.* (2020).

forest management intensity and the occurrence of TreMs suggests that retention forestry approaches are a useful tool to buffer the impact of past and current forest management.

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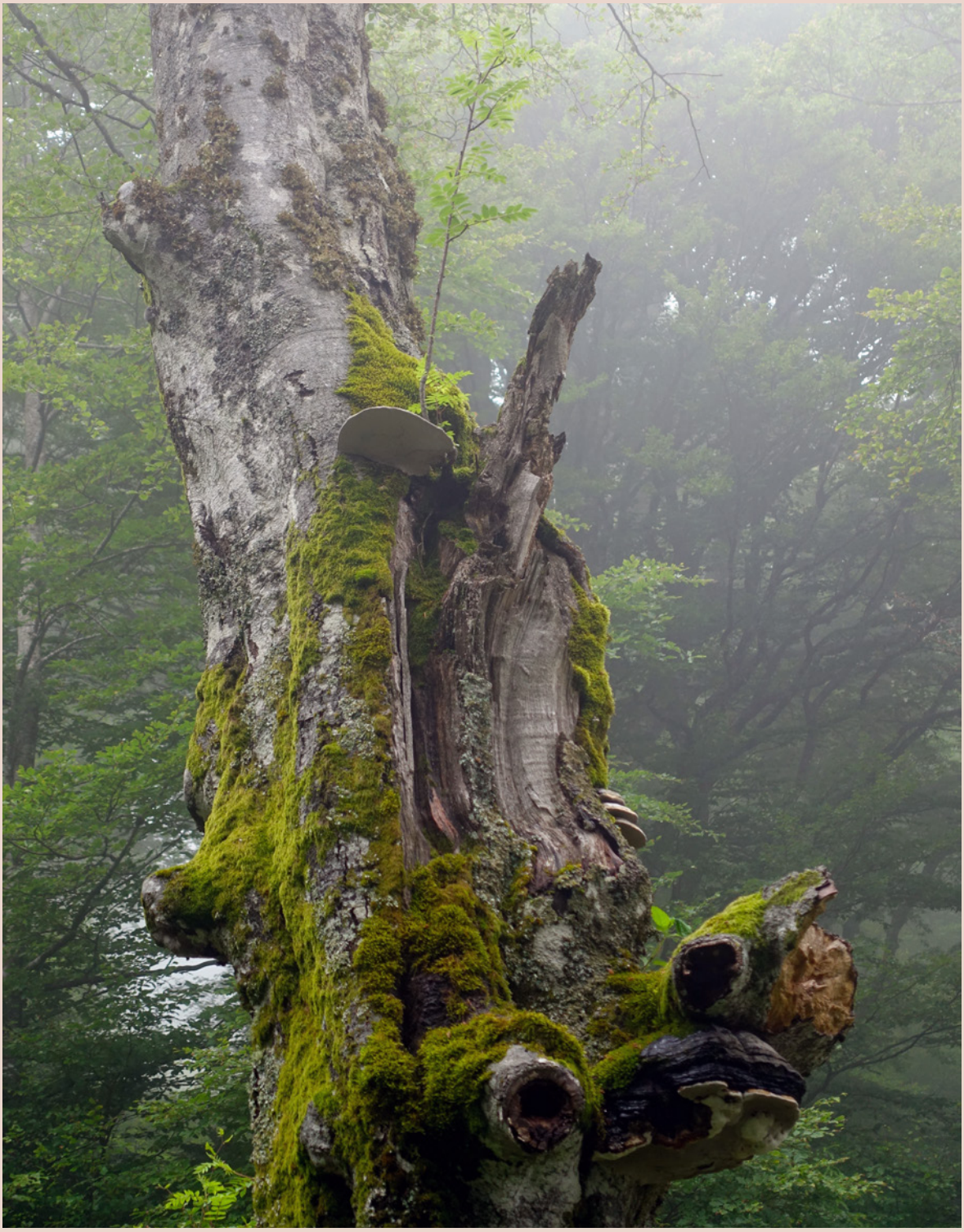

Fig. 3. Habitat tree providing a multitude of tree microhabitats (TREMs) at Mt. Schauinsland in the southern Black Forest (Photo: Andreas Rigling).

Hèches – 'Groupement Forestier des montagnes particulières de': a case from the mountains of southwestern France

C 9

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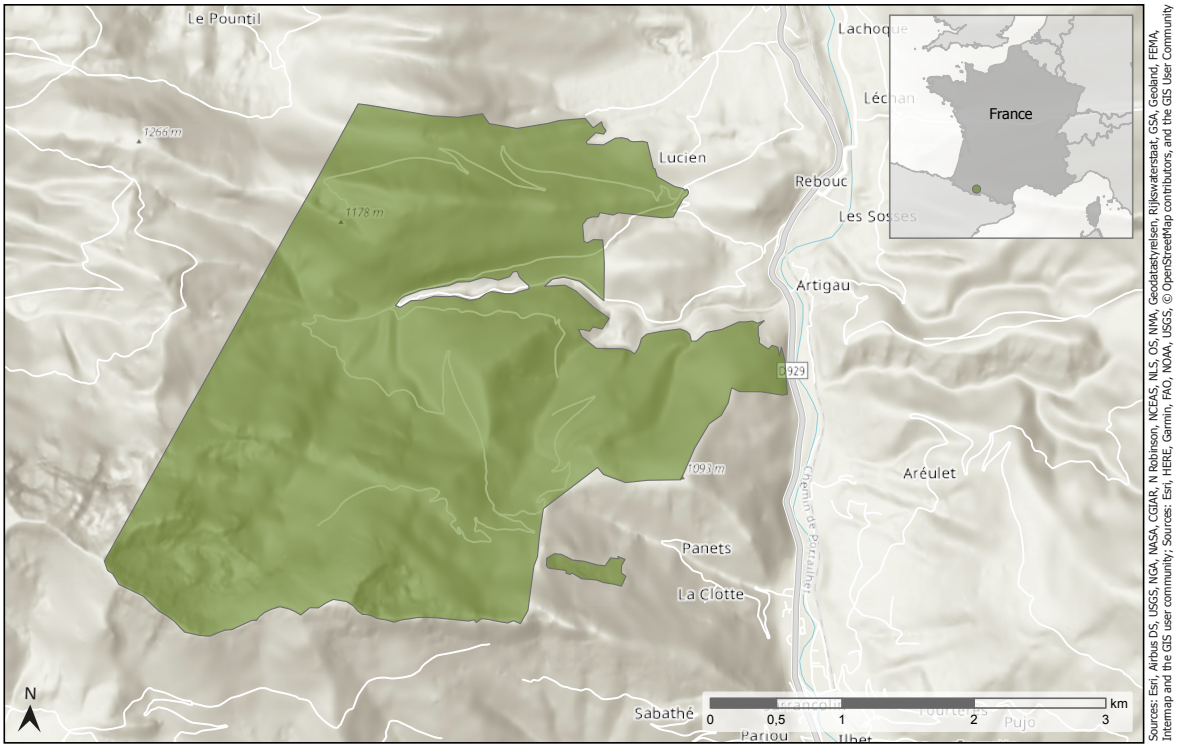
Context, legal frame, and ownership structure

The private forest area called 'Groupement Forestier (GF) des montagnes particulières de Hèches' is located on the northern slope of the central Pyrenees mountains in the region of Occitanie (fig. C9.1). The forests here have always been multifunctional, and have mixed wood production, pastoralism, hunting, and harvesting of mushrooms and forest berries.

In accordance with the presence of a wide array of geological substrates, stands thrive in areas where the soil is thick and nutrient-rich, while in



< Fig. C9.1. Overview of the GF property; beech-fir stands dominate; however, the complex topography and geology favours a wide range of forest habitats. Because of the a very old tradition of livestock farming, grasslands have replaced the subalpine forest (Photo: Laurent Larrieu).

Statement

"In the context of rapid biodiversity loss and climate change, we must adopt a fully integrated management approach to try passing on to our children a property which will last centuries while providing all the ecosystem services we have enjoyed to date."

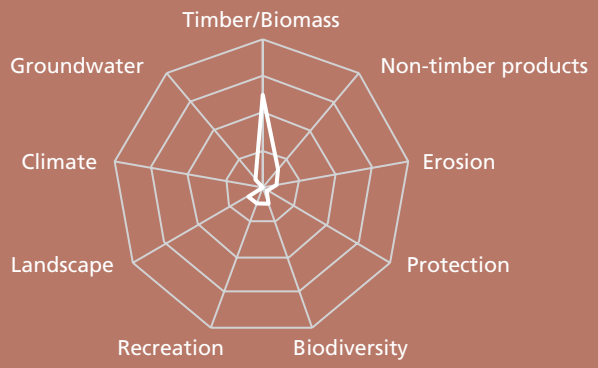


Table C9.1. General information on the forests of the GF des montagnes particulières de Hèches.

Forest community	Mostly mixed beech-fir montane forest (*Fagion sylvaticae* and *Luzulo-Fagion*). Locally *Tilio-Acerion* ravine forests and *Cephalanthero-Fagion* dry beech forest
Total forest area	930 ha (+272 ha of subalpine meadows)
Main management type	Selective cutting system
Total mean volume	Very wide range according to a wide array of soil conditions; from a few m^3/ha (rocky soils) to more than 600 m^3/ha (thick fertile soils)
Annual growth	Very variable. More than 10 m^3/ha for the most productive stands
Deadwood	Wide range depending on local conditions and management intensity: from 9 to 60 m^3/ha (diameter >10 cm)
Altitude	620–1900 m a.s.l. (forest: 620–1500 m)
Ownership	Private forest; 'Groupement Forestier' status
Geology	23 different substrates. Four main categories: (i) hard nutrient-rich Mesozoic limestones and dolomites; (ii) soft nutrient-rich Mesozoic clayey limestones and marls; (iii) acidic nutrient-poor Palaeozoic shales, Mesozoic puddingstones (conglomerate), ophite, etc.; and (iv) very acidic and strongly nutrient-poor Palaeozoic quartzite and shales
Protected area	0 ha
Nature protection area (Natura 2000)	0 ha
Protected area for the water spring of the community	20 ha with specific constraints on management
Area without harvesting	Roughly 200 ha (20 %)

other areas (e.g. on rocky soils and in open sunny areas) the stands are made up of small trees. However, the Atlantic macroclimate means that the average precipitation is high and the temperatures are relatively warm (fig. C9.2), meaning that forests can thrive.

The forest owner group is made up of roughly 100 local people. The management decision-making body is a board with 14 members led by a president. The forest operations and management are carried out by the owners themselves. When needed, owners can be helped in technical decision issues by an adviser from the Centre Regional de la Propriété Forestière d'Occitanie (CRPFOcc, Occitanie Regional Forest Ownership Centre). Except firewood, the wood is sold to independent forest operators. Every summer, sheep, cows, and horses are grazed on the subalpine meadows. The animals belong to two of the owners of the GF, but also to livestock farmers who lease the right to graze their

animals on the land. Hunting rights and rights to mushroom harvesting are reserved for the GF owners and village inhabitants.

Two of GF's owners are employed part-time as rangers, with one focussing on forest issues and one focussing on livestock issues.

Portrait

"As the president representing the owner set of the GF, my mission is to apply sustainable and multifunctional management that benefits the owners, but also the other villagers. The challenge is to reconcile production of high-quality timber, hosting of livestock, the presence of a large game population allowing traditional hunting activities, and finally harvesting of edible mushrooms and berries. In addition, this property is also an area for recreational activities for people from outside the village."

Forest history and cultural heritage

The subalpine meadows have been grazed by livestock for >5000 years. Old maps (Cassini's maps, 1770; Vallauri *et al.* 2012) show a forest cover similar to the current one. Most of the stands were harvested periodically between the seventeenth and twentieth centuries, mainly for charcoal production. In the nineteenth century, the forest owners were also the owners of steel mills.

A group of local farmers bought the property in 1860, with the main aim to use the subalpine meadows for livestock grazing in summer. Livestock also used some stands for grazing, particularly the stands alongside paths, and stands located on south-facing slopes which are sunny and become free from snow early in spring. Wood products were mostly for domestic use (firewood from broadleaves, timber from silver fir) or charcoal production for the local steel industry (that were in production until 1943). For charcoal production, stands were managed according to the coppice selection method. This forest history explains the current dominance of beech *(Fagus sylvatica)* at the expense of silver fir *(Abies alba*) since grazing, fire and intensive logging favours tree species which can sprout.

In the period from the end of World War II to 1978, there was very little harvesting. In 1979, the owners shifted to timber production. However, summer grazing by livestock remained a necessity. A huge effort to build a road network (about 45 km) combining both truck and dirt roads provided access to about 80 % of the area. As beech timber has a high value, the stands were regularly logged until 2000, and annual harvesting was on average about 3000 m³. A drop in wood price slowed down the rate of logging after 2000 and to 2010. Since 2010, about 6000 m³ of timber have been harvested annually.

Stands are mainly composed by naturally regenerated native species (fig. C9.3). There are only a few plantations of non-native conifers (about 10 ha),

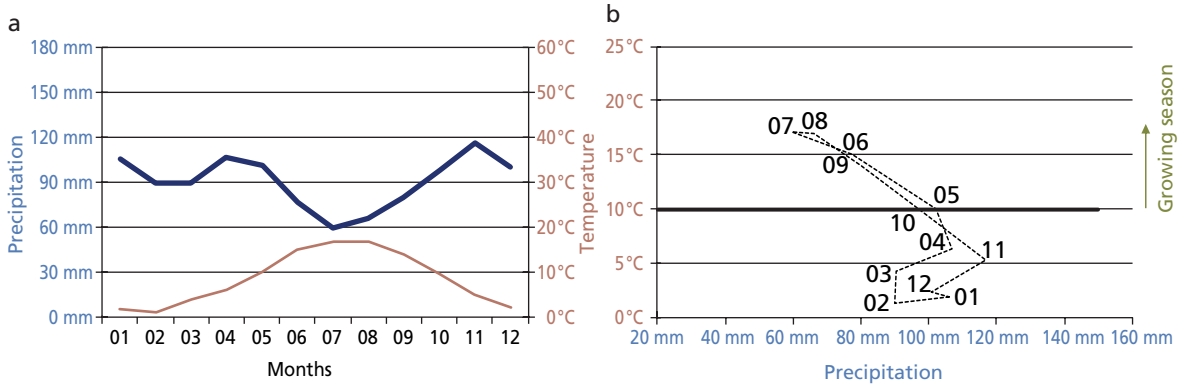


Fig. C9.2. Weather data (Hèches, 940 m a.s.l., Aurelhy model, 1981–2010); panel a: ombrothermic diagram using the scale ratio P = 3T since macroclimate is Atlantic; panel b: Climate graph, numbers indicate months.

including Douglas fir *(Pseudotsuga menziesii),* black pine *(Pinus nigra),* European larch *(Larix decidua).* Some native broadleaved species have also been planted, including sycamore *(Acer pseudoplatanus),* wild cherry *(Prunus avium),* and beech (about 20 ha). The conifers were planted in 1992 and the broadleaves were planted in 1997, on ancient grazing or burned areas.

The water spring, used for decades by the whole village, is located on the property. A new protection buffer has been set up in 2000, strictly protecting about 0.2 ha and constraining the management of forest on the 20 ha around the spring.

Aims of the owners

In a global framework of sustainable management, the current economic aims of the owners are to obtain an income from timber, provide annual fuelwood for the owners (about 120 m³), and optimise the use of the subalpine meadows by allowing livestock owners from outside the GF, since there amount of livestock belonging to the local forest owners has declined.

Most important services and products

The wood sale is the most important income for the owners, mostly timber (about 30–45 % of the volume) (fig. C9.4). The main expense is due to the maintenance of the road network (fig. C9.5).

Conservation interest – habitats and rare species

Eighteen habitat types have been identified, including forest and non-forest habitats (Pénin and Largier 2000). Biological inventories revealed the presence of 374 species of beetles (including some rare species such as *Teredus cylindricus, Denticollis rubens, Microrhagus emyi* or *Malthinus bilineatus*), 104 species of hoverflies (Diptera, Syrphidae), 17 species of bats, and the spider *Harpactocrates ravastellus* which is endemic to the Pyrenees (Larrieu 2005). Fungi assemblages observed in dry *Sesleria caerulea* beech-fir forest are unique in comparison with other European habitats of *Cephalanthero-Fagion* (Corriol and Larrieu 2008).

Because of the wide array of substrata and topo-climates, vascular plants are very diverse.

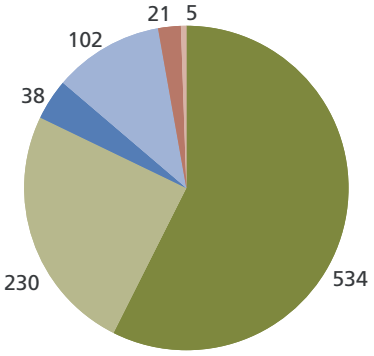


Fig. C9.3. Forest area per dominant stand type (ha).

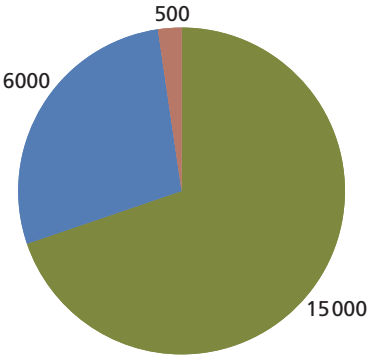


Fig. C9.4. Mean annual income for 2014–2019 (€/yr).

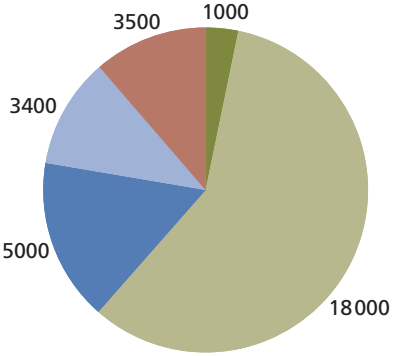


Fig. C9.5. Forest management costs – mean expenses for 2014–2019 (€/yr).

Some of them are protected at the regional or national levels, such as *Cerinthe glabra* subsp. *pyrenaica, Cystopteris montana* or *Ramonda myconi.* The bryophyte *Buxbaumia viridis* (fig. C9.6a) occurs on some large pieces of deadwood in old-growth stands (Larrieu 2005).

Cliffs provide nesting sites for the rare birds Eurasian eagle owl *(Bubo bubo),* peregrine falcon *(Falco peregrinus),* Egyptian vulture *(Neophron percnopterus),* and also for rocky-dwelling bats such as the European free-tailed bat *(Tadarida teniotis).* The Pyrenean subspecies of capercaillie *(Tetrao urogallus* subsp. *aquitanicus*) is found at the upper forest limit (Larrieu 2005).

The forest is fully within a 'Zone naturelle d'intérêt écologique, faunistique et floristique' (ZNIEFF; Natural zone of ecological interest, fauna and flora).

Nature conservation

The current management plan (2000–2029) includes expert reports about both flora/habitats and capercaillie. In order to take into account the chemical fragility of certain very nutrient-poor soils (Larrieu *et al.* 2006), a stand (roughly 20 ha) has been set aside. During harvesting, recommendations of specialised scientists for an insect- and fungi-friendly management (Larrieu *et al.* 2005, 2008) are taken into account. Even though oak *(Quercus petraea, Q. robur)* dominated stands have a very low productivity, no replacement is planned since these stands are used by bats for foraging. A proportion of the very large trees (>70 cm diameter) are retained within harvested stands, and some crowns from harvested trees remain on the ground without being cut; however, there is no minimum density or volume of deadwood to be kept in the forest. Snags are fully conserved; some lying deadwood items are used for firewood when they are very close to roads, but most of them remain within

a

b

c

d

Fig. C9.6. The Green Shield-moss *(Buxbaumia viridis)* is mainly observed on large downed coniferous deadwood items (a). The Lesser Stag Beetle *(Dorcus parallelipipedus):* the adult feeds on sap while the larva is saproxylic (b). The Weaver Beetle *(Lamia textor)* is more commonly observed near streams since its saproxylic larva lives mainly in the deadwood of *Salix, Populus* and *Alnus* (c). The Porcelain fungus *(Oudemansiella mucida)* is a saproxylic species living in crown deadwood of beech (d) (Photos: Laurent Larrieu [a–d]).

Fig. C9.7. Attractive tourist spots for cavers, hikers and climbers, but also for rare bird species as Eurasian eagle owl *(Bubo bubo),* peregrine falcon *(Falco peregrinus),* Egyptian vulture *(Neophron percnopterus)* (Photo: Laurent Larrieu).

stands. In naturally mixed stands currently dominated by beech, silver fir is systematically conserved in order to increase its proportion. Post-pioneer tree species are promoted since they support specific biodiversity and they very often have a high commercial value.

In 2004, a harvesting operation was delayed for several months in order to minimise disturbance in a stand where a breeding pair of goshawks *(Accipiter gentilis)* were found. Climbing is regulated to minimise disturbance to protected cliff-dwelling birds; areas and periods where climbing is allowed are fixed every year in accordance with the bird species and the location of their nests. Figure C9.7 shows attractive places for nesting sites but also for tourists and adventurers.

Fig. C9.8. Important for recreation and production. The entrance to the forests is controlled by gates and only forest owners can access the area by car (Photo: Laurent Larrieu).

Recreation

The GF allows free use of cliffs and caves for climbers and cavers, and also free use of roads and paths for trekkers. However, forest entrance is controlled by a gate and only owners can drive by car through the area (fig. C10.8). Hunting and mushroom harvesting are reserved for the owners and local people.

Strengths and weaknesses

Management
The GF does not generate enough money to pay for professional forest management, and therefore marking of trees for logging is done by council members; however, none of the council members are professional foresters. In 2017, a marteloscope (a 1 ha silvicultural training site in which all trees are numbered, mapped, and recorded; fig. C9.9) belonging to the European network Integrate+ was set up on the property. The council members were trained to carry out the monitoring and measurement of the trees. The wood is sold as standing timber by the 'lump sum' method (i.e. the timber is sold in advance before harvesting).

Policy
Management daily decisions are taken by the president or by the board (which meets four times a year). Once a year, a meeting gathers all the members of the ownership group and the main strategic guidelines are discussed and then approved. During this meeting, the president also presents the financial statements.

Science
Since 2000, this property has hosted many ecological studies focussing on biological conservation and sustainable management. For many studies, the area was one part of a larger study (e.g. Bouget

Fig. C9.9. The 1 ha-marteloscope was set-up in a beech-fir stand, the dominant stand type on the property (Photo: Laurent Larrieu).

et al. 2020; Friess *et al.* 2019; Larrieu *et al.* 2018; Courbaud *et al.* 2017; Müller *et al.* 2015; Larrieu and Cabanettes 2012). However, this forest was sometimes specifically studied for impact of harvesting on soil chemistry (Larrieu *et al.* 2006), on hoverfly communities (Larrieu *et al.* 2015), on both deadwood and tree-related microhabitats amount (Larrieu *et al.* 2012), or on beetle communities (Brin *et al.* 2010).

Adaptive management is not really implemented, but the owners have tried to improve the silvicultural methods following the science, e.g. by allowing part of harvested tree crowns to remain in the stand to increase the amount of deadwood amount, or by setting aside stands growing on very nutrient-poor soils.

Communication

Since 2001, the property has been used for training courses about pedology, botany, pastoralism, integrated forest management. The target audiences are students, forest advisers, forest managers, and also other private landowners.

Nature conservation is not really integrated by all the GF's owners, in accordance with a long traditional farming use of the area. However, the president and other board members are aware of the need to promote more integrated management. The forest management of the GF has been labelled by the Programme for the Endorsement of Forest Certification (PEFC; certificate 10-21-15).

Conclusion

Owners participating in management decisions or practical issues such as tree-marking need to be better trained. The establishment of the martelo-scope on the property will help to provide information and to train the owners about biodiversity-friendly silviculture.

Financial incentives to retain very large trees would benefit biodiversity conservation as these trees play a huge role in biodiversity conservation, but landowners often consider them as competitors for younger and more productive trees. However, in France, such financial support only exists in N2000 areas.

The amount of deadwood could be increased, e.g. by stopping the harvesting of lying deadwood as a source of firewood for the owners. However, this action would need a change in the old status of the GF that legally prevents the GF stopping collection of lying deadwood. Pioneer tree species such as silver birch *(Betula pendula)* and aspen *(Populus tremula)* should be better considered, in view of their support for biodiversity, although their commercial value is low. Finally, when a stand gets a fully regular structure, some mature trees should be retained when the stand is being regenerated to provide ecological continuity between the two commercial cycles.

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Osterwald Eglofs – a cooperative forest enterprise

C 10

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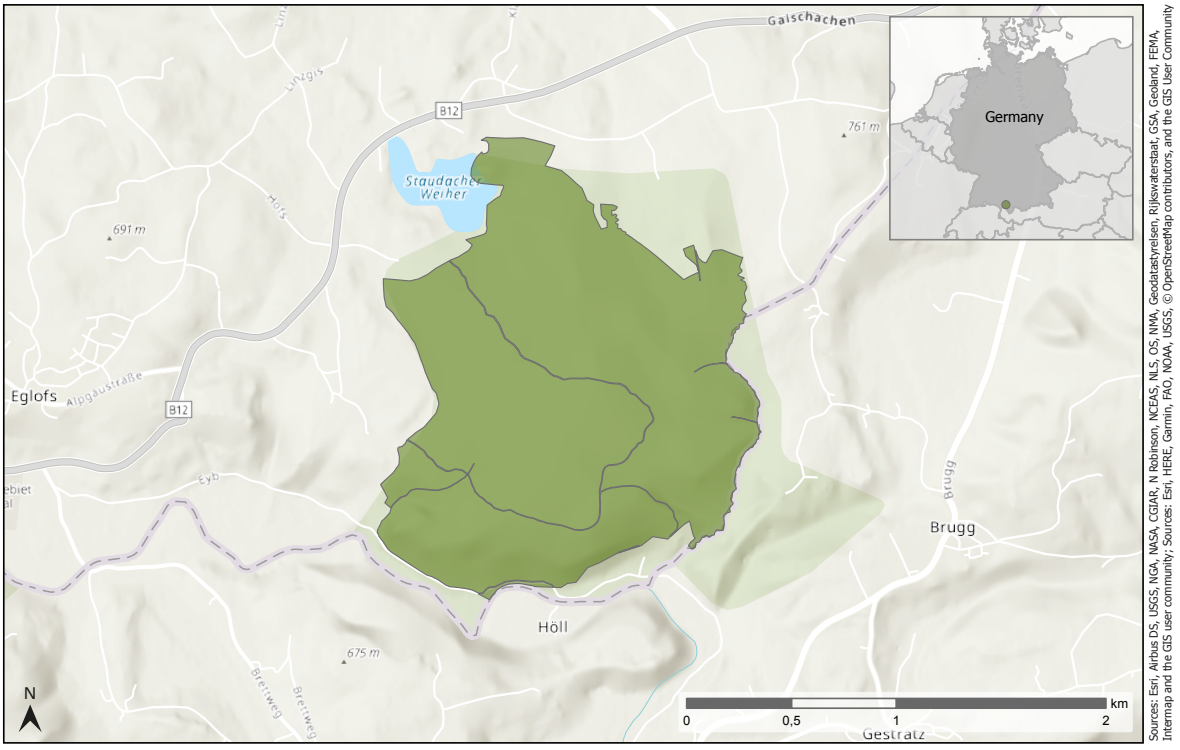
Background

'Osterwald Eglofs' is a 260-ha forested area owned by the forest cooperative of the same name, rich in tradition. The forest is located around Eglofs in the Argenbühl municipality, in the district of Ravensburg. The village of Eglofs has a population of less than 2000 while Argenbühl municipality has around 7000 inhabitants. Eglofs and Osterwald forest are situated on the southeastern border between Baden-Württemberg and Bavaria in the idyllic region of the 'Württembergisches Allgäu', as



< Fig. C 10.1. Osterwald from above in the typical landscape in southern Germany. Big farms outside the villages between grassland and forest patches (Photo: Denis Rauch).

Statement

"From history with tradition into a successful future."

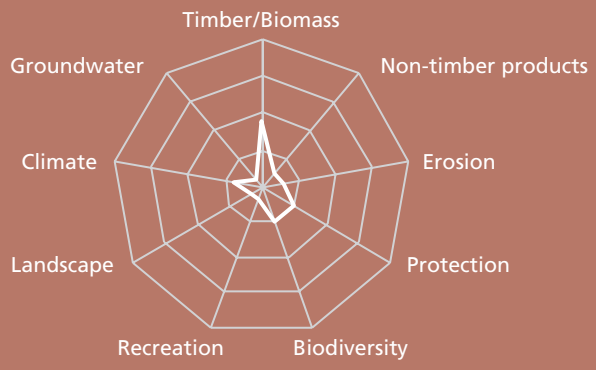


Table C 10.1. Portrait of the Osterwald Cooperative.

Geology	Glacial moraine (Würm period); hilly, south-western Alpine foothills
Climate	Submontane, 600–700 m a.s.l.
Topography/Site	80 % plain to slightly inclined slopes, 20 % steeper slopes
Average annual precipitation/temperature	1500 mm/7 °C
Potential natural vegetation	Submontane mixed mountain forest composed of Norway spruce *(Picea abies),* silver fir *(Abies alba)* and beech *(Fagus sylvatica):* 75 % Ravine forest communities: 10 % Peatland and riparian forests: 15 %
Total forest area	261 ha
Tree species composition	Norway spruce (57 %); silver fir (25 %); beech (8 %); other broadleaves (9 %) including ash *(Fraxinus excelsior),* alder *(Alnus glutinosa),* sycamore *(Acer pseudoplatanus);* other conifers (1 %)
Annual growth	Annual increment amounts to about 13 m³/ha. Annual increment for Norway spruce is estimated at around 15 m³/ha and even higher for silver fir
Total volume	515 m³/ha
Annual cutting rate	13.5 m³/ha
Regeneration	On 60 % of the total area
Protected areas	– Natura 2000 area: 100 % – Forest biotopes: 10 % – Nature conservation areas: 1 % – Forest areas for soil protection: 17 %
Recreation areas	The entire Osterwald is designated as recreational area
Hunting	Implemented by Osterwald Cooperative since 1992

part of the foothills of the Alps. The area is characterised by small-scale farming, with emphasis on dairy farming. Tourism has also become increasingly important. In particular, a multifaceted handicraft industry as well as small- and medium-sized industrial enterprises are drivers of a flourishing economy and stable labour market.

Because of the high quality of life, stable economy, and active communities, the exodus that has often affected other rural areas, has not taken place in this region. The local population of Eglofs was able to maintain a healthy village structure and remain open-minded and progressive. This is perhaps due to the fact of continuous influx into this region and the adoption of soft tourism. With its forestry and historical peculiarities, Osterwald is inseparably linked to the history and landscape of Eglofs.

Forest history and cultural heritage

Following a first account in 817 AD, it was only in the thirteenth century that Eglofs gained historical significance. In order to extend his grip on power, Emperor Frederick II purchased large areas of land in this area to weaken the influence of the princes and sovereigns, and then gave more independence to the towns. He thus also acquired the territory of the 'County of Eglofs' for the sum of 3200 silver marks. The people of Eglofs saw this a unique opportunity to free themselves from the arbitrariness and hardship imposed on them by the ruling feudal lord. Without further ado, they raised 1000 marks to support the financing of the purchase. Frederick II was impressed by this financial commitment, but even more so by the willpower of the local people. Having already received the status of a 'free imperial city', the people of Eglofs were also granted the status of 'free citizens' and even 'imperial immediacy' (i.e. freedom from the authority of local lords). From that day onwards the people of Eglofs saw themselves, besides God, only as subordinates to the Holy Roman Emperor himself.

The urge for freedom, fighting spirit, and energy were passed from one generation to the next. The supposedly bought freedom, however, did not last for very long. Centuries including changing pledges, exploitation, oppression, and arbitrary rule followed. At the beginning of the nineteenth century, however, the state was reorganised and Eglofs became part of Württemberg. With the return of restrictions on feudal rights, some freedom, and law and order also returned.

Most likely inspired by ideas of enlightenment and revolution, there emerged a dispute with ruling royal patriarchs over traditional timber use rights. This went on for many years and the stubborn people of Eglofs seized the opportunity. About 140 of them approached the Royal Württemberg Court. With a surprising agreement on 14 May 1832, they obtained full ownership of a woodland area east of Eglofs including all of its meadows. The area was officially assessed and considered to be of little value. Because of this, the area given to Eglofs was an impressive 270 ha. In return, the people of Eglofs contractually and irrevocably waived all ancestral rights of use in the remaining forests. Instead of dividing the property amongst the citizens, they far-sightedly founded the 'Osterwaldgenossenschaft' (Osterwald Cooperative); this was one of the first such cooperatives.

Statutes of the Osterwald Cooperative

At first the Osterwald Cooperative established well-designed statutes, which were continuously adapted to actual requirements. To this day, the regulation of membership is at the core of the statutes. Initially, it is limited to natural or legal persons who are owners of a building listed in the statutes and in addition have their residence in Eglofs. Historically, the regulation is derived from the homes of the former trial winners and founding fathers. Membership is therefore not tied to persons or their origin, but to a residence in Eglofs.

Osterwald membership can be sold, given away or inherited in connection with one of these listed buildings. Furthermore, the division of the property among the cooperative members also goes back to the historical legal dispute. In accordance with the co-financing of the legal costs of about 6800 guilders at that time, the property was divided into a corresponding number of non-material shares. Any trade of the shares is carefully regulated. They are only freely tradable and transferable amongst the currently 89 cooperative members. To prevent a concentration of power and to protect the common interests of the cooperative, ownership is limited to a maximum of 250 shares per member (this represents a modest 3 % of the total ownership). To date all external or internal attempts to break up the Osterwald Cooperative have been fended off.

Decision-making processes

The essential decisions, including the authority to issue forestry guidelines, are subject to the annual general assemblies. The distribution of profits is decided by a majority vote and, instead of payment in kind, is now transferred as an annual dividend per share. In a special election procedure, the assembly appoints its executive and supervisory board members from among its own ranks. One-third of the board is elected annually for a three-year term of office, thus ensuring continuity of the board. This approach allows preservation of valuable experience and important knowledge in the

board, while also ensuring that new ideas and perspectives continuously find their way into the decision-making processes. These statutes are the foundation for the success of the Osterwald Cooperative. This has led to a strong identification with the cooperative and an impressive forest spirit of all members. Instead of following often changing views on managing forests or looking for short-term profits, the Osterwald Cooperative values long-term preservation of their forest, and with that the aim of sustainable value added. Economic, social, and ecological sustainability and the responsibility towards future generations is at the heart of the cooperative's philosophy.

Forest management strategies

Old records provide an insight into the former state of Osterwald. Logging data from archived protocols as well as economic accounts are both contemporary witnesses and advisers. From 1930 onwards there are also standardised forest inventory records. Those give a good understanding of how forestry

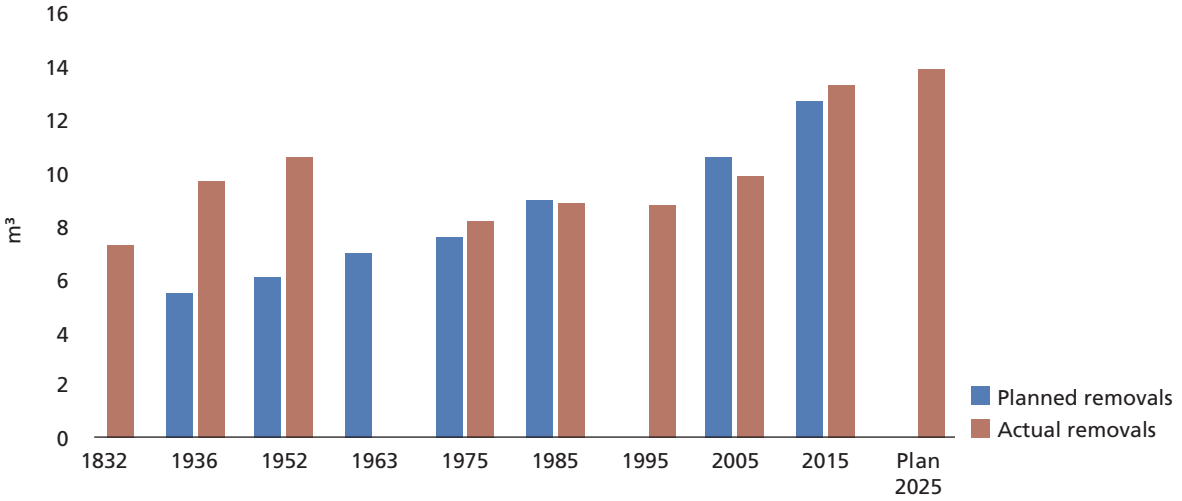


Fig. C 10.2. Planned and implemented annual removals in the inventory periods (in m³) from 1832 to 2015 in Osterwald.

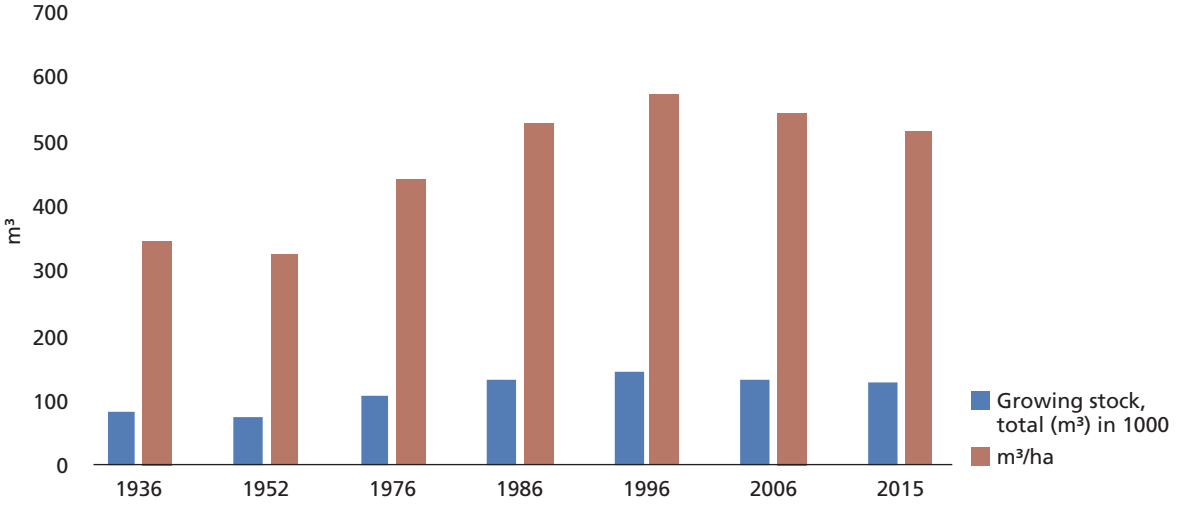


Fig. C 10.3. Development of growing stock in Osterwald (1936–2015). The blue bars show the total growing stock in 1000 m³, while the orange bars present volumes in m³/ha.

and silviculture measures have developed over time in Osterwald. Especially the last two inventories of 2005 and 2015 provide important structural data to guide future silvicultural activities.

After 1832, forest use continued at a low level (fig. C10.2). One reason for this is that the forests were often impenetrable, because of the marshy and moist conditions in the lower parts of the area, which are typical of the Allgäu region. Also, the rights for use of the wood were extremely restricted during the time of feudal oversight. Timber harvesting was then primarily limited to removal of single mature trees.

As forest utilisation took place on third party property not much care was taken which trees were actually cut, or if certain areas were over-exploited. On occasion people also took to poaching to feed their families. Such a situation of course did not allow for any kind of 'orderly forestry'. Thus, at the time of the official assessment of the forest land in 1832 it was no surprise that it was labelled as being of 'little value'. Stands were often by chance made up of small forest patches of silver fir characterised by small openings ('Femel') and multi-aged/multi-storied 'Plenter' structures. These structures were distributed haphazardly and the stands were usually understocked. Such forest structures, however, resulted in rich natural regeneration. The founding of the cooperative then brought about a drastic change. The most important goal set out at the time was to ensure a long-term, continuous, and sustainable use of the forest.

The cooperative showed astonishing foresight and wood harvest was temporarily reduced to allow the growing stock to increase. Reaching an appropriate stocking level and ensuring intensive game control, highly productive stands continued to develop. Some of the remains of those decisions can still be observed in the form of individual, large silver fir trees. In the 1930s, the people of the Osterwald Cooperative occasionally sought advice from the forester Karl Dannecker, then unknown, and today regarded as a highly renowned 'Plenter' forest expert.

This period of good management was interrupted by World War II and the subsequent 'reparation' harvests, as well as a number of other setbacks, causing a decrease in the growing stock (fig. C10.3). Using the past experiences and knowledge, the Osterwald Cooperative again started to rebuild the growing stock in their forests. This was accelerated owing to a decline in the demand for wood. In contrast to the trends in forestry at that time, the Osterwald Cooperative continued to rely on natural regeneration. However, the constantly increasing wood volumes and the move to high forests managed by strip shelterwood fellings soon negatively affected the 'plenter' forest structures and with that the occurrence of silver fir declined. Drastic increases in game populations further reduced the proportion of silver fir from a former 30–50 % to only a few percent in the period from 1960 to 1980.

In 1990, Storm 'Wiebke' left its mark on the forest. In the aftermath, there was a need to either immediately secure natural regeneration in the partly devastated Osterwald forest, or to replant affected areas and protect the artificial regeneration from browsing damage by fencing.

Self-organised hunting

Because of this alarming situation, the people of Eglofs cancelled the hunting lease in their forests and decided to hunt themselves. They defied the hostility from the local hunters and the hunting lobby. They were by then used to taking their fate into their own hands. The number of roe deer *(Capreolus capreolus)* shot was immediately quadrupled. Their self-determined and responsible actions thus led to a significant reduction of browsing damages. As a consequence, there was an explosion of silver fir natural regeneration in Osterwald within only a few years and with that a change in forest structure and tree species composition. The transfer to continuous cover forest, actually being a return to previous conditions, could now begin.

Current silviculture practices

Owing to a wide variation in site conditions on the one hand, and favourable climatic conditions for silver fir on the other hand, long-term silvicultural planning in Osterwald allowed development towards the potential natural forest community of the region. The largest part of the forest area is currently covered by Norway spruce, silver fir, and beech. By far the largest amount is Norway spruce (57 %) of which quite a share is located in moorland. Silver fir accounts for 25 % of the forest area followed by beech (8 %), ash/sycamore (4 %), and other broadleaved species (5 %) (fig. C10.4).

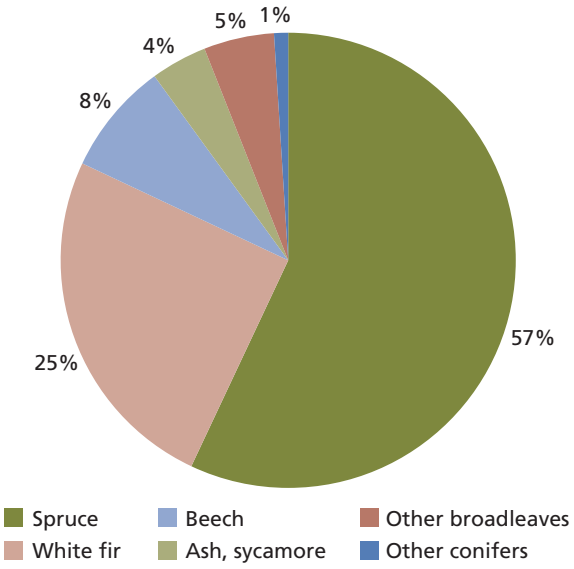


Fig. C 10.4. Tree species distribution in Osterwald (% of total forest area).

Distribution of diameter classes

The data on diameter distribution for the entire growing stock clearly show a predominance of larger dimensioned trees (fig. C 10.6). This is an obvious consequence of past silvicultural practices in which only the largest trees in a stand were harvested (fig. C 10.5). The availability of such considerable amounts of large timber has in fact longer-term economic consequences for the Osterwald Cooperative. A rapid reduction of the large timber reserves would of course, in the short term, result in high economic return. As a consequence, this would then lead to high cultivation costs for decades to come and question the aim of continuous economic sustainability for generations to come. Further, the proportion of silver fir in the medium diameter classes is also declining. However, those diameter classes are seen as a crucial stabilising element for moving towards continuous cover forests.

Lessons learned from the past have shown quite obviously that clearcuts and strip shelterwood fellings lead to considerable damage to nat-

Fig. C 10.5. Big silver fir trees as a result of past silvicultural practices where only large trees were harvested. The forest shows typical 'Plenter' forest structures (Photo: Josef Jehle).

ural regeneration. There is then often a negative effect on the quality of the wood in the stands using such systems. Natural regeneration can only develop its full potential to produce quantitative and qualitative high value timber under canopy. This is especially the case for 'Norway spruce-silver fir-beech' forests. Especially if the observed decline of silver fir in the lower diameter classes would continue it would not only severely impact the profitability of the Osterwald Cooperative but, perhaps, even threaten their existence. Such decline or even loss of silver fir, would further cause massive stand stability problems, especially as the conditions in the Allgäu are particularly favourable for this species. Silver fir is also seen as a main pillar in silviculture for adapting future forests to climate change in the region.

Forest regeneration

Fortunately, the decline of natural regeneration could be contained and it is now thriving. Currently, about three-quarters of mature stands that require a healthy natural regeneration are fully secured (fig. C 10.8). Notably, not only the amount of broadleaves is steadily increasing, the same accounts to the proportion of silver fir as compared

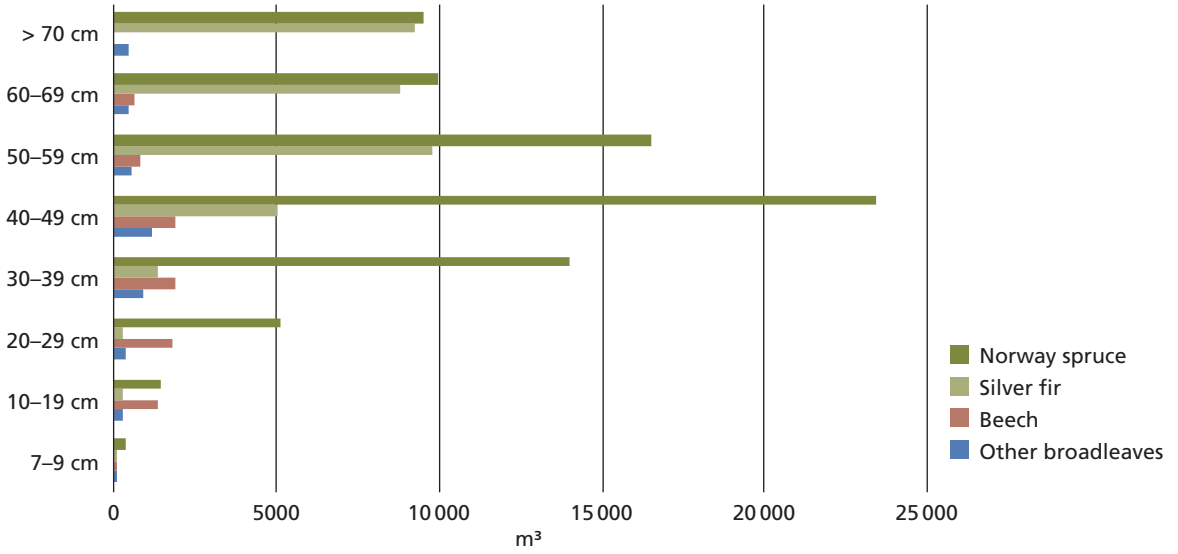


Fig. C10.6. Distribution of growing stock (m³) by tree species and size classes (2015).

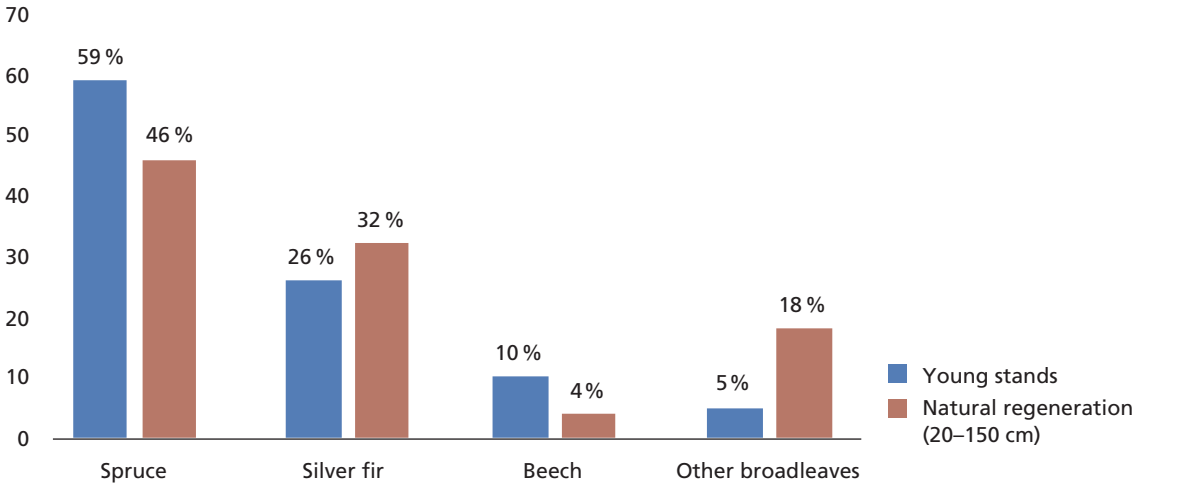


Fig. C10.7. Comparison of area distribution by tree species (in %) for young stands and natural regeneration (20–150 cm).

Fig. C 10.8. Abundant regeneration in mixed mountain forests. The amount of silver fir and broadleaves is steadily increasing. (Photo: Josef Jehle).

to Norway spruce (fig. C 10.7). The aim is now to maintain this positive development in the long term.

Future perspectives in silviculture

Because of climate change, Osterwald is once again facing new challenges. The Osterwald Cooperative should now take full advantage of the opportunity to continue their path towards continuous cover forests and thus be well prepared for the stormy, hot, and dry times to come. The task for the near future is now to find the right pace for reducing the growing stock and that at a calculable risk. This will require both patience and consistency.

The second challenge is how to deal with the currently well-developed stand regeneration throughout Osterwald. The achievements in this respect are highly admirable but may lead once more to rather uniform next generation stands. Again, a promising strategy can be to patiently prolong the rotation period of mature stands, so that they provide canopy cover over the next few decades. This will support a diversification of regeneration.

Ecology

The ecological function of Osterwald is recognised, due to its closeness to the natural forest community of the region and the high proportion of large and old trees (fig. C 10.8), which provide refuge to these rare species, as well as other forest dwelling species. The following species listed in the Natura 2000 Habitat Directive's annexes are found in Osterwald: the greater mouse-eared bat *(Myotis myotis),* the Eurasian beaver *(Castor fiber)* and the green shield-moss *(Buxbaumia viridis)*[1]. On peatland sites one can encounter also black stork *(Ciconia nigra),* sundew *(Drosera)* and clubmoss (*Lycopodium)* species[2]. This ecological significance is to a large extent the consequence of the extraordinary ownership struc-

[1] Personal communication: Regierungspräsidium Freiburg – Forstdirektion, Referat 84 – Waldnaturschutz, Biodiversität und Waldbau (14th of September 2020).

[2] Personal communication: Ulrich Herkle (25th of September 2020)

ture of the cooperative, the unique forest spirit of its owners, and their foresight in forest management.

Since the cooperative members are reluctant to be regulated, this may occasionally lead to conflicts with nature conservation. One example: without having consulted information on the origin and history of the Osterwald, the entire forest was designated as a Natura 2000 area owing to the Osterwald Coperatives' extraordinary management approach. The forest owners then saw themselves having little to no influence on the consequences that follow from such a designation. Resulting restrictions, bureaucratic, and organisational efforts increasingly led to financial impacts for the owners, without seemingly any visible added value for nature. Such a situation is not helpful when it comes to accepting nature conservation and its aims and concerns in a particular forest. One can only hope that the Osterwald Cooperative will nonetheless continue to fulfil their ecological responsibility.

Effects of climate change

What are the effects of a steady increase of disturbance events that can be observed in recent years? Will climate change severely impact management in Osterwald? The diversity of site conditions, and in some cases the occurrence of locally unsuitable tree species and unstable stand structures, are often the source of damage. The forest, however, shows us how we can best cope with such challenges. The more differentiated forest stands are, the better they are able to deal with disturbances. To some extent, disturbances can support development towards the desired forest stand structures. In this way forests become self-stabilising systems (fig. C10.9). This is in contrast to even aged high forests, which have a more uniform structure. A disturbance in such a forest management system can result in severe negative effects, or at least result in considerable damage across large areas. The likely consequence for owners is that they will be increasingly driven by disturbance events, and their range of management options becomes narrower.

Continuity and change

Based on its organisational structure, the Osterwald has seen a blessed continuity. Of course, societal changes have also affected Eglofs, as have varying forest trends, although to a more modest extent. To be accepted, changes must be seen as meaningful for the Osterwald Cooperative. Another anecdote illustrates this vividly:

On the occasion of a review of the management plan of Osterwald during the 1950s, the then

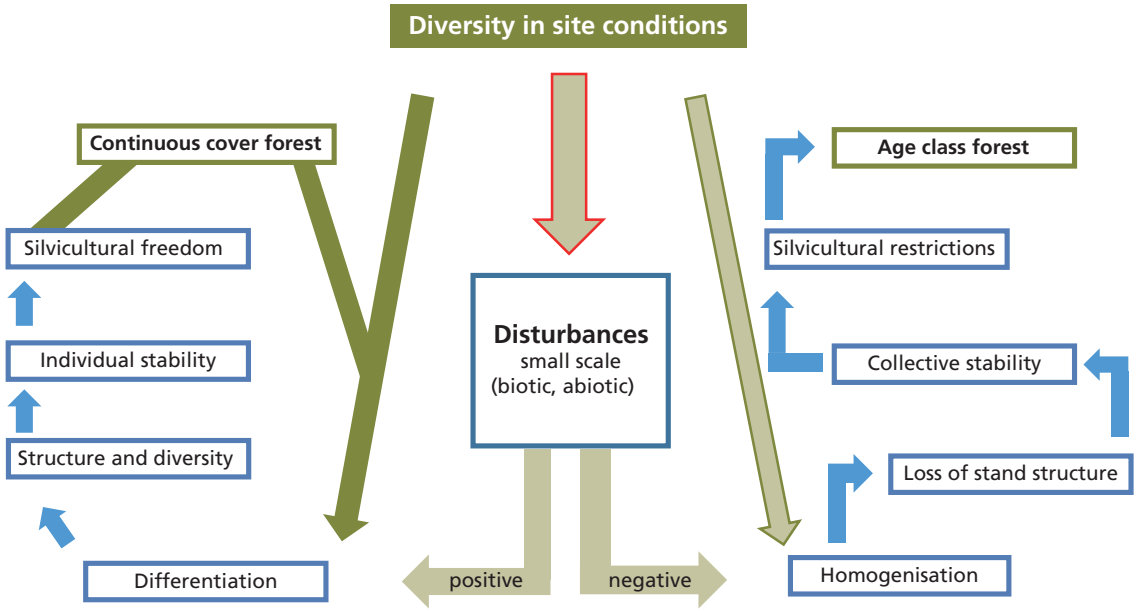


Fig. C10.9. Feedback between disturbance and different silvicultural systems.

forest president of Baden-Württemberg was, besides many local foresters, a guest in Eglofs and joined an excursion to the forest. A lively discussion took place on the silvicultural prescriptions and forest management approaches during which the president ran out of arguments to support his view that the management applied in Osterwald should change. Somewhat disrespectfully he blurted out that the people of Eglofs were 'only simple farmers, without real knowledge of forestry'. The board chair of Osterwald was actually less enraged by the statement of the forest president, but out of historical obligation and inner attitude he immediately forbade himself any paternalism by an authority and firmly requested the forest president leave the forest. Following this, the remaining local foresters discussed the current and emerging challenges for Osterwald calmly and professionally. The anecdote shows that the Osterwald Cooperative can act decisively, quickly, and, if necessary, against the current conventions. Such is the balancing counterpart to perseverance and constancy. The well-manageable size of the cooperative, common sense, and democratically supported decision-making allow actions to be taken quickly and pragmatically, but nevertheless ensuring long-term solutions when needed.

Economics insights

Even though the amount of the annual dividend payment is not disclosed to the public, it is no secret that the forest yields are quite substantial. Apart from good site conditions and a high increment, the low costs for planting and tending, the substantial amount of construction timber and large-dimensioned wood assortments of the highest quality are the main reasons. Utilising this potential, while ensuring that it is replenished, requires committed and motivated personnel. Nowadays, professional support is provided by the responsible forest enterprise in the form of a service contract. A well-established network of local companies carries out timber harvesting. One can sense the pride and satisfaction of all actors (the cooperative members, the forest enterprise, and the contractors) to be able to contribute to the success story that is the Osterwald Cooperative.

Future perspectives for Osterwald

The natural conditions are ideal, while forest structures and current silvicultural prescriptions offer numerous options. Organisational structures are in place for a prosperous future and can easily be adapted accordingly. But most importantly the Osterwald Cooperative should preserve its admirable forest spirit and solidarity, its courage, level-headedness, wisdom and foresight in its thinking. Looking back on many years working as a forest manager for the Osterwald Cooperative I would like to conclude on a personal note: "Continuous cover forestry is an attractive forest management approach, especially for such small-scale cooperatives as it is for private forest owners. Conversely, if such a forest could choose its owner, I am sure it would not hesitate to select the members of the Osterwald Cooperative. Seen in this light, it is a perfect match, and that will hopefully continue for many years to come".

Box C7

OAK Schwyz – a traditional form of an ownership association

F. Lüscher[1], F. Krumm[2]

[1] Oberallmeindkorporation OAK Schwyz, Switzerland
[2] Swiss Federal Institute WSL, Birmensdorf, Switzerland

Historical background

The OAK Schwyz (Oberallmeindkorporation Schwyz [OAK]) is an old-law corporation according to the cantonal public law with its meeting place and headquarter located in Schwyz in the centre of Switzerland. Forest management corporations are still frequent in Switzerland, especially in mountainous areas. The OAK Schwyz is one of the biggest cooperations in Switzerland and has almost 20000 members. The earliest document in the name of the OAK-corporation is a rule of imperator Henry IV from 1114 between the convent of Einsiedeln, a monastery nearby and the district of Schwyz concerning an argument about borders. Important to note that the OAK is older than the Swiss federation, which was founded in 1291. The OAK has developed over time and was forced to adapt to societal and economic developments. Following a big revision and reorganisation process at the end of the past century, the OAK has transformed into a professional organisation and appointed the first managing director. In 2006 OAK Energy company was inaugurated as a co-operative enterprise.

This historical context is crucial to understand the specificity and finally the success of this ownership format as it serves as a main reason for a very sustainable approach to manage multifunctional landscape – the entire real estate, including forests, in a mountain area under difficult conditions.

More than forestry

The managed forest area spans a bit more than 9000 ha and with this OAK Schwyz is the biggest non-governmental forest owner in Switzerland. The forests are important for the region as the value chain and wood procession is deeply rooted in that area. The corporation is a very important local actor also beyond forestry. Alpine farming,

Fig. 1. The south-facing slope of the Mt. Rigi is an example for the challenging forest management conditions of the OAK Schwyz, comprising of protective, and social services (Photo: OAK Schwyz).

agriculture, nature conservation, protection of people and goods, energy management, CO_2 compensation, tourism, landscape management and the production of timber products for a mostly regional market are integral part of the OAK portfolio (fig. 1). A main focus is on the management for the protection against natural hazards on 56 % of the area. Timber production is the main function on 26 % of the forest area whereas on 18 % landscape and nature protection is priority. The forests stretch from the valley bottom on 450 m a.s.l. up to treeline on 1800 m a.s.l., dominated by Norway spruce that accounts for more than 75 % of the tree species, followed by Abies alba with 10 % and few broadleaved species. The product palette is broad, whereas the annual cut rate is lies between 25 000 and 30 000 m³/yr and a major part goes into construction assortments. Further, energy wood plays an important role. All forests that are managed by the OAK are certified with recognised labels and this serves as a strategic marketing goal according to a mission statement.

The real estate comprises beside forest of about 8000 ha farmland and about 7000 ha of unprofitable mountain area. Parts of the 24 000 ha sized estate are used in winter and summer for touristic purposes. Own residential and commercial houses and a family hotel belong to the property and are following high ecological standards and use regional timber for the construction, the complete value chain is therefore part of the overall concept. These many different business units allow the corporation to constantly develop further, also in difficult times. The energy company OAK Energy delivers renewable energy for all own infrastructures and beyond. With a forest climate protection project, CO_2 certificates are generated for the voluntary market in order to be able to put the climate performance of the forest into value. These elements are integral parts of the business model.

Ecology

Nature conservation is a high value in the whole matrix of forests and landscape as the area is characterised by different site conditions and structures that favour the diversity of fauna and flora. There are protected areas outside the forests covering bogs and mires, pastures and dry meadows on more than 1100 ha. Nature reserves inside the forests are on more than 1500 ha and old growth islands forest edges and habitat trees have recently been integrated as additional measures to promote nature conservation. This also includes the old and very valuable reserve 'Bödmerenwald', a forest reserve of national significance and the reserve 'Furenwald' in Oberiberg (fig. 2).

Conclusion

The majority of the forest work is conducted by OAK personnel. The cooperative employs about 30 people, supports the local job market and offers training possibilities for young people. The local people are very connected and they carry on the idea and attitude together with OAK as they are directly employed, or are clients of the broad product portfolio. The cooperative maintains quality jobs for a region that cares for societal, economical and ecological values. This is the great achievement of the OAK and makes this enterprise case example.

The great palette of products and the adaptive management is a show case how a forest enterprise can act as a successful and highly valued part of a local value chain. Forest products, successfully marketed in an ecologically viable environment are part of positive future outlook.

The portrait of the OAK Schwyz states: "We, as the largest non-governmental forest owner in Switzerland! Forests - as far as the eye can see - provide work, income and also a lot of responsibility for the protection of people and nature" (https://oak-schwyz.ch/wp-content/uploads/2020_07_07_OAK_Broschuere_web.pdf).

Fig. 2. Nature reserve Furenwald in Oberiberg (Photo: OAK Schwyz).

Christinehof-Högestad Estate – a case from Scania in southern Sweden

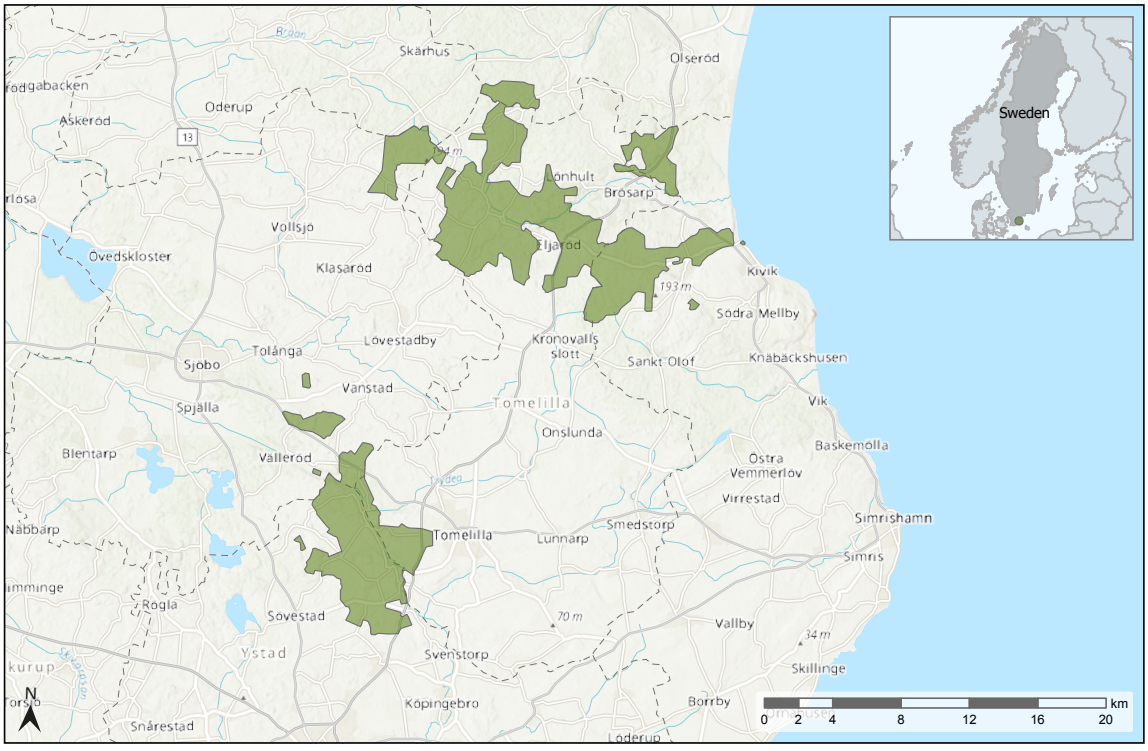
C11

A. Ekstrand

Forest manager, Christinehof-Högestad, Sweden

History and background

The Christinehof-Högestad Estate is situated in the very southeastern corner of the Scandinavian peninsula. Most of Sweden belongs to the northern boreal zone, but southern Sweden is part of the middle European temperate broadleaf zone where oak- (*Quercus petraea* and *Q. robur*) and beech- *(Fagus sylvatica)* dominated forests in mixture with other broadleaves are common. Two small rivers (the Fyle and the Verkeån) flow through the estate to the Baltic Sea. Around 50 % of the forests con-



< Fig. C11.1. Attractive landscape with a mix of grazed areas and forests of Christinehof-Högestad in the background (Photo: Anders Ekstrand).

Statement

"Continuity is key to succesfully adapt and transform forests in order to maintain multiple ecosystem services."

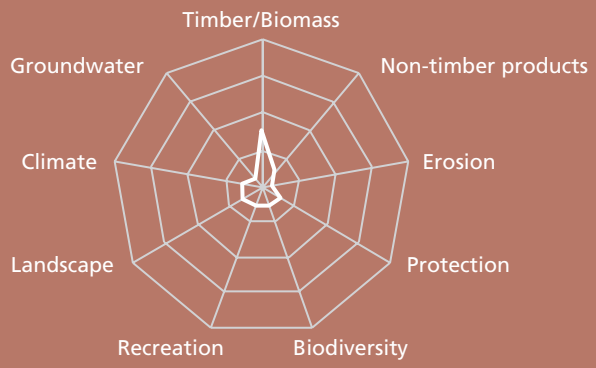


Table C 11.1. General information of the Christinehof-Högestad enterprise.

Forest community	Lowland oak/beech and pine forests of the middle European temperate broadleaf zone in south Sweden
Total forest area	7000 ha
Main management system	Clearcutting with considerations (according to the Swedish law, a certain amount of the volume must remain for biodiversity – in this case 6 % of the volume); Nature management for biodiversity NS (In management plans I Sweden NS stands for Nature management where the biodiversity needs human intervention (like cattle) to exist; Compared to NO which is Nature untouched)
Total volume	200 m³/ha
Annual growth	8.5 m³/ha
Annual harvest	7.2 m³
Deadwood	In Ecopark 20–40 m³/ha; In plantation forest 5 m³/ha
Altitude	0–100 m
Ownership	Private
Geology	Glacial soils from sand to clay
Protected areas	Christinehof Ecopark 1000 ha private protected area; 6%, respectively 420 ha of productive forest are FSC certified with a special status
Nature reserves (national)	Fyledalen (853 ha); Verekeån (1131 ha)

sists of natural or semi-natural broadleaved forests. The rest are plantations of Norway spruce *(Picea abies)* and Scots pine *(Pinus sylvatica)* in former heathlands, and plantations of short rotation poplars (hybrid *Populus trichocarpa x balsamifera*) and birch *(Betula pendula)* in former agricultural fields.

The estate has been owned by the Piper family since 1725 when it was bought by Christina Piper (fig. C 11.2). The current owner of the estate is Count Carl Piper. According to the old primogeniture laws, the oldest son inherited the whole estate and it could not be sold or divided. This law ends with the current owner. The next generation Anna and Fredrik Piper are now taking part of the management of the estate.

Before 1725, the estates had been passed through several noble families during the period when the province of Scania belonged to Denmark. Then in 1658 the province was lost in war to Sweden. Field Marshall Carl Piper (1647–1716) was created the first count of the estate in 1698. In 1690 he married Christina Piper, née Torne (1673–1752). Carl went with King Charles XII to Russia to fight in the Great Northern War and spent his final years as a prisoner-of-war in Russia before he died in 1716. During his absence and after his death Christina

Fig. C11.2. Christinehof castle in Southern Sweden (Photo: Anders Ekstrand).

was a fantastic manager and bought and managed several industrial complexes and estates, including the Christinehof-Högestad Estate. The estate and the beautiful Baroque castle she built are named after her.

Today, the Christinehof-Högestad Estate consists today of ca. 13 000 ha of land, of which 7000 ha is productive forest land. This makes the estate the largest privately-owned estate in the province of Scania and the third largest privately-owned estate in Sweden. Forestry is the main economic activity, but agriculture and hunting also contribute to the estate's revenues.

The Christinehof estate originates in one of the earliest industrial developments in northern Europe. In 1637, Jochum Beck was given a concession by King Christian IV of Denmark to extract 'alum' (KAl[SO4]2×12H20) from a deposit of alum slate in Andrarum. Alum was used both for medical purpose but also in the process of gunpowder. It was one of the first chemical industries in Sweden. The extraction of alum needs huge amounts of firewood and Jochum Beck got the right to harvest timber from all forests (ownership of land and trees) within 20 km from the alum factory. I those days oak and beech was the property of the king in all land. The This is the origin of the land belonging to the estate. One of the oldest forest management plans in northern Europe, from the first half of the seventeenth century, was to provide a permanent flow of wood to the alum factory. So, there is a long tradition of forestry in the area. In 1725, Christina Piper bought the estate and its industries. Around 1500 m³ of firewood per boiler and year at the Alum factory, was used at full production. This means that most of the annual growth from the forests was used.

One of the more substantial questions at the time was to produce sufficient food for the growing workforce for the industries. In the 1800s, as the workforce grew, a lot of forests where cut to make way for agriculture, like in many parts of Sweden; this agricultural land has often ended up as heathland.

However, the land close to the factories and the manor houses has always been maintained with old-growth oak, lime (*Tilia* spp.) and beech. There are some large areas that now are nature reserves or part of the private Ecopark that have had continuous forest cover. The slopes of the Fyle Valley had continuous beech forest, and other parts, especially around the Christinehof manor house have had

continuous presence of old-growth oaks for at least 300 years, meaning that there is a very complex biodiversity connected to old hollow oaks, including the hermit beetle *(Osmoderma eremita)* and several species of the click beetles (*Ampedus* spp.). In total, more than 150 species from the Swedish Red List are found in the area.

Nature conservation

There are several factors that contribute to the high biodiversity of the estate.

Nature reserves
Along the rivers there are two large nature reserves: (1) Fyledalen (the valley along the Fyle River; 853 ha) is entirely within the estate; and (2) Verkeå Reserve (the valley along the Verkeån River; 1131 ha) is mostly within the estate. Smaller reserves like the Högestad Bog (79 ha), Ållskog (189 ha) and Vitemölla (20 ha) are also formally protected areas. With respect to the formally protected areas, the estate has been compensated financially from the Swedish state for the loss of income from forestry.

Fig. C 11.3. Old oak serving as a valuable habitat tree (Photo: Anders Ekstrand).

Christinehof Ecopark
On top of this, the Christinehof Ecopark (ca. 1000 ha) is an entirely private project connected to the cultural and natural heritage of the Christinehof manor house. It is financed by the family, but there is some additional income from tourism. Old-growth trees and deadwood is preserved. Lichens and insects associated with oak are common (fig. C 11.3). Research is conducted in the Ecopark where different projects collect and analyse about habitat and species. A variety of infrastructure is set up in the park and serves as a good example of a collaboration between science and practice (fig. C 11.4).

Wetlands
When drainage channels in agricultural land have not been maintained, the land is now converted back into wetlands. In one area (Borsta kärr) in the Ecopark, land that had held one generation of Norway spruce *(Picea abies)* has been converted back into wetland. This means that fauna and flora connected to wetlands, frogs, birds, and plants are common. The water quality in the two rivers is excellent and trout *(Salmo trutta)* and salmon *(Salmo salar)* are common (fig. C 11.5).

Biodiversity
There is a long list of rare species present in the Christinehof-Högestad Estate. The birdlife is especially rich and there are several breeding pairs of golden eagle *(Aquila chrysaetos)* and white-tailed eagle *(Haliaeetus albicilla)* (fig. C 11.6). Red kite *(Milvus milvus),* the Eurasian buzzard *(Buteo buteo)* and the European honey buzzard *(Pernis apivorus)* are especially common. At the start of the migration in August up to 16 species of raptors have been observed in one day. Most Swedish frog species and

Fig. C11.4. Insect study platform in the Ecopark Christinehof. An infrastructure serving for scientific studies (Photo: Anders Ekstrand).

Fig. C11.5. Water quality in the river streams has improved since drained land was transformed back into wetland. Valuable fish (*Salmo trutta* and *Salmo salar*) have reacted with increasing populations (Photo: Anders Ekstrand).

Fig. C11.6. White tailed eagle *(Haliaeetus albicilla),* a frequent breeder in the forests of Christinehof-Högestad (Photo: Anders Ekstrand).

most Swedish bat species are present. The area is also home to many red-listed insects and lichens.

Recreation

The forests are open to public, and there are car parks and hiking trails through the area, often in cooperation with local authorities and Non-governmental-organisations (NGOs). You are allowed to pick wild berries and mushrooms.

Hunting

The nominate race of red deer *(Cervus elaphus)* described by Carl von Linnaeus in the eighteenth century was preserved on this estate after poaching had made it almost extinct in other parts of Sweden. There are very high populations of red deer, fallow deer *(Dama dama),* roe deer *(Capreolus capreolus),* wild boar *(Sus scrofa),* and also some moose *(Alces alces),* although the area is at the southern limit of the range for this species. Hunting might be much more important from an economic point of view in the future.

Economy

As a base for forestry there is a forest management plan with stands of single tree species or sometimes mixed forests. The normal system of regeneration for Norway spruce is clearcutting and planting, and for beech and Scots pine natural regeneration with seed trees. All tree species, without Norway spruce must be fenced to prevent browsing by deer, that reaches high numbers and creates problems for the regeneration.

The forest area is slowly increasing, and the annual growth is bigger than the annual cut. In the planted areas, for each tree cut there are at least 3–5 new ones planted. In the naturally regenerated areas there is even more regeneration.

For the moment, Norway spruce is the most important tree species from an economic point of view, since large plantations were established on heathland and agricultural land 50–70 years ago. On more fertile soils, monocultures of Norway spruce were planted, and on sandy soils Scots pine was established. These are areas where there is relatively low biodiversity since there have been long periods where these areas did not have tree cover. There is a long-term goal to regenerate a semi-natural forest of oak and some beech–aiming at more than 50 % broadleaved species in the productive forest and therefore substitute unnatural Norway spruce forests to a certain degree. This will take

some time because all broadleaved species must be fenced to protect against browsing by game while young. During the transformation period some aspen, poplars and hybrid larch (*Larix decidua* x *kaempferi*) will be used as quick growing crops to give an even annual return.

About 45 000–55 000 m³ are cut every year, and the annual turnover is around € 2 500 000 and the net profit is around € 1 000 000. Between 5 and 7 people are employed full-time in forestry, and most clearcuttings are made using local contractors.

The most value is produced from the oak timber. The highest volumes of timber are from beech (for export) and spruce (for local sawmills). Pulpwood for paper and textile are stable products, and wood for bioenergy is a growing market.

All forests are certified according to Swedish rules for FSC (Forest Stewardship Council) and PEFC (Programme for Endorsement of Forest Certification).

Strengths and weaknesses

Stable ownership has meant that consistent forest management has been possible. The estate has long-term and well-educated staff. These factors guarantee continuity on all levels. Close connections to the local communities are important and promote local identification with the forest management. The area is popular among tourists and the number of visitors is steadily increasing. This is a good development since it means that activities in nature are gaining importance in society, however, high levels of tourism might to disturbances and overuse of the area.

Most areas (especially oak stands and wetlands) need active management – e.g. in order to achieve good regeneration in oak stands, grazing by cattle is required at appropriate times to create suitable conditions for acorns to germinate and oak seedlings to grow. This maintains biodiversity values that are depending on such management approaches.

The future for the estate looks positive; a process to ecologically restore areas used for agriculture has begun, and the next generation of owners are taking part in the leadership and management of the area.

Dobie family – Abbey St Bathans – Scotland

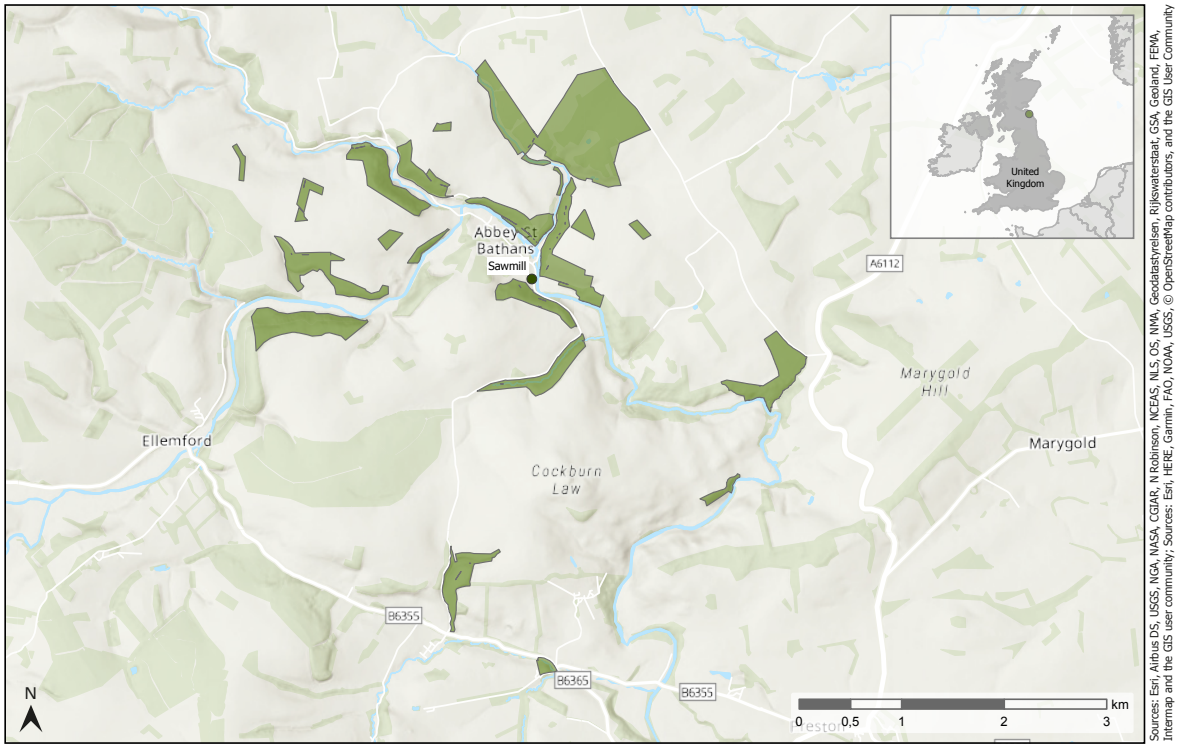
C 12

J. H. C. de Koning[1], E. Dobie[2]

[1] European Forest Institute and University of Copenhagen, Denmark
[2] Abbey St Bathans, Scotland

Portrait

In the rolling hills of South-East Scotland, not far from the border with England, lies the quiet countryside estate of Abbey St Bathans. Its ancient oak woodlands straddling the banks of the small Whiteadder river have long been recognised for their natural value and beauty. The previous century has seen the addition of productive conifer stands. Previous generations have managed to pass down the estate's cottages, pastures, woodlands and sawmill, into the current ownership of William



< Fig. C 12.1. Abbey Timber sawmill framed by ancient oak woodland, with a backdrop of mixed conifer and broadleaf forest, and sheep pastures (Photo: Ellinor Dobie).

Statement

"The woodlands support a medley of ecosystem services; though timber is the primary aim of the coniferous forest, its management encourages many additional services, which are further supported by the native woodland."

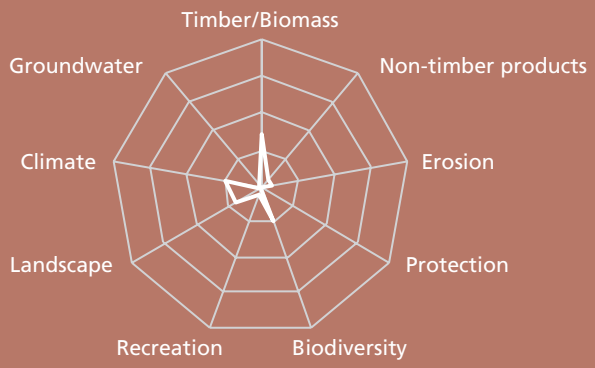


Table C 12.1. General information on the forests of the Abbey St Bathans.

Forest community	A patchwork of small stands with predominantly coniferous single-aged, single-species sub-compartments (0.5-1ha) on valley sides and as shelter-belts on the hill-tops, and ancient oak woodlands on the steepest slopes.
Total forest area	278 ha, divided over: – 210 ha of conifer dominated stands – 22 ha of ancient oak woodlands (of which 15 ha is designated as a Site of Special Scientific Interest) – 16 ha of recently established native woodland to expand and connect the ancient woodland sites – 30 ha of open land and set asides within larger woodland areas
Main management types	– Transition from clearcutting to continuous cover forestry with small gaps (<0.5 ha) and single tree selection of the conifer dominated stands – Based on the yield class, thinning every 4–5 years, slightly over the annual increment rate to bring stocking down – Steady small-scale regeneration (<0.25 ha) of the ancient oak woodlands
Standing volume	– Averages 550 m³/ha in the conifer stands. – 75 m³/ha in the ancient oak woodland
Annual increment	– Averages roughly 3 m³/ha in the conifer stands – 1–2 m³/ha in the ancient oak woodland
Annual harvest volume	– 700 m³/year in the conifer stands – 0 m³/ha/year in the ancient oak woodland. Plans to allow for more light in some areas to enhance regeneration
Ownership	Private family owned and managed
Climate	– approx. 7.7 °C mean annual temperature; – approx. 760 mm mean average precipitation
Altitude	Between 120–250 meters above sea level
Soil and geology	– Brown earth soils of moderate fertility with forests planted on the poorer and steeper sites. – The top soil is thin, resting on bedrock made up of Gala group greywack – rock fragments of hard sandstone.
Protected area	– Most of the 22 ha of ancient oak woodland is designated as Site of Special Scientific Interest (SSSI). – Smaller self-imposed retention areas of open land and edges in woodlands are maintained for diversity and conservation. They amount to about 32 ha in total.
Protective function	None

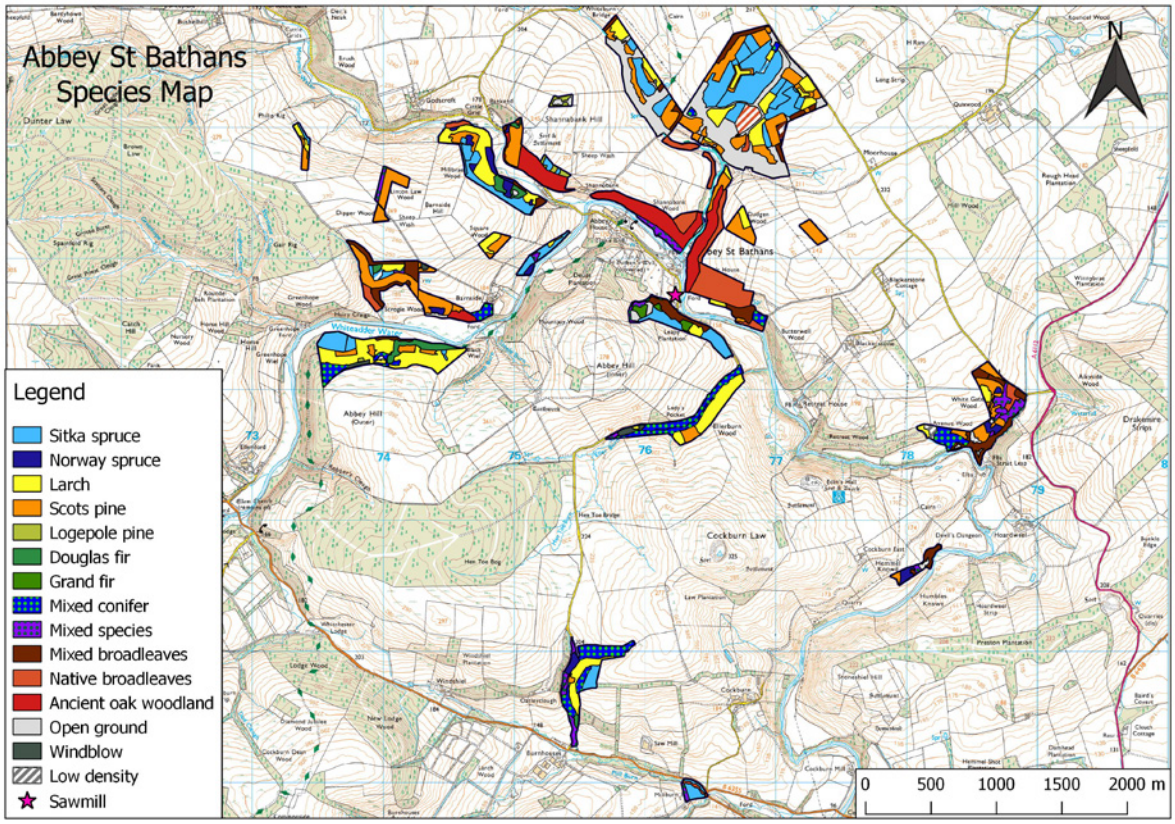


Fig. C 12.2. Species distribution in forests of Abbey St. Bathans presents a broad portfolio of different tree species.

Dobie and his family. In this case we describe the forestry business of a privately owned and managed Scottish family estate in search of the balance between economic viability and natural abundance and beauty, with the key ingredient of an estate sawmill (fig. C 12.2.). The functional integration of different elements of the estate is set against the backdrop of the family's efforts to modernise and professionalise forest management and sawmilling, and transfer the estate's management from this generation to the next.

The vision for the forests of Abbey St Bathans in the simplest of terms: 'Resilient forests that provide a steady supply of quality timber for the estate's sawmill, as well as benefiting the surrounding farmers and enriching the landscape for ecology, aesthetics, and recreation.'

Forest history and cultural heritage

Privately owned estates such as the one in this case have played a defining role in determining the social, economic and ecological landscape of the Scottish countryside. Abbey St Bathans exemplifies the common composition of such estates with its fine grained mix of land use types. Agriculture, hunting, tenants' rent, biomass heating, wind energy, and forestry all contribute to its household economics (fig. C 12.3.). Here we focus on the forestry part, only briefly touching upon the other elements to do justice to the integrity of the estate. The estate's land uses follow the productive capacity of the land. The grasslands and heathlands are extensively grazed by sheep and cattle for meat production, and the forests provide timber, shelter for the livestock, and cover for the pheasant shoot. In this intricate mosaic of land uses, no single piece

Fig. C 12.3. The main valley of Abbey St Bathans, with the Whiteadder River flanked by ancient oak woodland and coniferous forest. The wooden building to the right of the photo is the village hall, which is currently being rebuilt, and its cladding is from Abbey Timber (Photo: Ellinor Dobie).

of land is used for merely one purpose. The rolling hills of Southern Scotland are a well-known and much appreciated landscape for autumn pheasant shooting. Interwoven with all other land uses are smaller areas set aside for conservation, and there are rare lichen and butterfly species on the estate, such as the rare and beautiful pearl-bordered fritillary *(Boloria euphrosyne).* The family has decided to acknowledge the importance of the continued survival of these species, since they have been sharing the estate as their home with generations of the Dobie family. Costs of such measures are the forgone use of these lands, since management is often not needed and commonly undesirable.

Flat hilltops and some small strips along the stream are grazing lands, leaving the steep hillsides and most exposed hill-tops to form the estate's 278 ha of woodland. There are two main types of forest on the estate and they could not be further apart in their appearance and purpose. Along the valley sides there are gnarly oak woodlands, like pearls on the silver string of the small Whiteadder river. These ancient forest remnants, left in part because of the inaccessible terrain on which they grow, are of great aesthetic and natural value, not least to the 40 or so residents of the village of Abbey St Bathans itself. In recent times however, a lack of recruitment due to the high influx of browsing roe deer and a lack of management have gradually hollowed out these oak forests. The open canopy and their connection to the ancient history of these lands contrasts sharply with the estate's other forest type. Rationalised forestry reached these lands in the beginning of the previous century in the form of conifer forests made up of single-age, single-species sub-compartments (fig. C 12.2). There are many reasons why some of the grassland was planted with conifers – to help the future war effort, potential financial returns, untaxed returns on forestry investment, to improve aesthetics and most of all, it was the 'done thing' amongst land owners at the time. After World War II, timber prices in Europe dropped and newly planted stands were left barely managed for over half a century.

Fig. C12.4. The perfect forest stand: diverse productive species (Douglas fir and Norway spruce shown here), with ample regeneration of conifer and broadleaf species, and a conservation element (standing birch deadwood, with fungi and a woodpecker hole) (Photo: Ellinor Dobie).

Present and future forestry activities

Management of all woodland, both tending for stand improvement and harvesting of timber, became an incidental occurrence. Over time the old oak woods became hollow and the then young conifer stands became overstocked. This might have still been the case, had it not been for an important element, tying together all the forests of Abbey St Bathans: the estate sawmill, which has been in use since mid-1800s.

While many smaller sawmills have disappeared from the area due to low timber prices and ultimately losing the battle of scale to the few bigger sawmills in Scotland and Northern England, the estate's sawmill has managed to stay afloat (fig. C12.5.) Moving on from the original water-powered circular saw, William Dobie initially expanded and modernised the sawmill to provide an outlet for the small roundwood from the first and second thinnings of the estates forests when timber prices were low and there wasn't a market for them, with no other 'local sawmill'. Although it is comparatively small, there are some distinct reasons it still plays a vital role for both the estate and local forest owners and managers alike. The first being its lack of specialisation. The simple machinery consisting of a large bandsaw, a small bandsaw and a circular saw for re-sawing, another circular saw for cross-cutting, a planer and a kiln can be rather easily be used to saw both different species and different dimensions, a feature that has been lost in many modern sawmills. The secondary processing machinery also allows the sawmill to get more value out of its timber. For example larch, which would often have low-value uses as pallets or fence posts, can have considerable value added by being made into cladding or materials for boats. Another connected reason is the capability to process relatively small orders of sawn timber and provide for customers who want specific products, which other sawmills would not be able to cater for.

However, the energy in keeping the mill going in the difficult times and catering to the high demand for its products means that tending, thinning and harvesting has been overlooked for some

Fig. C 12.5. 'Abbey Timber': Abbey St Bathans` sawmill (Photo: Ellinor Dobie).

time, and there has often not been the staff, skills, or time available for forestry work. The most recent contribution to forestry took place 23 years ago when 57 ha of commercial and 28 ha of native woodland were planted. In the young commercial forests, tending and thinning will take place every 4–5 years, depending on their productivity. This should promote the trees with good form and allow for wider spacing and thus better anchor them. The mature commercial stands (over 40 years old) will be also thinned every 5–8 years, with the additional aim of increased light availability for natural regeneration. Ellinor Dobie, educated forester and daughter of the current owner, is currently employed as the estate forester and bandsaw operator. In due time, she seems perfectly positioned to take over the management of the entire forestry and sawmill business. Her days are therefore spent preparing the forests for that task. Whenever needed, Ellinor can call upon the aid of locals, including the sawmill workers, to help her with the forestry work. When she came into full-time employment of the estate some two years ago, she found the estate's forests in need of in-depth, long-term planning and rigorous management, so that they could grow into their potential and sustainably supply timber in future.

The new forest manager has set firm targets for the future of the forests. Forest stability and diversity, and steady wood production for the sawmill will be the guiding principles for future management. In practice, this means transitioning to continuous cover forestry on the more productive sites and to small scale shelterwoods on the poorer and more inaccessible sites. Both allow the use of natural regeneration, cutting overall establishment costs, while providing a slow and steady flow of timber to the sawmill. Where the genetics need improving and/or tree species diversity is lacking, richness will be increased by underplanting. Broadleaf species and shrubs will be introduced along the streams and woodland boundaries, to improve water quality and shelter. Cutting will be done by hand for most saw logs, letting the excavator, equipped with a newly acquired harvesting head, process the tops, as well as dealing with first thinnings. This management will form a sharp contrast with common practice in Scotland, where Clearcuts are commonly 5-10 ha, and in some places reach 50 ha at a time, while 2 m high deer fences

Table C 12.2. Area covered by different tree species in Abbey St Bathans.

Tree species	hectares
Scots pine *(Pinus sylvestris)*	50
Sitka spruce *(Picea sitchensis)*	47
Hybrid larch *(Larix decidua* x *kaempferi)*	43
Native broadleaves	42 (of which 22 ha is ancient oak woodland)
Mixed broadleaves (e.g. sycamore maple, birch, lime)	21
Mixed conifers, including all conifers in this table, and additionally Western hemlock *(Tsuga heterophylla),* Western red cedar *(Thuja plicata),* and Corsican pine *(Pinus nigra)*	18
Mixed (broadleaves and conifers in intimate mix)	10
Norway spruce *(Picea abies)*	7
Douglas fir *(Pseudotsuga menziesii)*	5
Grand fir *(Abies grandis)*	2
Lodgepole pine *(Pinus contorta)*	1
Integral open ground*	32
Total	278

* Integral open ground within the forest larger than about 0.1 ha. Mostly areas that failed after planting or were windblown years ago with no re-planting. Also areas left open so they can provide good woodland-edges and ungrazed grassland habitats. Such is encouraged by Scottish Forestry/Forestry Commission.

have to be put in place to safeguard restocking investments.

This new management regime will undoubtedly support forest stability and hopefully help to increase species richness and structure which in turn may benefit biodiversity. The latter gets additional management attention in future, through the rejuvenation of the ancient oak woodlands. As stewards of the land, the Dobie family is very committed to its continued survival. Small gap cuttings, followed by regeneration with local material and browsing protection will be employed to secure its future (Fig. C 12.7.). Full-scale deer fencing will be rarely practiced, because of the small scale of regeneration. Instead, a professional hunter has been employed to permanently reduce the number of roe deer, while small, temporary exclosures will be used if necessary. Also this form of applied management is in stark contrast to the contemporary common management in the United Kingdom, where following large clear-fellings high deer fences are installed and hardly ever removed after the regeneration phase.

Aims of the enterprise

When William Dobie inherited the estate, he wanted to put his energies into sustaining Abbey St Bathans. Rather than having a city job and the estate being a mere asset, the initial aim of the enterprise – of managing the woodland and expanding the sawmill – was to give himself a livelihood on the land here, and also provide employment for other locals.

In quantitative terms, the aim of forest management is specifically to provide quality timber to the sawmill. Subsidies are incidental and cannot be relied upon or expected to cover the costs of management. Getting a steady positive nett return is valued over an incidental large gain as the sawmill does not have the capacity to deal with large quantities of timber at one time. The recent investments in forestry planning and equipment, including the sawmill, are thought to smoothen the transfer of management to the next generation of estate owners.

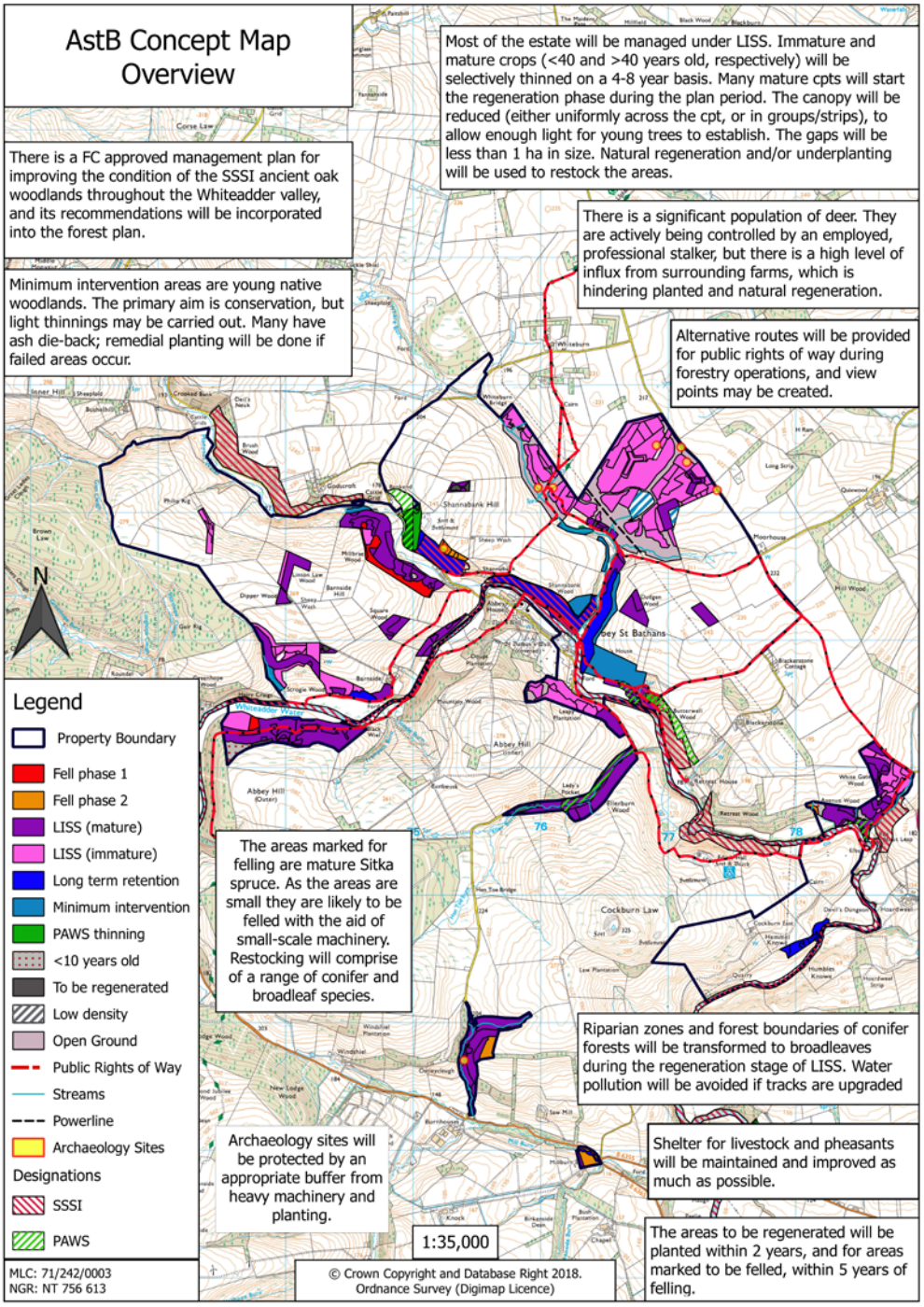


Fig. C12.6. The Abbey St Bathans forest management plan. FC: Forestry Commission – (recently changed to Scottish Forestry); SSSI: Site of special scientific interest (areas protected by law to conserve their wildlife or geology, certain management restrictions, grants available for targeted management); LISS: Low Impact Silvicultural Systems (systems that work towards mixed age and species woodlands, and exclude large clear-cuts); PAWS: Plantations on Ancient Woodland Sites (current conifer stands on ancient forest sites, grants are available for their conversion back to native woodland).

Fig. C12.7. Ancient oak woodlands designated as sites of special scientific interest (Photo: Ellinor Dobie).

Specific aspects Abbey St Bathans

Forest management

Forest management follows the principal economic doctrine of continuity of the enterprise and profit where possible. Continuity includes amenities which do not directly contribute to the economic output, but increase its value to the owner and the community. Employment of locals, biodiversity and scenic beauty are considered as such. As a small forestry enterprise we are on occasion supported by the government in our mission. Although the main goals as stated will sustain, forest management will gradually change from incidental to continuous under management regimes that increase the diversity, resilience, and stability of the forest and should lead to a steady output of timber for the sawmill.

Economics

From 2015 to 2020 the average operating surplus of the forest was £10 000/year. The price of timber has risen sharply over this period. In 2015 the average standing value of all timber harvested was £15/m³ (total value of £40, minus £25 to cover the cost of felling and transport to the roadside). By 2019, the standing value of timber being harvested had risen to over £25/m³. As all timber harvested goes to the sawmill, rather than being sold, the operating surplus is essentially the money 'saved' by the sawmill through using the estate's timber rather than buying it in.

The average increment is around 12 m³/ha while the annual harvest is far below that. This results in an increase of standing volume. The overall annual surplus, however, is lower than intended, as workers trained in forestry equipment have only occasionally been available for timber harvesting – so timber that could have been provided by the estate had to be bought in instead. Ideally, the sawmill would be flexible, to process only harvested timber from the estate in times in which buying timber and transport costs are very high, purchase roundwood externally when wood and transport prices are low, or when there is need to meet a specific order. The harvestable volume from the woodlands by itself is too small to turn a sustained profit without the sawmill. Also other sawmills are too far away and often require large volumes at once.

The average yearly income of the sawmill for the period 2015 to 2020 was about £200 000/year.

Expenses were approximately £170 000/year, which consist mainly of labour for the sawmill and forestry work. Due to a government grant for small scale forestry business the estate was able to attain a new harvesting head and bandsaw for half the cost. Both are considered vital investments into the continuity of the enterprise. Most of the village dwellings, the sawmill and its kiln are heated with wood chips harvested from the estate. These woodchips are attained from harvesting residue and since the government wishes to increase the use of biomass for such purposes, the estate receives a small fee per kilowatt hour.

Nature conservation and biodiversity

Increased light from thinnings should benefit diversity in the understory. Relying on natural regeneration and underplanting with the aim of diversification in structure and species should also support biodiversity, as will retaining standing and lying deadwood as well as dying trees. The plan to increase the proportion of broadleaves in the forest species mix, as well as planting native trees and shrubs along streams and woodland boundaries, will provide more varied habitat and food for woodland and aquatic species. There are few direct costs associated only with nature protection or management, since most of the areas that serve this primary purpose are best left unmanaged. Forgone income could be considered a cost. A running cost partly attributed to nature conservation is a professional hunter employed to cull the roe deer population for increased natural regeneration in both the commercial and the ancient oak woodland. The estate feels honour bound to forgo some revenues in the form of set-aside areas or for specific protection measures. In these matters, there is occasional assistance from government grants.

Social aspects

The right to roam extends to all the estate's lands and tourists may thus travel freely through the fields and forests. There are several Airbnb options in the village that are rented out to tourists. The estate plays a central role in the continuity of the rural community in which it is situated, by providing direct employment to 5–7 people in forestry and the sawmill and doing business with small scale forest owners in the extended area.

Forest resilience

In these areas, wind is the main natural disturbance. Stable species such as Scots pine and larch have been established as shelter-belts on the ridges of the hills to break the winds coming in from the south-west. The small area of conifer stands that are too unstable to be gradually transformed to continuous cover management will be clear-cut over time and preferably naturally regenerated with a diversity of species. Stands of species less susceptible to windthrow, can be gradually transformed to uneven aged and mixed species stands, through thinning and group harvesting. Several pests and pathogens may direct the future species choice. Corsican pine is unlikely to be used in future since they are currently under attack from red band needle blight *(Dothistroma septosporum).* Ash trees in the recent extensions to the ancient woodland sites have been dying due to ash dieback *(Hymenoscyphus fraxineus)* and will be replaced naturally or through additional planting. Another pathogen which is likely to arrive in due time is *Phytophthora ramorum* which has been extending its range in recent times and may cause dieback of the larch stands. North American species seem well suited to the region, and diversification will include Western red cedar and more Douglas fir. However, it is difficult to predict how climate change will affect the British Isles, and so the only way to account for this is to increase diversity, and then favour the species that are best-adapted to the future climate.

Conclusion

Forestry at Abbey St Bathans runs counter to the predominant management system in the UK of clear-fell rotation. There are others doing the same, thus we see ourselves as a good example of how two key factors – a small-medium scale sawmill and a secure future – can positively impact forest management, while ensuring social, economic and environmental sustainability. In order to maintain its position as custodian of the landscape and its people, the estate has to remain economically viable, with the forestry in tandem with the sawmill. In doing so, it can continue to provide employment to local people and invest in the natural amenities such as diverse forests, rare lichen and insect species, and the ancient oak woodlands. An increase in

forest management is urgently needed in order to reduce the risk of natural hazards due to overstocking, improve the quality of the standing timber, and encourage the regeneration of more varied species. Recent investments in the sawmill, forest machinery, game management and the full-time employment in forestry of one of the heirs secure the future of the estate.

Explanatory note

A series of interviews lies at the basis of this case, in which Johannes de Koning took on the role of interviewer and Ellinor Dobie was interviewee. Additional information was provided by William Dobie, who owns and manages the Abbey St Bathans estate

Link

Forest Research. Continuous Cover Silviculture. Collection of publications and research on Continuous Cover Silviculture. Research Agency of the UK Forestry Commission. https://www.forestresearch.gov.uk/research/continuous-cover-silviculture/

Box C8

Nature and culture on a small agricultural enterprise in southeast Brazil

P. Bonfils

https://www.naturavali.com/

Just nine crops cover two-thirds of the world's food requirements (FAO 2019). Agriculture based on economies of scale and mechanisation produces food at the lowest possible cost, while biodiversity is lost. The Food and Agriculture Organization (FAO) provides an alarming picture of the situation in 2019. Not only the actual crops are affected, but also the associated biodiversity, which provides valuable ecosystem services for agriculture (FAO 2019). Natural ecosystems such as forests continue to be cleared in a haphazard manner, even though they represent source and retreat areas for biological diversity (Betts *et al.* 2017). The tropics, which host more than three-quarters of the world's plant and animal diversity, are particularly affected by such impacts (Barlow *et al.* 2018). With this in mind, Patrick Bonfils takes us on a tour of his small agricultural enterprise (Sitio) in southeastern Brazil.

The Sitio Beija Flor is situated in a hilly landscape on the edge of the Cinturão Verde, the green belt surrounding the metropolis of São Paulo. The main landscape elements characterising the Sitio are forests, pasture, and cultivated areas, but there are also buildings for work, production, and living. The spatial distribution, combination, and design of all these basic elements of landscape are decisive for the economic and ecological balance of the farm (fig. 1).

Forests influence temperature, humidity, wind, and light conditions on adjacent areas (e.g. pastures, cultivated fields, gardens). Their effects are, however, not limited to only physical aspects. Parts of the farm are also managed as agroforestry production systems (fig. 2). Trees are pruned and cut to use the leaf material for soil cover and as a fertiliser (Götsch 1992). The aim is to increase the amount of organic matter in the soil (humus), thus creating optimal structures for water and nutrient retention. Furthermore, this contributes to improved conditions for soil organisms. Through this, the soil will become a living organism and biodiversity a produc-

Fig. 1. Diverse, small-structured landscape. Forest, pasture, orchards, and tree gardens provide more than a dozen different agricultural products and are a storehouse for a vast array of biodiversity (Photo: Patrick Bonfils).

Fig. 2. Agroforestry. Tree vegetation has established itself in an abandoned plantation with turmeric *(Curcuma longa).* It grows well in the fresh microclimate in semi-shade. Without fundamentally changing this state, the amount of light on the site should be increased, the tree vegetation cut regularly, and the leaf mass used as ground cover and fertiliser. Turmeric root can be easily marketed at a good price (Photo: Patrick Bonfils).

tion factor supporting energy and resource-efficient food production.

More and more small farms such as *Sitio Beija Flor* are opting for (bio-)diversity-based management. This includes the cultivation of a wider range of crops. The crops are spatially arranged and combined so that they complement each other and can be grown in rotation (fig. 3). In addition to maintaining soil fertility, the development should also reduce the occurrence of pests and plant diseases. The costs of artificial fertilisers and plant protection products have risen sharply in recent years and need to be reduced. In the case of organic production, they should be eliminated almost completely. Product diversity supports not only ecological but also economic, and thus social, resilience; the more complex a system, the more resilient it becomes (Agenda Götsch 2015). Farm animals also play a pivotal role. This is true in particular for cows. In addition to the possibility to produce milk and cheese, they provide manure which is a highly valued raw material for producing compost and compost-like organic fertilisers (fig. 4).

The coexistence of nature and production is quite challenging, especially in the tropics and subtropics. The nocturnal work of the leaf-cutting ant or the ravenous hunger of the slaty-breasted wood rail *(Aramides saracura)* can cause considerable damage to crops and gardens. Blood-sucking vampire bats can induce anaemia even in adult cattle, and they are also vectors for spreading serious diseases (e.g. rabies). The list of questions becomes extensive when addressing the close coexistence of natural and cultural landscapes. Besides investments such as fences or stables, dealing with such challenges requires, above all, an in-depth understanding of both the prevailing ecosystems and possibilities of adequate production and management measures.

There is a lively debate about which type of agricultural production best meets the mix of ecological, economic, and social challenges of today (FAO 2017). With regard to biodiversity, however, it can be stated that conventional agriculture based on industrial logic has failed to date (FAO 2019). Alternative farming methods, such as those offered

Fig. 3. Risk compensation. On the Sitio, maize, beans, and pumpkins are grown as mixed crops on the same area. They each use different soil horizons and are not in competition above ground. The bean, being a legume, binds nitrogen. In 2019, it was very dry when the maize was sown corn, and so it did not grow well throughout the entire region. However, the beans and pumpkins hardly suffered. On the right side of the image there is an Annatto shrub (*Bixa orellana;* alternative common name – Urucum). The seeds of its fruit are used as a spice and natural colouring of food (Photo: Patrick Bonfils).

by agroforestry systems, are attracting increased interest (FAO and ICRAF 2019). Today, creativity, practical understanding, knowledge, and courage are expected, not only from agricultural producers, but also from politicians, administrators, and especially from consumers. New thinking and behaviour are urgently needed; failing to preserve biodiversity will endanger humankind's future (Glaubrecht 2019).

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Fig. 4. Farm animals. Cows are important for organic farming. Milk and cheese can be marketed easily. Cow dung is used as fertiliser (Photo: Patrick Bonfils).

Dikchan – Multifunctional forestry in Bulgaria – the experience of a State Hunting Unit

C 13

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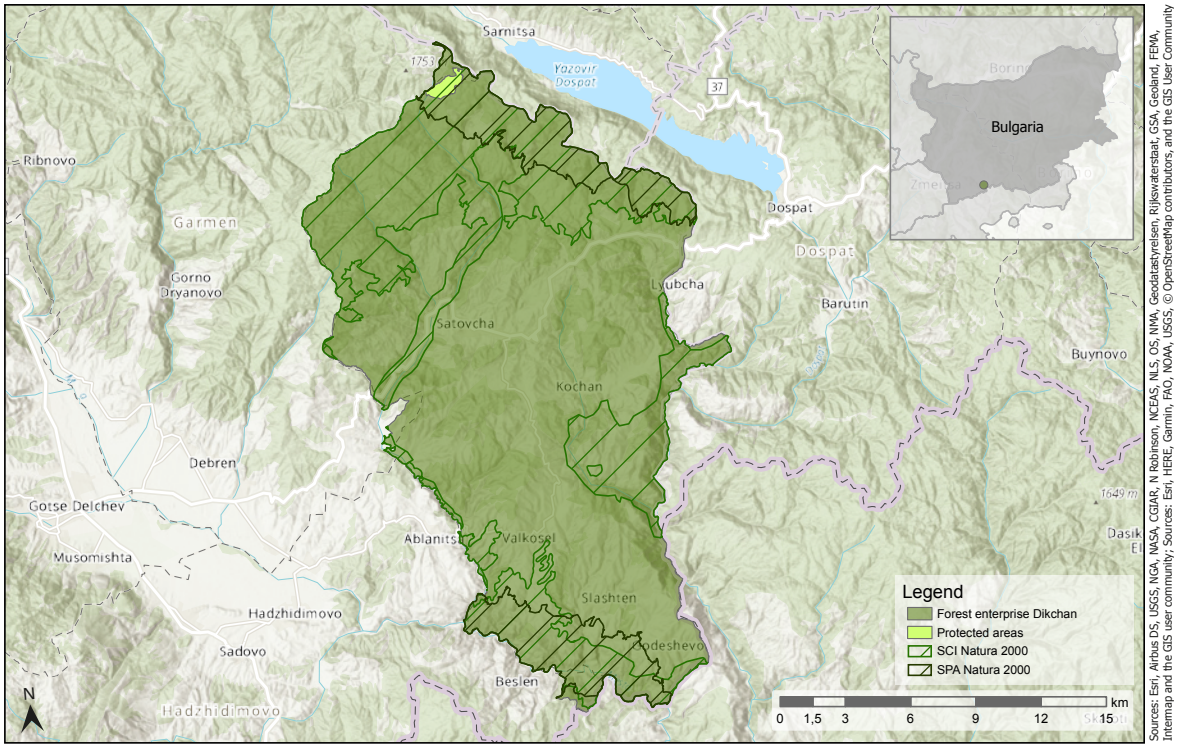
Background

Bulgarian forests are managed by six state-owned forest enterprises. State Hunting Unit Dikchan (hereafter SHU Dikchan) is a division of the Southwest State Enterprise and is FSC-certified. It is situated in the western-most part of Rhodopes mountain range in southwestern Bulgaria (between 41°27′ to 41°45′N and 23°55′ to 24°06′E, for more details please see the online forest map at https://gori.uzdp.bg/en). Within the current boundaries of SHU Dikchan there are 14 villages with a total pop-



< Fig. C 13.1. Landscape in SHU Dikchan. In the distance are the slopes of Falakaro Mountains (Photo: Georgi Gogushev).

Statement

"In general, ecosystem services and especially nature conservation have not been accounted for by markets, and therefore have often been considered as an economic burden. However, state forest enterprises as the SHU Dikchan have an important role to play in the supply of ecosystem services. "

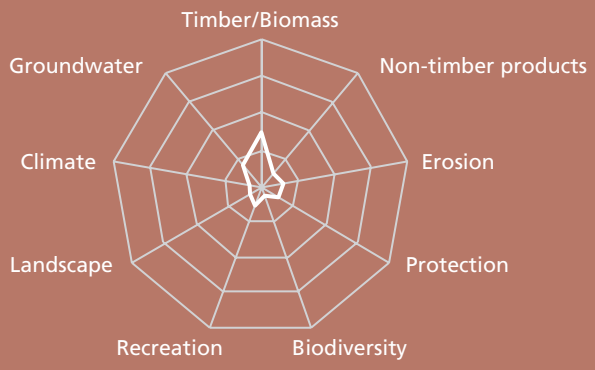


Table C9.1. General information on the forests in State Hunting Enterprise Dikchan.

Total forest area (incl. private and municipal)	20857.6 ha
Total state-owned forest areas	18306 ha
Main forest types	Coniferous and mixed coniferous-broadleaved forests
Altitude	400 to 1750 m a.s.l.
Main silvicultural system	Selective cutting system
Average wood stock	235 m³/ha
Average annual increment	3.94 m³/ha
Ownership	State, community-owned and private forest
Forest reserves	77.4 ha
Natura 2000 Protected areas	15523.9 ha
Protective forest function	3084.7 ha
Old-growth islands	32 ha (in progress)
Habitat trees	150 (in progress)
Protective function	43 ha

ulation of 17200 people. It is a representative example of the way the multifunctional forestry concept has been practically implemented in Bulgaria.

The main aim of SHU Dikchan is sustainable management of the forests within its boundaries in accordance with the national Forestry Act of Bulgaria from 2011. This act aims to ensure the multi-functional and sustainable management of forest ecosystems. The enterprise produces high-quality wood, provides opportunities for organised hunting, protects valuable forest patches in reserves and Natura 2000 areas and serves multiple ecosystem services of which the local people are highly dependent. The vast majority (nearly 87 %) of forests in Bulgaria are in public ownership, and this presents opportunities and challenges for the management of the forests. The concept of multifunctional forestry is defined in the national Forestry Act and incorporates the principles of sustainable forestry promoted by the international Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC) standards.

Portrait

SHU Dikchan manages 20857 ha mountain forests with an average stand age of 64 years and an annual harvest of 42000 m³, which is 58 % of the annual volume increment. The focus of the timber production is high-quality coniferous wood, which accounts for more than 65 % of the total harvest. Broadleaves are mainly used to supply firewood for the local population. Most of the land is state-

owned (91 %), with some community-owned (7 %), and only 2 % privately-owned. The majority of community-owned forests are a result of self-regeneration on abandoned agriculture lands. The very high percentage of state-owned forests allows the enterprise to implement long-term management plans and maintain biotope trees and sufficient amounts of deadwood; in other regions of Bulgaria with a higher percentage of community-owned forests, maintenance of biotope trees and deadwood in the forests has been problematic, though there is progress as some municipalities recently accepted to declare higher rate of protection of old forests after WWF-Bulgaria mapped and presented on a public GIS platform such forests (https://gis.wwf.bg/mobilz/en/). In SHU Dikchan there is one forest reserve – 'Konski dol' (34.4 ha) – and one protected site – 'Manastirishte' (71 ha) – serving as a buffer zone for the Konski dol reserve. The Konski dol forest reserve preserves old-growth mixed beech-fir-spruce *(Fagus sylvatica-Abies alba-Picea abies)* forests, which are highly valuable for the biodiversity and genotype protection and also for the scientific research. The majority of SHU Dikchan is also included in the partly overlapping Natura 2000 protected areas according to the Habitats Directive (Sites of Community Importance SCI BG0001030 and BG0000220) and the Birds Directive (Special Protection Areas SPA BG0002063 and BG0002076 (see map).

While timber production is the main economic activity in SHU Dikchan, ca. 76 % of its area are categorised as forest territories with special functions: protected areas, water provision, tourism, game management, collection of non-wood products. For instance, besides Konski dol forest reserve another 1845 ha of the state forest area (10.1 %) are designated for strict protection of old-growth forests and other valuable natural habitats. The remaining 89.9 % of the forests, particularly those with special functions, are managed so that other ecosystem functions besides wood production are in focus. The main goals of the silvicultural systems are to: maintain heterogeneous forests; gradually transition from stands with artificial structures to more close-to-natural forests; create multi-aged forest structures with higher species diversity. The target for deadwood is to be not less than 10 % of the forest growing stock, and the aim is that the forests should contain three to five biotope trees per hectare. However, the target for deadwood volume has not yet been accomplished, except in some inaccessible areas and the Konski dol reserve (discussed later). Natura 2000 areas for the moment do not have accepted special management plans, but the regime is similar to the FSC standards with special focus on maintaining conditions for protection of certain habitats listed as vulnerable.

Forest history and cultural heritage

As for other regions of mountain and forest areas in Bulgaria, the historical information about the SHU Dikchan area is limited. We can derive some information from historical sources, local place names, and from the first descriptions of foresters, who started working in the region at the beginning of the twentieth century (Tsavkov 2016).

The whole territory of SHU Dikchan was ruled by the Ottoman Empire until 1912, when it regained its independence and became part of Bulgaria. The name 'Dikchan' comes from the Turkish words – 'Dik' and 'Cam', meaning 'Straight pines'. Some forests in the area were also known as 'Karaorman', which means 'Dark/black forest'.

Although there is little information about the times before the twentieth century, it is known from historical and local sources that the land was mainly valued for summer pastures. Sheep farming was a very important source of income and the flat areas were maintained as grasslands for grazing and hay production. This was done by tree cutting and use of fire, but only on flat terrain, which in the Rhodopes is found on the top of ridges and along the valley floors. The steeper slopes were forest areas, where there was limited irregular selective logging closer to the villages to satisfy demand for wood (construction timber or fuelwood). In addition, the public access to some areas was restricted, to allow the areas to be used for private needs such as hunting. The lack of larger access roads and the remoteness of the area limited commercial exploitation for the whole inner part of the Rhodopes mountain range. According to Konstantin Baikushev, who in 1894 made the first forest map for areas in the Western Rhodopes which accompanied a book describing the forests, wood harvesting was restricted only to areas close to the villages (Baikushev 1895). In some other areas (i.e. the Yakuruda region), large rivers allowed harvested logs to be transported using water and this

marked the start of commercial exploitation at the beginning of the twentieth century; this was not possible in the area of Dikchan. These factors created a landscape of wide-open grasslands on the ridges and dark forests on the slopes, which was maintained for a long period. After the middle of the twentieth century, sheep breeding was limited, but much of the former pasture lands were used for growing potatoes. However, some land not favourable for farming activities was abandoned, which allowed re-forestation by pioneer species such as Scots pine *(Pinus sylvestris)* and silver birch *(Betula pendula).* Consequently, there is now an unusually large area of birch, which is not typical for other areas in the Rhodopes.

The Dikchan forest enterprise was created in 1913. Since the creation of the enterprise it has experienced several periods with different management regimes. In the first decades, there were strong rules regarding access to the forest and logging was limited. Commercial logging started after 1934 when professional wood-fellers from other regions (i.e. Bansko at the foot of Pirin Mountains) were invited to the area. They optimised the technologies for wood transport by building a primitive transport system using wooden rails along which the harvested wood was pulled by oxen. Photographs and written accounts from that period indicate the presence of large silver firs *(Abies alba)* and spruces *(Picea abies)* with diameters of up to 170 cm for silver fir (fig. C 13.2).

During the 1960s the annual total volume of harvested wood reached 100 000 m³, which was twice as much as the annual increment. This period of very high harvesting coincided with a house-building and industry development boom in Bulgaria with high demand for wood. These very high harvesting levels lead to deterioration of the condition of some forests.

During the 1970s and 1980s the felling levels were drastically reduced, and the focus was on afforestation of damaged or eroded areas. In total, there are about 7000 ha of plantations in SHU Dikchan. This, along with natural regeneration on

Fig. C 13.2. Giant trees as the silver fir (a) and Norway spruce (b) that could be found until the early twentieth century in the region of SHU Dikchan (Photos: archive of SHU Dikchan).

abandoned farming lands and pastures, are the main reasons why the main tree species is Scots pine *(Pinus sylvestris),* the most favoured species for planting in the mountain areas of Bulgaria. Other commercially important species in SHU Dikchan are Norway spruce *(Picea abies),* Austrian pine (*Pinus nigra* subsp. *nigra*), silver fir *(Abies alba),* beech *(Fagus sylvatica),* oaks (mostly *Quercus petraea* with some *Q. pubescens* and *Q. frainetto* on lower and south-facing slopes), and limited areas of other species such as black alder *(Alnus glutinosa)* next to rivers, plantations of black locust *(Robinia pseudo-acacia)* and dense shrubby stands of oriental hornbeam *(Carpinus orientalis)* on eroded slopes at lower elevations (fig. C 13.3).

The main silvicultural systems have changed over the decades. After the 1940s, the most used systems were shelterwood and group-selection cuttings. Presently the focus is on selective systems with use of natural regeneration. Planting is used only in the cases of larger disturbances, when the natural regeneration is not considered sufficient. Presently, the majority of harvesting (60 % of the harvested volume) is within thinning and tending operations. The aim of the management of older forests is to create or maintain multi-cohort forests.

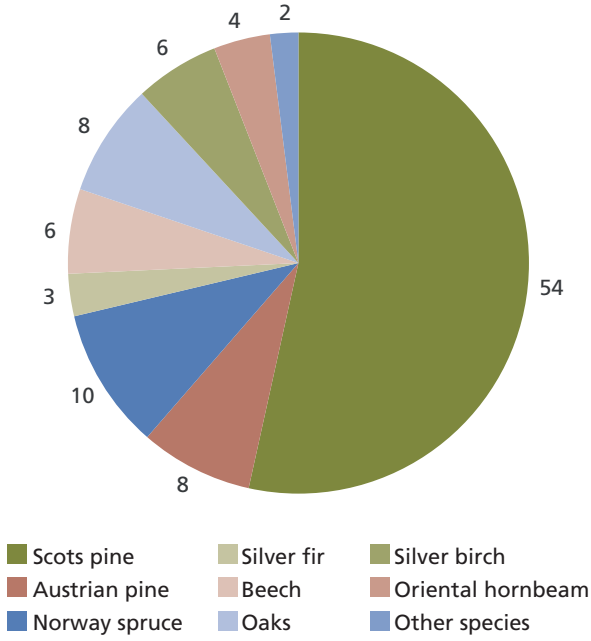


Fig. C 13.3. Main tree species and occupied territory in the State Hunting Enterprise Dikchan.

Economics of the SHU Dikchan forests

The main ecosystem service provided by the forests is wood production, often in combination with managed meadows that serve for grazing and hay production (fig. C 13.4 a and b). The annual harvest is 42 000 m³, of which 65 % is high-quality construction wood (pine and spruce), and 35 % is lower-quality wood used for heating, mostly by local people. There are long traditions of providing the local population with a cheap source of fuelwood. Traditionally people could collect deadwood in managed forests and harvest a limited amount of

Fig. C 13.4. (a) Typical landscape for the higher parts of SHU Dikchan. (b) Meadows used for grazing and hay production and coniferous forests that serve for valuable timber production (Photos: Georgi Gogushev).

Fig. C 13.5. Hunting house in SHU Dikchan used to accommodate hunters, who visit the region for organised hunting (Photo archive of SHU Dikchan).

Fig. C 13.6. Scots pine-dominated forests in the Rhodopes mountains. They are valued for high-quality wood but also for tourism, forest fruits and mushroom collection (Photo: Georgi Gogushev).

Fig. C 13.7. Typical barbeque house and fountain for drinking water in Rhodopes mountains. Local people build these to commemorate relatives. At weekends family members gather for meetings (Photo archive of SHU Dikchan).

wood, mostly from thinnings. One of the present-day challenges is to limit these activities and insure the leaving of higher levels of deadwood in the forest.

The harvesting is done mostly by small privately-owned companies, and to a lesser extent by workers at SHU Dikchan. The wood is extracted by mixed use of animals (horses) and tractors. The average sale price of wood in 2019 was 42 €/m³. Price varies according to wood quality.

In the region of Satovcha village, which is the biggest village in the area, there are numerous small wood-processing sawmills with a total volume of annually processed wood of 50 000 m³. These sawmills have to buy wood from other neighbouring enterprises which creates a certain demand for timber on SHU Dikchan.

The second economically important ecosystem service for SHU Dikchan is hunting. The enterprise has two fenced areas, which support breeding populations of red deer *(Cervus elaphus),* fallow deer *(Dama dama),* mouflon (*Ovis orientalis* subsp. *musimon*), and wild boar *(Sus scrofa).* These animals can be hunted in trips organised by SHU Dikchan. This is the basis of commercial hunting, which is also an important source of income (fig. C 13.5). Annually nearly 30 wild boars, 10 mouflons and individual mouflons, fallow dear, roe deer and capercaillies are hunted. For 2019 they contributed an income of about 36 000 €.

Another important ecosystem service, which provides income for local people, is collection of mushrooms and edible forest fruits (fig. C 13.6). Annually, about 30 tons of mushrooms (mostly *Boletus* spp.), five tons of blueberries *(Vaccinium myrtillus)* and 1 ton of wild strawberries *(Fragaria vesca)* are collected. Most of this collection is sold by local people to traders and this is an additional source of income. The forests also provide pure drinking water for the local communities. Water is also used in other regions of the country thanks to a complex system of dams, for which the territory of the enterprise provides some of the water. In addition, tourism and recreation are traditionally important, with visitors coming mostly in summer for hiking, recreation and fishing. Local people also have long traditions of weekend meetings at family barbeques and ornamental fountains (fig. C 13.7). Local people build these to commemorate relatives or just as gifts for the community. Currently there are more than 1100 fountains and 200 barbeque houses.

Challenges for forest management in SHU Dikchan

The main natural challenges are associated with natural disturbances, which have become more frequent in the last decades. For example, an exceptional wet and heavy snowfall occurred at the end of January 2019, and this led to breakage and collapse of at least 15 000 m³ of pine and spruce trees. Thus, all planning for the summer of 2019 had to be quickly changed in order to salvage the damaged wood and limit the chance for bark beetle outbreaks. The previous similar event was in 2015. Then an exceptional wet snow in March led to more than 1 million m³ of damaged wood in the whole of the Rhodopes range. The collection of this wood was delayed by various problems and this resulted in a bark beetle outbreak, which damaged even higher amounts of wood, mainly in Scots pine stands. In the vicinity there have also been several large windthrows and fires, which lead to even greater damage than the recently caused by the wet snow (Panayotov *et al.* 2017). Another natural challenge is associated with climate change and the uncertainty related to it. Some of the territory of SHU Dikchan is at low altitude, and this is considered to be especially vulnerable to the expected increase of summer droughts and extreme climate events. The proximity of the lowlands to territories with Mediterranean climate to the south may also mean that the forests in SHU Dikchan are at increased risk of invasion by insect pests and fungal diseases, which are presently limited in the region by lower temperatures, but can be expected to migrate northwards as climate change progresses.

In addition to the natural challenges there are also challenges associated with the change of management focus and slower acceptance of these ideas by local people. FSC standardisation, which has been accepted by SHU Dikchan and large territories of Natura 2000 protected areas set increased requirements for deadwood in the forests, set-aside areas for development of old-growth conditions, and protection of habitat trees. However, over the generations, local people have a tradition of taking fuelwood from the forests, and are reluctant to accept the need to leave wood in the forest to increase the amount of deadwood. This transition is made difficult by the fact that the economic prospects for the local population are not good and most of the income sources are related to the forests.

Finally, our case demonstrates the crucial role that the state forest ownership can play when implementing the international commitments for sustainable forestry and biodiversity protection which are often considered as a serious economic burden.

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Companhia das Lezírias – towards a sustainable forest management

C 14

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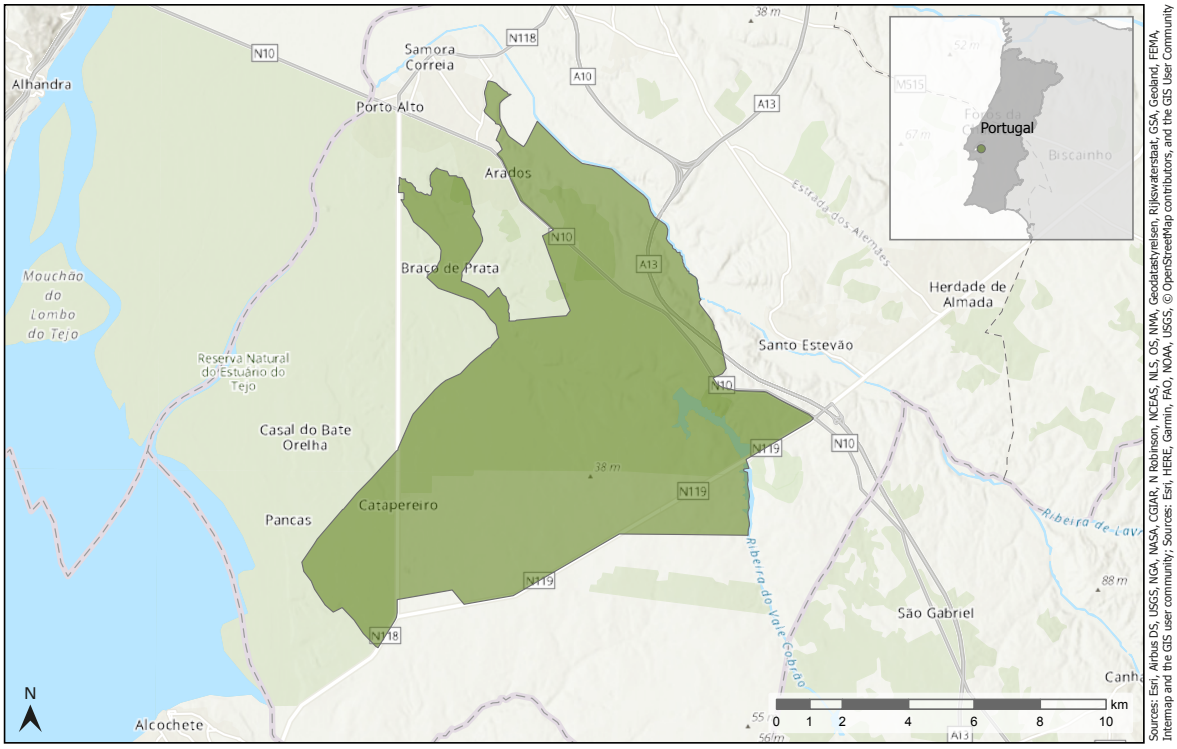
Portrait of the enterprise

More than ever, forest management must take into account the full range of goods and services produced by forests. The challenge for management is to maximise these goods and services and contribute to their appreciation, as well as the resilience of all systems.



> Fig. C 14.1. Old cork oak in the forest of Companhia de Lezírias in Portugal. Sustainable use of valuable cork and employment of people in a multifunctional rural area (Photo: Rui Alves).

Statement

"Our main aim is to pursue a forest policy in accordance with the objectives of sustainable forest management based on the principles of transparency and rigour, conservation of natural resources, improvement of operating results and social well-being, and the valuation of the 'Companhia das Lezírias' brand."

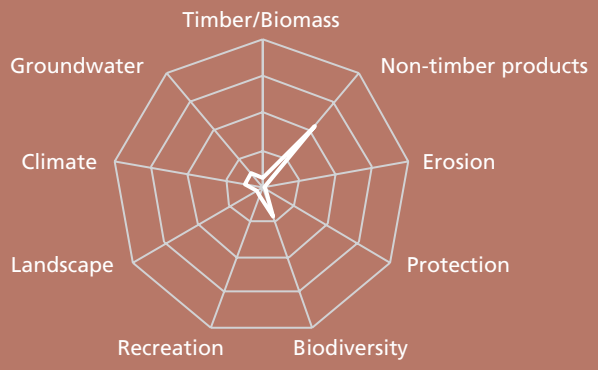


Table C 14.1. General information on the forest area of Charneca do Infantado.

Forest community	Mostly stands of cork oak (*Quercus suber* – 6600 ha), including 4707 ha in agroforestry systems; different size stands (12) of maritime pine (*Pinus pinaster* – 1000 ha); umbrella pine (*Pinus pinea* – 680 ha) and eucalypt (*Eucalyptus globulus* – 560 ha)
Total forest area	8840 ha
Main management type	Annual production of non-wood products like cork and pinion. Selective cutting system of maritime pine The eucalypt is produced for fibre for pulp production.
Total mean volume	Cork: 624 t/yr (average of 9 years) Pinecones: 429 t/yr (average of 4 years) Pinewood: 1552 t/yr (average of 5 years) Eucalypt roundwood: 1360 t/yr
Economic results	
Annual average forest results	1.04 x 106 €
Annual average cork oak results	0.805 x 106 €
Annual average cork sales	0.916 x 106 €
Average sales of wood	0.177 x 106 €
Average sales of pinecones	0.137 x 106 €
Area for forest herding	5625 ha
Altitude	0–53 m
Ownership	Companhia das Lezírias, S.A. belongs to the Portuguese Republic
Geology	Mostly sandy soils, sometimes with sandstones and clay beds
Protected area	0 ha
Nature protection area (Natura 2000)	4961 ha
Conservation area for biodiversity proposals	3005 ha
Protected area for soil and landscape proposals	1714 ha

Context, legal frame, and ownership structure

The Companhia das Lezírias, S.A. (CL), founded in 1836 by private shareholders, became public in 1975. It is one of the country's largest agroforestry companies responsible for managing approximately 19 500 ha with a large diversity of economic activities: production of rice, maize, wine and olive oil; cattle and horse breeding; forestry; and tourism. The largest property, 'Charneca do Infantado,' is made up of 11 000 ha and located 30 minutes

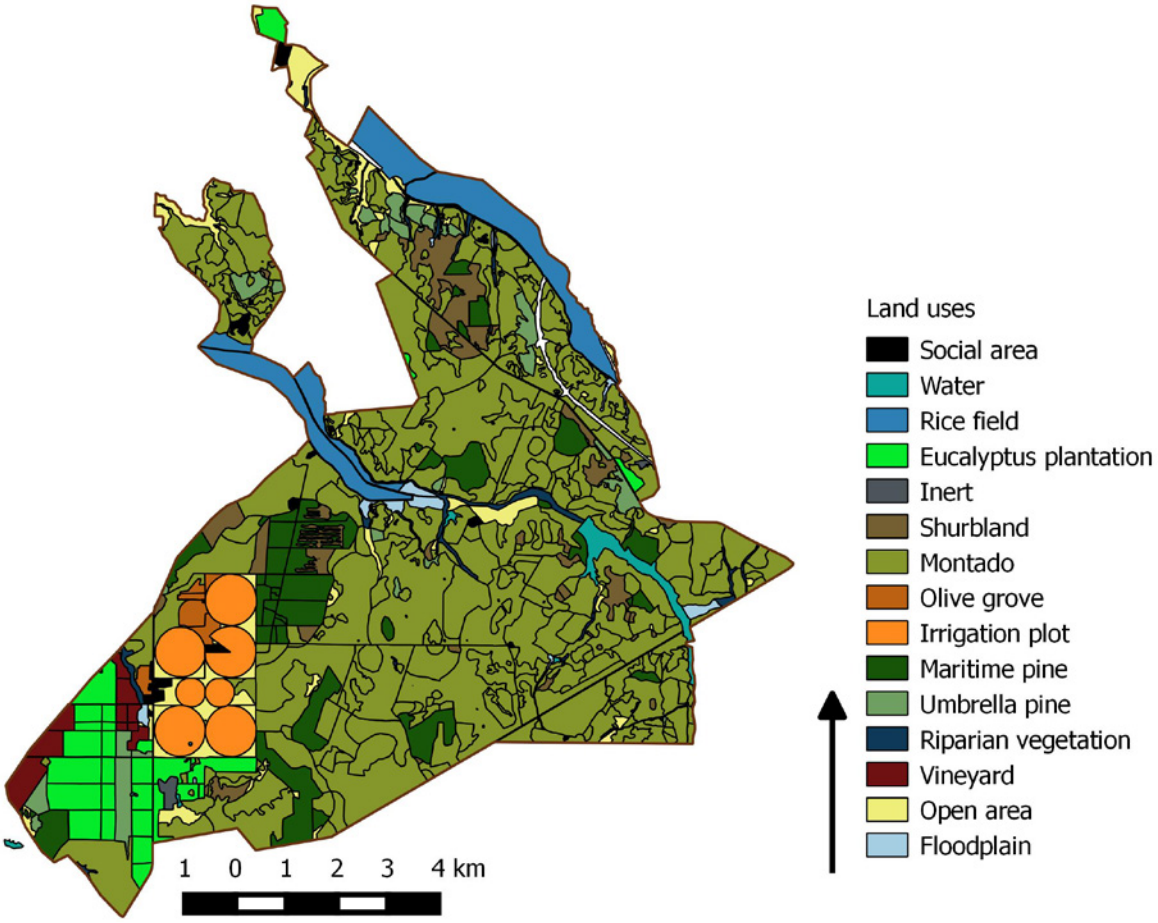


Fig. C 14.2. Land uses within Charneca do Infantado.

northeast of Lisbon. The forest occupies 8840 ha, of which 6600 ha are cork oaks *(Quercus suber),* with variable tree density (average of 80 trees/ha) where most of the forest area is used for cattle grazing, making up the agroforestry system typical of southern Portugal (montado – 22 % of the Portuguese forest – 720 000 ha) (Fig. C 14.2). The umbrella pine *(Pinus pinea)* appears in pure stands and mixed with cork oaks (680 ha). Because of the proximity to the Tagus estuary and the Atlantic, the forest also features 1000 ha of maritime pine *(Pinus pinaster)* (fig. C 14.4) and 560 ha of eucalypt *(Eucalyptus globulus);* thus, the country's four most important forest species in regard to area and economy are present.

Strengths and weaknesses

Because of its proximity to Lisbon, and conditions stemming from its inclusion in the Natura 2000 Network, as well as the fact that it sits on Portugal's largest aquifer, CL's business model aims to maximise the forest's contribution towards human well-being, especially where ecosystem services are concerned.

In areas with cork oak the goods and services they produce in addition to cork, limit the way the area is managed. The need to maximise the production of cattle forage leads to a simplified vegetation structure resulting in a low diversity of habitats and species. The physical presence and concentration of cattle has a negative impact on

the regeneration of cork oaks and results in compression of soils. However, cattle play an important role in biomass management, a fundamental aspect in reducing the forest fire risk in summer. The option to have bovines, as opposed to small ruminants, which dominated these systems 30 years ago, is largely due to more beneficial EU's common agricultural policy measures but also less need for manual labour. With the apparent decrease in rainfall, and an increase in the number of heat waves, the changeover to species such as the maritime pine and cork oaks have made the signs of cork oak and maritime pine increasing inadaptation, both in regard to the growing decline and mortality of trees, as well as their less vigorous natural regeneration.

Management

The agroforestry system in place exists in areas of poor soil and water limitations during the summer season, which limit the system's primary productivity. The management system is extensive (rather than intensive), and concentrates mainly on production of non-wood products such as cork, pasture, and pine nuts.

The harnessing of the pasture is done by allocating, on average, one cow per two hectares of land during six months, which enables the entire pasture to go into organic production mode. Pastures are the result of natural vegetation, or are improved seedling other herbaceous species for periods of 10 years. Every year cork is extracted from a determined area, since it normally takes nine years to grow. Cork oak bark possesses unique physical-chemical characteristics, and can be removed to a determined degree without damaging the tree. The cork has countless applications, the most valuable being the production of cork-stoppers for wine bottles. Once the trees have died, they are used for firewood. The main management activities revolve around the regeneration of the cork oak, using natural or artificial protection, but they also include pruning young trees, and controlling invasive pines and shrubs. In part of the area (36 %) pasturing does not take place; instead there is an area composed of cork oaks, and cork oaks with maritime and/or umbrella pines, with a tendency for an increase in tree coverage. Furthermore, Iberian pigs graze in the montado between November and February. Maritime pine

Fig. C 14.3. Montado system with improved pastures (Photo: Jorge Barros; copyright CL).

Fig. C 14.4. Maritime pine with dense Mediterranean shrubs (Photo: Rui Alves; copyright CL).

Fig. C 14.5. Umbrella pine plantation (Photo: Rui Alves; copyright CL).

logs are sent to sawmills to produce sawnwood. The maritime pine is thinned every ten years, in 40 to 50 year cycles (fig. C 14.4). Umbrella pines produce a highly valuable edible seed (pine nut); the pine cones are harvested by the buyer, who then extracts the pine nuts. For all three species, the management systems are highly dependent on natural regeneration to guarantee new plants are well adapted. Compatibility with grazing implies the protection of individual plants, particularly of cork oaks under 15 years, which are protected with wire tree guards. Close to 29 600 guards have been installed.

The forest receives 6500 visitors annually: 76 % are visitors taking part in paid activities, and the remainder take part in community activities. The entire area's forest management is sustainably certified.

Economics

Traditional products are: cork, wood, firewood and pine cones. The relative importance of these products has varied throughout time.

On average (2011–2018) the forest generates close to €1.9 million per year for all activities, with 85 % of the income originating from cork oak stands, 8 % from the umbrella pine, 6 % from the maritime pine and 1 % from the eucalyptus plantations managed directly by CL (100 ha). Costs related to monitoring and investments directed at conservation are accounted for separately and translate into an investment of €479 000 (2011–2018) with public funding totalling €110 500. On the other hand, visits from students and tourists, meetings and corporate teambuilding activities, and hunting have allowed us to partially appraise ecosystem services related to the landscape and biodiversity, which represent only 5.7 % of revenues. However, the ecosystem services are appraised at an unquantified value because they are associated to traditional products such as wine (under the 'Tyto Alba' brand).

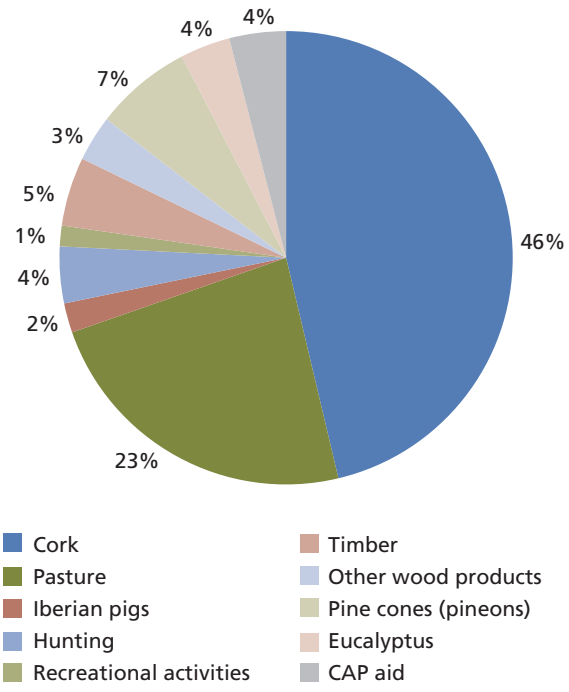


Fig. C 14.6. Income for different forest activities.

CL supported a study using the ecosystem services approach with three scenarios representing plausible future development trajectories for the farmstead given market and policy trends, and the risk of urbanisation because of CL's proximity to Lisbon and the capital's growing urban population (von Essen *et al.* 2019). These scenarios were Cattle Intensification, Forest Improvement, and Residential Development. Using the InVEST toolkit, we evaluated how 'Provisioning' (cork production) and 'Regulating & Maintenance' (carbon storage and sequestration) services would be affected by the corresponding changes. The outcome was that increasing cattle or residential development would deliver substantially lower levels of services, while extensive management, improvements to forest quality, and promotion of traditional livestock grazing would perform better than the business as usual model. A Forest improvement scenario would result in gains of 13.5 % for carbon storage (worth between US$0.34 and US$7.79 million depending on the carbon price) and 62.7 % for cork production (total value of US$3.5 million). In conclusion, forest-centred land management can provide higher amounts of ecosystem services while preserving the traditional character of the Montado; however, to help support this iconic Mediterranean landscape in the future, a shift in economic incentives is needed.

Ecology

The ecological relevance of the Charneca results from its multi-functional character and the fact that more than 50 % of its area is part of the Natura 2000 Network (Tagus Estuary – PTZPE0010 and

Fig. C 14.7. Plantation of native species in the green corridor and ecological restauration actions of watercourses (Photos: Jorge Simões; copyright CL).

PTCON0009). Moreover, besides Habitat 6310 – Dehesas with evergreen *Quercus* spp., which represents the main cover type of the Charneca, four other Natura 2000 habitats, occur in the area (Correia and Mexia 2011). Field surveys have allowed us to identify 335 species of vascular plants, 150 species of birds, 24 species of mammals, and 11 other vertebrate species. Several of these species have a threatened conservation status: e.g. conehead thyme *(Thymus capitellatus)* (Correia and Mexia 2011), Bonelli's eagle *(Aquila fasciata)* (Pereira *et al.* 2015), Cabrera's vole *(Microtus cabrerae)* (Gonçalves *et al.* 2012).

However, the challenge over the last two decades has been to mitigate the effect of landscape homogenisation and degradation of water courses, while simultaneously promoting wild species occupancy and population connectivity to ensure gene flow.

Examples of measures to achieve such goals are: (i) establishing grazing-exclusion plots to promote cork oak natural regeneration and conservation purposes; (ii) designation of the cork oak stands as a model forest with international certification, improving the general condition of the stands by preserving the soil, protecting natural regeneration and controlling tree health; and (iii) since 2005, using natural pastures, direct sowing or the establishment of permanent legume-rich biodiverse pastures (currently >3000 ha), as a way to enrich the soil, fix organic matter and remove carbon from the atmosphere, a service remunerated by external entities (e.g. TERRAPRIMA).

One successful example of these actions was the implementation of a green corridor as a management tool to improve connectivity for birds and mammal communities that involved the restoration of degraded watercourses and the planting of strips of native species to act as linkage elements (fig. C 14.7). It has been monitored since its implementation with species responding positively both in terms of richness and abundance (e.g. Alcobia and Santos-Reis 2018; Rabaça *et al.* 2018).

Another line of action CL is investing in is the recovery of the wild rabbit *(Oryctolagus cuniculus),* a potential provisioning service as a game species, but also a valuable food resource as prey for carnivores and raptors, and whose local monitoring activities have demonstrated a continuous declining trend (Alcobia and Santos-Reis 2017); to counteract this trend, translocation of individuals from places of high abundance to places of low abundance, without resorting to outside genetic material was tried. In addition, the captive breeding from a stock of individuals resistant to the epizootics, which are the main cause of death of the species, with the offspring to be released in the wild, will soon follow. This measure also further supports the two pairs of threatened Bonelli's eagles that were found (2008 and 2016) nesting in two mature maritime pine stands. Planned clear-cutting and other operations were cancelled when the eagles were found.

While management practices are adjusted for protection of endangered bird species, common birds can be allies of sustainable forest manage-

ment providing balance to the ecosystem functioning. One such balance, for example, can be found in insectivorous birds playing an essential role as regulators of their prey populations, and having the potential to combat forest pests without prejudicing the ecosystem. CL forest productivity has been affected by defoliator insects, especially the pine processionary moth *(Thaumetopoea pityocampa)* in pine stands, and the European oak leaf-roller *(Tortrix viridana)* and the sawfly *(Periclista andrei)* in cork oak stands. Because many insectivorous birds in pine and cork oak stands are cavity-nesters, a nest box installation programme directed at these species was implemented, aimed at increasing their populations. Both pine and cork oak stands affected by defoliator insects before nest box installation showed a marked decreasing trend in defoliation signs following nest-box occupation – mainly by great tits *(Parus major)* and blue tits *(Cyanistes caeruleus)* (Rabaça *et al.* 2012). For instance, in a young pine stand (75 ha) where 15 % of the trees showed processionary moth nests before the nest box installation program, processionary nests have decreased over 10 % in the three years following the installation of 43 nest boxes for tits (Rabaça *et al.* 2012). In the same study, the pine stands where no nest boxes were installed showed a marked increase in processionary nests. A total of 130 nest boxes for insectivorous birds have been installed in CL pine and cork oak stands.

The installation of nest boxes was also implemented to provide nesting for barn owls *(Tyto alba).* Barn owl populations are declining in Portugal and other EU countries (SEO/BirdLife 2013; Lourenço *et al.* 2015), but large numbers of barn owls can be seen in the Tagus Estuary, a floodplain adjacent to Charneca do Infantado, especially during autumn and winter. These birds are mostly dispersed juveniles looking for food and shelter. The seven barn owl nest boxes installed in Charneca do Infantado between 2007 and 2012 were occupied within three years and on average fledged one to three owls per year.

CL's efforts towards sustainable management were publicly recognised in 2014 within the framework of the Green Project Awards, where the winning project was 'Companhia das Lezírias: forest management for biodiversity' in the category of Agriculture, Sea and Tourism. It was also a finalist in the European Business Awards for the Environment in 2016/2017.

Social

The project also includes a strong social component on three fronts:

1. Taking on social responsibility through direct and indirect job creation; ensuring that worker's social and labour conditions comply with an equivalent of 25 outsourced workers since the company only has a fixed staff of three technicians.
2. Developing a variety of tourist products and services, and structuring a business that will serve as an example for other agents in the sector. This has allowed us to promote participation in rural activities, natural values and research results (school visits, tourist visits, teambuilding events, survivor training, hunting and fishing journeys, mountain bike trails, etc.), while also creating recreational opportunities for local communities.
3. Increasing knowledge about forest systems and natural heritage through research opportunities and creation of educational initiatives. Since 2014, three PhD and ten MSc theses have been concluded, eight PhD theses, eight MSc theses, and 49 R&D projects are ongoing, and 50 papers have been published. In addition, 36 presentations were made at scientific events, and 17 educational actions were undertaken. CL is an ideal case for studying stakeholders' involvement in defining problems and solutions, and social learning. This case-study involved participatory workshops at local and regional levels to assess the ecosystem services most valued by montado stakeholders and their awareness of the threats and their vision for the future provision of ecosystem services (Rosário *et al.* 2019). As expected, stakeholders valued 'materials' (provisioning services) most; however, regulating services were also highly valued, revealing strong awareness about the montado's functioning. Cultural services were more highly valued at the local level.

Resilience

Despite its value, the montado is declining every year in Portugal and the resilience of this complex socio-ecological system is threatened, and this includes the montado in CL.

Besides establishing permanent biodiverse pastures as a carbon sink, reducing the grazing pressure on the system is also a target in the near future.

Establishing grazing-exclusion and conservation plots were essential measures to restore a degraded forest because of the legacy of resource overexploitation. Although positively affecting carbon sequestration, soil fertility, and biodiversity, shrub development may have unintended effects in a scenario where water is a limited resource for the functioning of the forest ecosystem (Rolo and Moreno 2011). In spite of being located on one of the largest aquifers in Portugal, with expected increase in drought events, such as those CL has faced in recent years, the decrease of groundwater levels may severely affect cork tree growth and, ultimately, tree survival (Mendes *et al.* 2016). Cork oak mortality is increasing and its spatial pattern and main cause are not yet fully understood (fig. C 14.8). This is a research priority for CL.

Assessing changes in the ecosystem demands time and baseline data. CL has become one of the research and monitoring sites of a Long-Term Socio-Ecological Research platform devoted to the montado (LTsER Montado). This allows concentration of efforts from different research institutions in the same space, building a stronger knowledge base of the forest's structure and functioning that allows for the search of evidence-based solutions for the future. This platform is part of the larger European Long-Term Ecological Research (LTER Europe) and of the International Long-Term Ecological Research (ILTER) networks.

Conclusion

Sustainably managing the forest in CL is a challenging and time-consuming task that requires long-term investment in terms of both economic and human resources. Observed trends previously described allowed for the evaluation of management efficacy adjustments already carried out. It also enables some recommendations for future management adaptations to be made.

Links (all checked 3 July 2020)
https://www.cl.pt
https://www.terraprima.pt/pt
http://www.ltsermontado.pt
https://www.lter-europe.net
https://www.ilter.network
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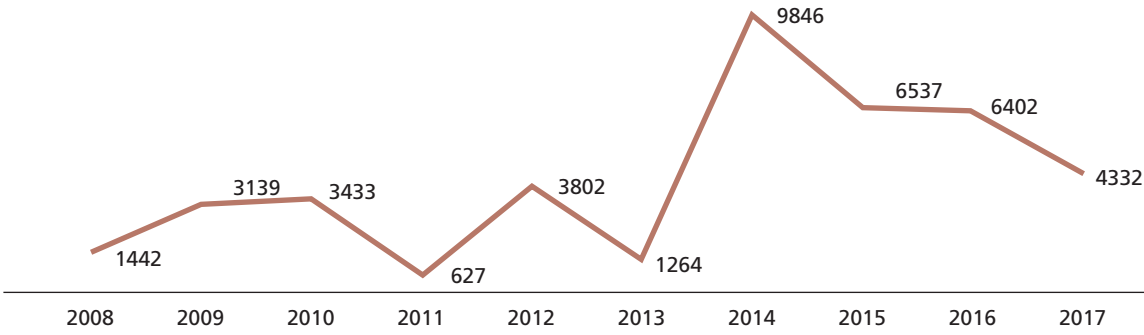

Fig. C 14.8. Cork oak mortality between 2008 and 2018.

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Box C9

The forest of Les Landes de Gascogne

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Les Landes de Gascogne (Moors of Gascony) is a region in the southern half of the region Nouvelle-Aquitaine in southwestern France. Formerly the landscape was dominated by vast wet moors and heathlands, but also forests of maritime pine *(Pinus pinaster),* often with oak (*Quercus* spp.) trees. The area was sparsely inhabited until the nineteenth century owing to poor soils and difficult agricultural conditions as well as the occurrence of malaria in the marshlands. The area was periodically burned to leave pasture for sheep. The sheep were managed by shepherds who moved on stilts through the marshland. By 1850 it is believed that that the number of sheep amounted to nearly 1 million. In June 1857, a law initiated by Napoleon related to improving the sanitation and cultivation of Les Landes de Gascogne. The law accelerated the end to traditional pastoralism and as a consequence the number of shepherds declined. The marshes were drained by canals and wide-scale, systematic reforestation was promoted, in order to rehabilitate the landscape and develop the regional economy. This led to large-scale plantations, mostly of local maritime pine, which were seeded/planted and managed for resin and wood production.

Unlike many other European forests, the forests of Les Landes de Gascogne have almost entirely been established and developed to serve wood production. With almost three quarters covered by forests, comprising about 1 million ha, it is the largest enclosed forest area in France. Local maritime pine was chosen not only because it is well adapted

Fig. 1. Young maritime pine *(Pinus pinaster)* stand. The forest is managed to quickly produce timber; therefore, tree habitat structures to support biodiversity rarely develop (Photo: Frank Krumm).

to very poor, sandy soils, dry summers, and wet winters, it also grows quickly. Nowadays the general rotation length is usually 35–50 years depending on the targeted product. The different timber assortments are used for furniture production, packaging, panelling, pulp, wood chips and firewood.

Many people in Les Landes de Gascogne, but also in adjacent regions, are employed in forestry and wood-processing including sawmills and paper mills, wood crafting, green chemistry and a revival of resin production. Figures from the former Aquitaine region estimate that more than 30 000 people are employed in the forest-based sector (Lesgourgues *et al.* 2015) with an annual revenue of more than €3 billion. About 20 % of the national wood production comes from this area.

The total area of managed forests in Les Landes de Gascogne is 890 000 ha of which 92 % are managed by 9000 private forest owners fulfilling PEFC standards. Private forests owners with a property of more than 25 ha (8 % of all private owners) manage around 80 % of the private forest area (IGN, FCBA, CRPF & INRA, 2012).

Broadleaved species account for around 13 % of the total standing volume, whereas maritime pine dominates with a total standing volume of nearly 90 million m³. The forest area is highly productive. The overall annual increment amounts to about 12 m³/ha, of which more than three quarters is harvested (~8 million m³ in total) is harvested annually (CRPF d`Aquitaine 2005). The forest stands are normally managed in a clearcut rotation system and approximately 80 % are replanted with the remaining regenerated by seeding.

About 790 000 ha of the forest area are certified under the Programme for the Endorsement of Forest Certification (PEFC) label. One of the requirements in terms of nature conservation in the context of pine plantations is to retain broadleaved trees. Preserving dead, senescent, cavity-bearing, old or large trees is voluntary. No indication is given on minimum diameter at breast height, or a minimum quantity of deadwood.

In general, the forests of Les Landes de Gascogne display low tree species diversity, old-growth elements, and other habitat-bearing forest structures. Therefore, the potential of further stimulating and developing biodiversity conservation measures in these forest plantations could be promoted.

Communication and open a dialogue with private forest owners on the benefits of integrating nature conservation measures into the management of their forests is an important precondition. One option is to provide demonstration sites, so called marteloscopes (see Box C4 in this book); One such marteloscope has been recently established in a maritime pine plantation forest. It could for example be utilised for knowledge exchange and training on how nature conservation measures can be embedded in such stands and what are economic implications of for example preserving habitat trees (fig. 2).

Local forest owners have for more than 20 years worked on enhancing broadleaves with some success. This includes natural regeneration of oak and birch on the margins of the maritime pine stands or in the understory. There may also be other forest management options that could be applied but are not common or well known. Again a marteloscope site such as the one presented in Figure 2. could be utilised for communicating potential management alternatives and their beneficial values during on-site training events.

The forests in the Nouvelle-Aquitaine region are often affected by disturbance events such as fires, windstorms, and insect pest outbreaks and fungal diseases. The windstorms of 1999 (Storm

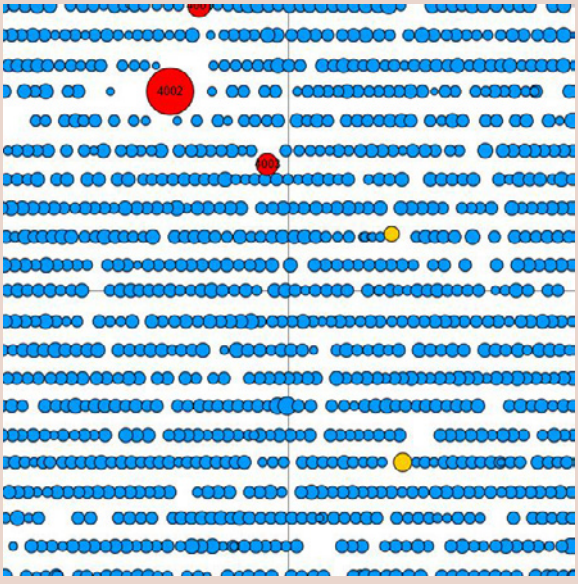

Fig. 2. Mapped stems for the 1 ha sized marteloscope 'Retjons' in the Nouvelle-Aquitaine region. Maritime pine (blue circles); pedunculate oak (red circles); silver birch (yellow circles). The size of the circles corresponds to the diameter of the trees (map provided by EFI).

Martin) and 2009 (Storm Klaus) were unprecedented and destroyed about 75 million m³ of timber, not only disrupting targeted forest management goals but also having profound consequences on wood production and timber markets. In numerous cases this jeopardised also the economic base of forest owners. Small disturbance events on the other hand may present an opportunity to allow for the accumulation of standing and lying deadwood and for small open patches to regenerate naturally.

The forests of Les Landes de Gascogne have great importance for the region and beyond. They provide employment for a large number of people and deliver wood to satisfy demands for renewable resources nationally and at European level. Further serving as highly appreciated areas for recreation, these plantation forests also have vast potential for integrating measures and tools that will increase forest biodiversity. Such measures can enhance both biodiversity and productivity. On the one hand, broadleaves provide more tree-related microhabitats at all stages of development as compared to conifers (e.g. Vuidot *et al.* 2011; Larrieu *et al.* 2012). Maintenance of broadleaved trees at both stand and landscape scales is critical for bat communities living in short-rotation conifer plantations, by increasing the availability and diversity of prey and roosting sites (Charbonnier *et al.* 2016). On the other hand, the presence of silver birch *(Betula pendula)* leads to associational resistance to the pine processionary moth *(Thaumetopoea pityocampa)* during the early growing stage of mixed birch–pine plantations (Castagneyrol *et al.* 2020). In addition, growing silver birch in maritime pine plantations can have a positive net effect on the long-term stand productivity (Morin *et al.* 2020).

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Ecoparks – Forest landscapes in Sweden with emphasis on biodiversity conservation and recreation

C15

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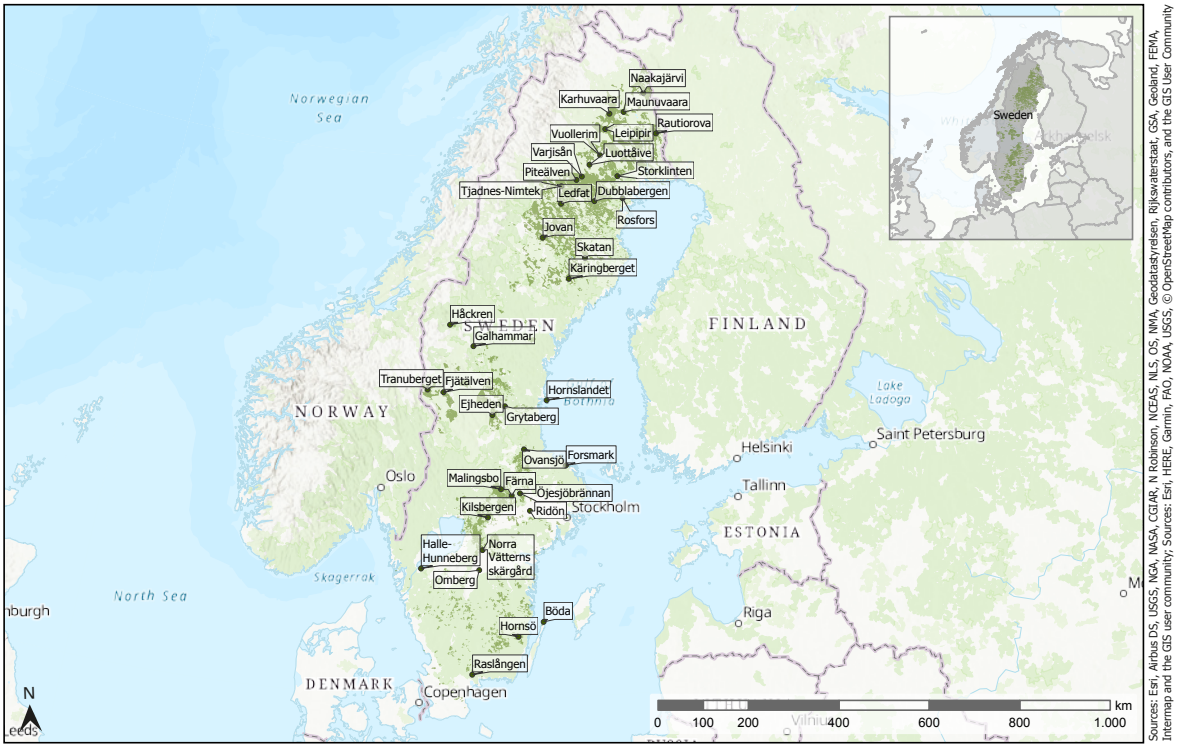
Aim of paper

The purpose of this chapter is to characterise and explain the ecopark concept to an international audience engaged in conservation practices and research. We describe why, when, and how ecoparks have been established, and how they are managed and monitored. We also reflect on the future of ecoparks and on possible applications of the concept in other contexts.



< Fig. C15.1. Burning forest area in Ejheden. Forest fires are frequent disturbances in Sweden (Photo: Sveaskog).

Statement

"Ecoparks have been established to host a rich biodiversity and offer opportunities for recreation in combination with a sustainable wood production at landscape scale."

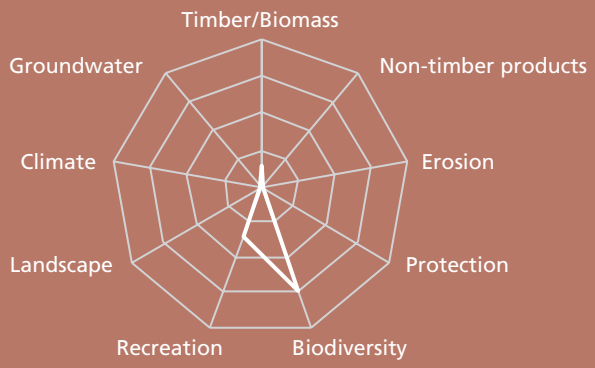


Table C 15.1. General information on the forests of the Swedish ecoparks.

Forest community	From boreal coniferous forests in northern Sweden to temperate broadleaved forests in southern Sweden
Total area of ecoparks	241 000 ha
Main management type	Free development or conservation-oriented management in conservation areas, clearcutting in areas designated for wood production.
Altitude	From 700 m in the north to sea level in the south
Ownership	State-owned
Protected area (total)	111 000 ha designated for nature conservation, including areas with conservation-oriented management
Natura 2000 (area)	21 000 ha

The state forest company Sveaskog

Sveaskog is a state-owned forest company and the largest forest owner in Sweden with a landholding of about 4.1 million ha (14 % of the Swedish forest land), and about 850 employees. Sveaskog's forests are scattered throughout the country (fig. C 15.2). The overall mission of Sveaskog is to manage the Swedish people's forests in a sustainable manner. The company supplies sawlogs to sawmills, pulpwood to pulp and paper mills, and biofuel to energy companies; the majority of customers are located in Sweden. The company also sells forest seedlings and silvicultural services. On average, about 70 % of the net annual growth is extracted per year with an annual delivery volume of about 11 million m^3. In accordance with Sveaskog's policies, nature conservation is the main priority in about 20 % of Sveaskog's productive forestland (forests with potential annual production >1 m^3/ha): 2.5 % designated as ecoparks; 10 % set aside for nature conservation as whole stands; and 7.5 % designated as eternity trees (live trees with special importance for biodiversity, retained beyond harvest), retention patches (patches of trees retained specifically for nature conservation), and special habitats (areas with specific conservation value) at final harvest.

Background

The first ecopark (Omberg) was inaugurated in 2003. The concept was introduced because there was a lack of large continuous forests with high value for biodiversity and recreation. A landscape perspective has long been recognised as essential in conservation and restoration (e.g. Crouzeilles *et al.* 2016), and large areas with structurally rich forests are often a prerequisite for long-term persistence of species populations (Woodroffe and Ginsberg 1998). Globally and regionally, there is a lack of large reserves (Cantú-Salazar and Gaston 2010). Also in Sweden, protected areas are typically small; only 3 % of national parks and forest reserves are >1000 ha in size and these areas are confined to the northernmost part of the country (Sveriges Officiella Statistik 2017). Areas voluntarily set aside

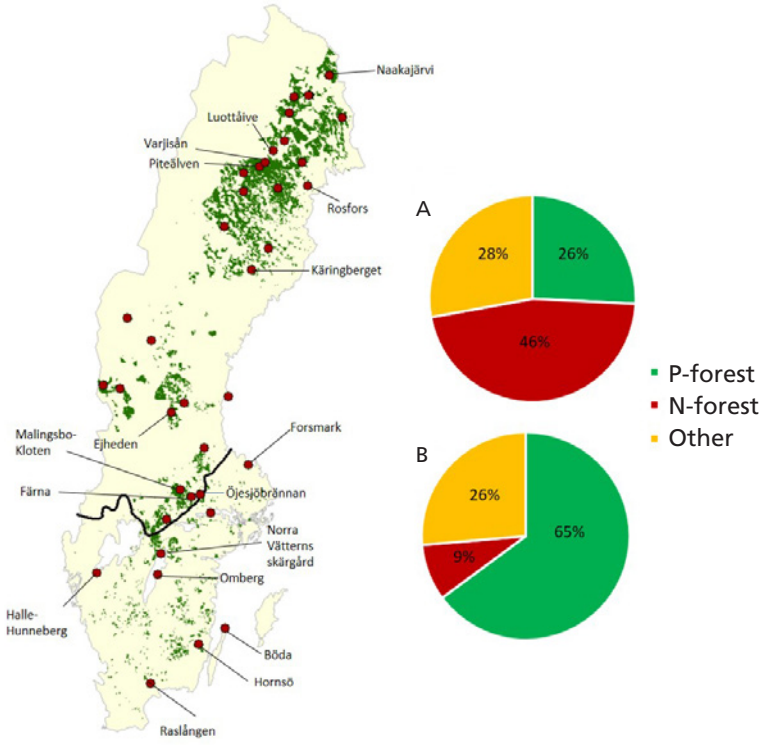


Fig. C 15.2. Map showing location of ecoparks and some statistics. Left panel: Sveaskog's landholding (green) and the 37 ecoparks (red dots). Names are given for ecoparks mentioned in the text. Right panel: Management categories within ecoparks (A) and outside ecoparks (B). N = nature conservation forest (red), P = production has highest priority (green). Other land (yellow) is non-productive forestland, water, mires, urbanised areas, or agricultural land.

by forest owners are considerably smaller, e.g. woodland key habitats have an average size of about 5 ha (Timonen *et al.* 2010). Nature-based tourism is one of the more rapidly expanding sectors within tourism in northern Europe (Fredman and Tyrväinen 2010), and the social functions of forests, not least recreation, have been increasingly highlighted in the last decades and have come up on the political agenda in many countries (Bell *et al.* 2009).

Thus, the ecoparks concept was launched to supplement the existing forest conservation area network in Sweden with a new component of forest landscapes, and with the aim to combine ecological, social, and economic goals. Since forests with limited anthropogenic impact have particular value for biodiversity (Paillet *et al.* 2010; Watson *et al.* 2018), one cornerstone of the ecoparks concept is to leave a number of stands unmanaged. Active restoration measures are taken in other stands to promote regeneration by broadleaved tree species, and to speed up recovery of old-growth structures such as deadwood. Promotion of structures of traditional agricultural landscapes such as solitary old oaks is also important since certain rare and declining species are associated with such habitats (Sandström *et al.* 2015). Another objective of the ecoparks is to maintain and strengthen the opportunities for outdoor recreation. Wood production should be integrated into the ecoparks but is given a lower priority than on other parts of Sveaskog's forestland (fig. C 15.2).

The 37 ecoparks

The ecoparks represent a large variation in climate, geology, forest types, and human history, from boreal forests in the north to temperate broadleaved forests in the south (fig. C 15.2, C 15.3). In 2014, the two assumed last ecoparks, Varjisån and Piteälven, were established. A mega-fire occurred in south-central Sweden in 2014 (Gustafsson *et al.* 2019), and the part of the fire area that belonged to Sveaskog was set aside as ecopark number 37 (Öjesjöbrännan). The total area of ecoparks is 241 000 ha with sizes of individual parks ranging from 22 000 ha to 1100 ha, with an average size of 6500 ha. The for-

ests are different from the rest of Sveaskog's forestland in that they have a considerably higher proportion of old forest; 52 % are >100 years old compared to 15 % outside the ecoparks.

Selection and planning

To be selected as an ecopark, a landscape needs to be dominated by forest, have a high value for biodiversity and recreation, and be >1000 ha in size in southern Sweden and >5000 ha in the northern Sweden. For Sveaskog, it has also been important to ensure that the ecoparks are located throughout Sweden, so as to capture the large latitudinal variation in flora, fauna, geology, and climate. Especially for the more densely populated southern Sweden, opportunities for outdoor recreation and proximity to urban clusters have also been important criteria. To identify potential landscapes, a first screening was made by consulting Sveaskog staff, many of whom had valuable insight into natural conditions of the land. Advice was also obtained from external experts with knowledge on biodiversity, forest types, and habitats of importance to flora and fauna. Experts were also asked about where there were remnants of old-growth forests and sites with traces of traditional agricultural practices. An analysis of hotspots for rare and declining forest species was made early in the ecopark selection process, based on information on the occurrence of red-listed forest species retrieved from the Swedish Species Information Centre. This largely confirmed what had already emerged from

Fig. C15.3. Examples of ecoparks. (a) Luottåive. This northern wilderness area is rich in mires, and old-growth forests still remain with 500-year-old Scots pine trees, and 300-year-old Norway spruce trees. (b) Ejheden. Forests shaped by natural fire dynamics dominated by Scots pine and broadleaved trees are the focus of this ecopark. The largest controlled fire to date in the country was carried out here in 2018. (c) Omberg, on the eastern side of Lake Vättern is one of the most visited ecoparks and has high recreational value. The area has a dramatic topography, large variation in forest types, rich biodiversity, and giant oaks. (d) Raslången. This is the southernmost ecopark and the only one within the temperate zone. There is a large lake in the centre of the ecopark, and the area offers many opportunities for outdoor activities. Southern broadleaved forests, especially beech forests, are common and their maintenance is an important goal (Photos: Sveaskog).

expert consultations, but some unexpectedly rich areas were identified; for example, a significant region for broadleaved-associated species in the southeastern part of the country was set aside as Ecopark Forsmark (Angelstam and Bergman 2004).

An ecopark plan is produced following a number of steps, starting with a nature conservation inventory and resulting in goal setting of each stand regarding emphasis on nature conservation (N-forest) or wood production (P-forest) (figs C 15.4 and 15.5). About 64 % of the total ecopark forestland (N and P forests, fig. C 15.2) consists of N-forest, i.e. they are managed for conservation or are set aside without management; this compares with 12 % outside ecoparks (fig. C 15.2). The proportion forestland with nature conservation as highest priority varies widely among ecoparks, from 100 % of the burned landscape of Ecopark Öjesjöbrännan to 51 % of the Ecopark Halle-Hunneberg. Spatial aspects are key to the planning process and the ambition is to create as cohesive areas as possible with high conservation values and good connectivity. Consultations concerning the proposed plans take place with Swedish Forest Agency, the County Administrative Board, and local stakeholder groups, like organisations for recreation, botany and ornithology, and for the mountain region in northwestern Sweden also reindeer herding representatives. Main goals are also formulated for whole ecoparks such as increasing the number of giant oaks to 5000 for Ecopark Omberg, retaining >50 trees per ha at logging in Ecopark Malingsbo-Kloten, and maintaining trees along roadsides in Ecopark Halle-Hunneberg.

Establishment

When a plan is completed (fig. C 15.4d), a nature conservation agreement ('naturvårdsavtal') between Sveaskog and the Swedish Forest Agency areas is established for the future management of N and P-forest (fig. C 15.2) in a 50-year perspective. Sveaskog, in contrast to small private forest owners with similar agreements, is not compensated for loss of revenue due to the adjusted management. For P-forest this means that the amount of retention at harvest is regulated in the nature conservation agreement while the N-forest (about 111 000 ha); has nature conservation as the only goal. In addition, all of Sveaskog's forestland is certified according to FSC (Forest Stewardship Council) as well as PEFC (Programme for the Endorsement of Forest Certification) standards.

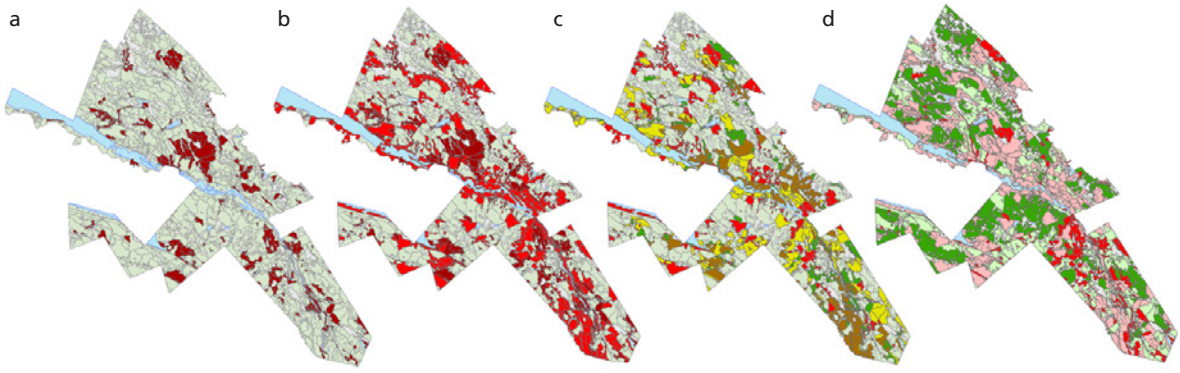


Fig. C 15.4. Development of an ecopark plan. (a) The first step is a nature conservation inventory of each stand using a standardised protocol developed by Sveaskog with indicators such as old trees, trees with special qualities, composition of tree layer, different kinds of deadwood, dynamics of deadwood, and identification of biotopes of particular importance to biodiversity. From this, stands with the highest conservation values are identified (dark red). (b) Information from the nature conservation inventory in combination with Sveaskog stand database information is used to map stands in need of biodiversity-oriented restoration (bright red). (c) Goals are set regarding forest types: dominated by Scots pine (brown), dominated by Norway spruce (green), mixed forest rich in broadleaved trees (yellow), broadleaved forest (red). (d) In the final plan, stands are classified into four categories, with nature conservation as the only goal (dark and light green), and production as the main goal (pink and red) (see fig. C 15.5 for explanation of dark/light green and pink/red colours).

Management for biodiversity

In the boreal region more focus is on the attributes of natural forests such as spatial and horizontal heterogeneity, variation in tree ages, old trees and high amounts of deadwood. Irrespective of the vegetation region, there is an ambition to increase the proportion of broadleaved trees since old broadleaved trees are a key resource for many rare and declining species (Sundberg *et al.* 2019), and such trees are scarce in Sweden today (Skogsdata 2019). A main measure in the south is to remove Norway spruce *(Picea abies)* and promote growth and regeneration of southern broadleaved tree species such as oaks (*Quercus petraea* and *Q. robur*), ash *(Fraxinus excelsior),* maple *(Acer platanoides),* elms (*Ulmus* spp.), and lime *(Tilia cordata)* (fig. C 15.6a–f). Before human reshaping of forests, fire was an important disturbance factor in the boreal forest landscapes of northern Europe and were important for regeneration of broadleaved trees such as birch (*Betula pendula* and *B. pubescens*), European aspen *(Populus tremula),* and sallow *(Salix caprea)* (Granström 2001). Thus, prescribed burning is a way to recreate former ecological functions and processes, and conservation fires are regularly executed in northern ecoparks (figs C 15.3b, C 15.6c). Another important measure is to restore hydrological conditions by refilling drainage ditches, and thereby recreating wetlands and swamp forests (fig. C 15.6d). Small-scale actions are also carried out, such as scarring of old pine trees to speed up production of terpenes and other protective substances, important to certain organisms (e.g. some species of lichen depend on the presence of old and hard deadwood; Santaniello *et al.* 2017). Conservation measures, such as green-tree retention, conservation burning, and flooding following hydrological restoration, increase tree mortality, which in turn increases the amount of deadwood. Creation of high stumps at final harvest (e.g. Jonsell and Weslien 2003) also contributes to increases in deadwood.

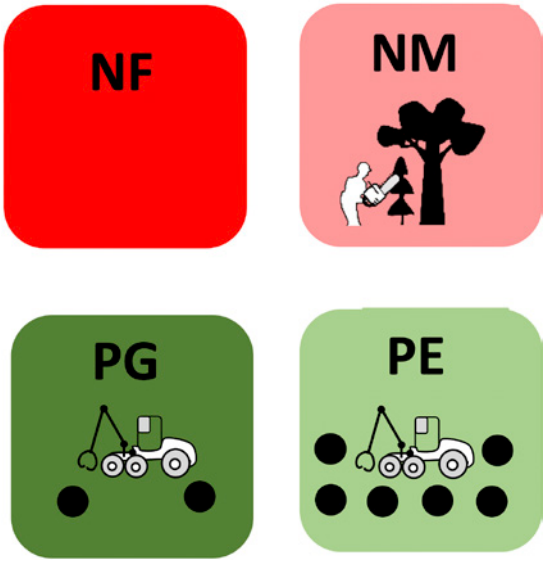


Fig. C 15.5. Management categories for stands. A goal for long-term management is set for each stand, in one of four categories: (i) NF = Nature conservation, free development; (ii) NM = Nature conservation-oriented management, often implying restoration measures; (iii) PG = Production with general conservation concern (green-tree and deadwood retention for biodiversity at harvest, represented by black dots). The minimum level of retention is specified, and always >15 % of the harvested area; (iv) PE = Production with enhanced conservation concern. The proportion area of each goal-category as an average for all ecoparks is 35 % for NF, 26 % for NM, 21 % for PE, and 17 % for PG.

Management for social values

A principal aim of ecoparks is to increase opportunities for people to experience nature, and arrangements that facilitate recreation activities have high priority (fig. C 15.7). Sweden's long tradition of right of public access implies that everyone can move freely in forests, which is also the case for ecoparks, although all visitors are expected to show concern for the environment. Visitors are free to pick berries and mushrooms. A pamphlet is available for each ecopark including maps, information on flora, fauna and sites of interest (also produced in English). Footpaths and resting places are available for hiking, and special trails are often prepared for mountain biking and horse riding. In many ecoparks, lakes and watercourses are popular for canoeing and other water activities, and there are picnic areas. The ecoparks contain good opportunities for fishing, and special fish conservation efforts are often taken. Individual visitors can buy fishing permits in many ecoparks. Hunting is allowed in various forms in ecoparks, and in most of them Sveaskog leases land to one or more hunting teams, while in some ecoparks, tourism companies arrange hunting activities. The visitation rate to some ecoparks is high; e.g. >500 000 visits per year for each of Omberg, Halle-Hunneberg, and Böda.

Fig. C 15.6. Examples of biodiversity-oriented management. (a), (b) Ecopark Färna: Norway spruce *(Picea abies)* is often removed in order to promote broadleaved trees, in this case European aspen *(Populus tremula).* (c) Ecopark Ejheden: Prescribed burning (conservation burning) is practiced in the boreal region to mimic natural fire dynamics. (d) Ecopark Halle-Hunneberg: Filling of ditches and other ways to slow down runoff water is a way to restore former hydrological conditions. (e) Ecopark Omberg: A log of oak *(Quercus robur),* not manageable by a wooden floor producer, has been relocated to the forest and positioned vertically as a way to create a coarse snag. (f) Ecopark Omberg: Clearing of overgrown, dense forest is made to liberate old broadleaved trees, in this case oak as a way to restore wooded pastures of traditional agricultural landscapes, most often in southern Sweden (Photos: Sveaskog).

Management for wood production

Of the area allocated to wood production or conservation (P and N forest, fig. C 15.2), 36 % are used for wood production areas in ecoparks compared with 88 % on other parts of Sveaskog's forestland. The prevailing harvest method is clearcutting but a higher retention level (17 %) than the average for Sveaskog forestland (10 %) is practiced. The annual harvest rate in areas allocated to wood production (P-forest) in ecoparks is only a fraction (10 %) compared to Sveaskog production areas outside ecoparks. To demonstrate balances between different ecosystem services, incorporation of wood production was a deliberate strategy at their initiation, although biodiversity and recreation are the main objectives. According to Sveaskog's mandate from the state, forests should provide a good financial return, and therefore a condition for establishing the ecoparks was that they would contribute, at least partly, to this aim. Combining goals of environment and production distinguishes ecoparks from the nature reserves and national parks formally established by the state, in which nature conservation is the only goal.

Monitoring and research

The biodiversity status of the ecoparks is monitored. One example is the Effekt 20 project established in 2009, in which insect and bird populations will be monitored in six ecoparks for at least 25 years. The project aim is to assess the response of biodiversity to the conservation efforts in the ecoparks. Preliminary analyses indicate a positive effect of removing Norway spruce and thereby creating warmer and more open conditions. In Ecopark Hornsö for instance, the rare beetle *Tragosoma depsarium* is now regularly observed on old, sunlit trees of Scots pine *(Pinus sylvestris).* Currently, the time-series data are analysed in cooperation with Swedish University of Agricultural Sciences.

Fig. C 15.7. Outdoor activities are popular in ecoparks. (a) Local nature organisations teach biology to children – Ecopark Omberg. (b) Canoeing in Ecopark Norra Vätterns Skärgård. (c) Arrangements are made for recreation such as picnic places – Ecopark Rosfors. (d) Fishing permits can be purchased in most ecoparks – Ecopark Naakajärvi (Photos: Sveaskog).

Student project work, at levels from Bachelor to PhD, is also encouraged and regularly performed in different ecoparks.

Reflections

Ecoparks have attracted a large number of visitors and have contributed to development of local ecotourism. Monitoring has indicated that there have been positive responses with respect to biodiversity. However, there are still concerns about the future of ecoparks, and questions about their management have been raised from nature organisations, ecotourism representatives, and other actors. The demand for wood production has been questioned, and new and broader ecopark plans have been requested with deeper involvement from local stakeholders. Development of a new administrative ecopark organisation has been suggested. A major future challenge is to secure a continued high quality and efficient management for biodiversity and recreation with greater acceptance among stakeholders. Climate change and human population growth make adaptation of management essential, as conditions for biota and outdoor recreation will continue to change. It is very likely that the importance of forest landscapes that have a focus on conservation, such as ecoparks, will increase even more in the future, with growing contrasts to the surrounding landscapes dominated by intensively managed production forests (Felton *et al.* 2019).

Conclusion

Ecoparks represent a new type of large-scale conservation area with combined ecological, economic, and social goals at landscape level, unique within Sweden (Michanek *et al.* 2019). The landscape scale, emphasis on biodiversity conservation, restoration and recreation and a subordinate role for wood production, large size, landscape plans manifested in agreements with the Swedish Forest Agency and arrangements for outdoor activities distinguish them from other conservation areas. The ecopark concept depends on extensive, contiguous forest landscapes under single ownership and may, therefore, be most suitable for state forests or land of other large forest owners. In Sweden, forestry companies such as SCA and Holmen have recently introduced similar conservation concepts, demonstrating that there is an interest in the idea also among large private forest corporations. Prerequisites for continued good progress of ecoparks is long-term support in Sveaskog's future policies, and permanent and sufficient funding for their conservation-oriented management.

Statement

Ecoparks are a promising approach to landscape management for multiple goals emphasising biodiversity and recreation, filling a gap between smaller protected areas and landscapes designated for wood production. Among the most important qualities are systematically developed management plans with goal setting for each stand, formal agreements with the forestry authority, areas with free development mixed with restoration measures, and arrangements to encourage outdoor activities.

Links

https://www.sveaskog.se/en/skog-och-virke/environment-and-nature-conservation/our-ecoparks

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Fig. C 15.8. The Jovan ecopark in Storuman (Photo: Sveaskog).

Box C 10

Waldlabor Zürich – the Zürich Forest Lab

A unique forest area in Switzerland to illustrate forest management to a large audience

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Starting point and relevance

The Zürich Forest Lab (Waldlabor Zürich) is a unique forest area in the Swiss Plateau. The forest lab is located on the outskirts of the city of Zürich, the largest Swiss city with a population of 400 000. The outdoor laboratory is made up of 1.5 km² of mixed broadleaved forest near ETH (Eidgenössische Technische Hochschule; Swiss Federal Institute of Technology) Hönggerberg (fig. 1). It incorporates historical, current, and future forms of forest management. The diversity of these forest management systems and their ecological prerequisites provide a good basis for a better understanding of changes to forest ecosystem services and forest management over time.

The forest lab is a place of learning, experience, and research: it is an outdoor nature classroom for students, a place of recreation and exploration for visitors, and an open space for experiments for researchers. There are many synergies between these three levels of use. The initiative for this project originated from WaldZürich, the local association of forest owners. For its centenary, WaldZürich aimed to create something that will last. The lab itself is designed to run for a period of at least 100 years. The set-up phase began in 2018 and will last till 2025.

The forest lab is operated by the Verein Waldlabor Zürich (Association of the Forest Laboratory

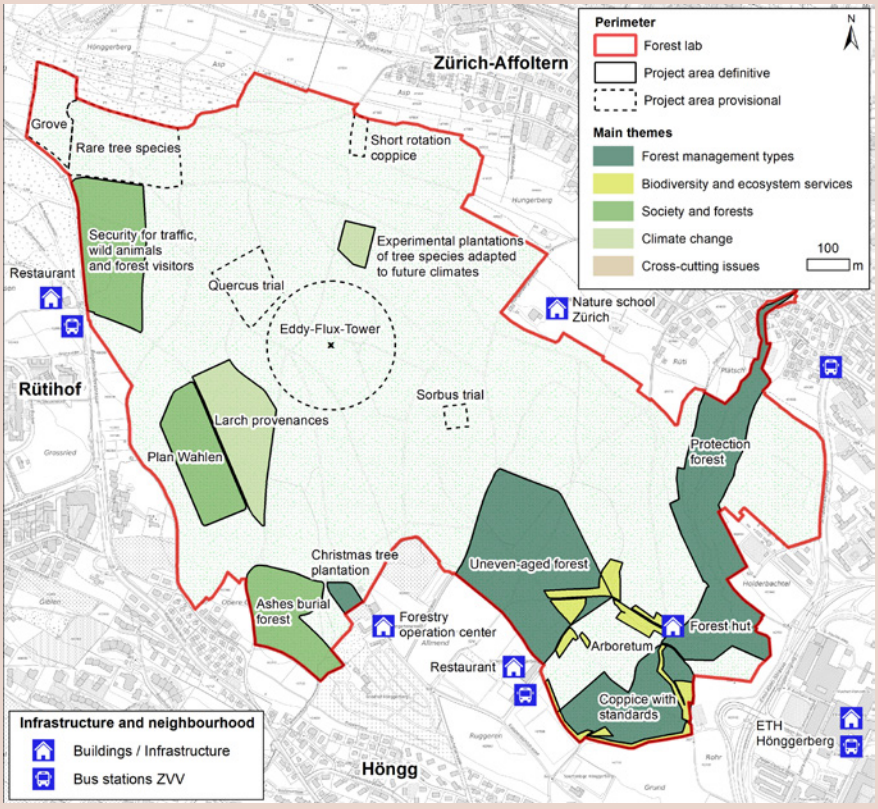

Fig. 1. Map of the Zürich Forest Lab.

Fig. 2. The five main themes of the Zürich Forest Lab.

of Zürich). The association members include: ETH; the Swiss Federal Institute for Forest, Snow and Landscape Research WSL; Green Stadt Zürich; the Office for Landscape and Nature of the Canton of Zürich; Wald Zürich; and the Association of Zürich Foresters.

Among the existing outdoor forest laboratories (e.g. Köln) the Zürich Forest Lab is distinguished by its size and main focus on managed forests. Special emphasis is given to diverse forest management systems. What further makes it unique is that the initiative originates from forest owners with the intention of uniting the interaction of both practice and research.

A total of CHF 2.7 million has been allocated for the 8-year establishment phase, including contributions from third parties, and financial and in-kind contributions from the sponsors. These figures do not include the expenditure of forest owners for forest management measures. The establishment phase is being financed with the support of the Lottery Fund of the Canton of Zürich, the Federal Office for the Environment, over 60 Zürich municipalities, and contributions from private sponsors.

Objectives and target groups

The forest lab has four objectives:

– The Zürich Forest Lab is an experience-oriented educational and research centre. It is the first such outdoor forest laboratory in Switzerland. The focus is on forests influenced by humans, also called 'cultural forests'. Such forests include a wide variety of forest management forms and associated sustainability goals differentiated by forest owner types, and by variations of importance in view of the forest services provided for society.
– The forest lab has been set up to run for 100 years. The different management forms present within the forest lab allow first-hand forest dynamics and visible changes to be observed.
– The forest lab stands at the interface between forestry practice, society, and research; therefore, the lab can be used to investigate a broad range of both practical and research questions.
– The audiences for the forest lab are the public, forest experts, and researchers. The public can be involved in projects and excursions, in field observation (citizen science), and also in practical forest work. Forest experts/practitioners at all levels are encouraged to visit the forest lab during their education and to apply practical training.

In particular, the urban population is a target audience for the forest lab. Increasingly, city dwellers have reacted more sensitively to forest issues and forest uses, and the forest lab seeks to actively engage with this part of the population. Further information about the forest lab can be found at Zürich Forest Lab website (http://www.waldlabor.ch).

In the main theme 'Biodiversity and ecosystem services', various questions relating to the occurrence and enhancement of animal and plant species as well as habitat occurrence are examined. One focus here is also on the effects of various forms of forest management on biodiversity.

Communication

Communication takes place via the forest lab website and information boards at the main entrance, the specifically designed forest lab App (Waldlabor, Andreas Garzotto GmbH), and flyers. Important platforms for communication are events offered at the forest lab as well as an annual event for all target audiences.

The forest lab distinguishes five main themes (fig. 2): (1) forest management types; (2) society and forests; (3) climate change; (4) biodiversity and ecosystem services; and (5) cross-cutting issues. With the help of a specifically designed colour con-

cept and corresponding pictograms, visitors are guided along the five main themes through the forest lab.

The chosen approach has different communication-oriented principles. Here we highlight them providing an explanation for each (Table 1).

Implementation

Implementation of the project started in early 2019. Currently, 38 projects are listed and are at varying stages of implementation. Among them are research projects and cross-cutting actions such as the establishment of a monitoring database. These will help create new insights and ensure the preservation of knowledge. This is of high importance when it comes to communication with the different target audiences. The first documented silvicultural interventions are expected to take place during the winter of 2020/2021. The following illustrations highlight some of the planned implementation measures (figs 3–4).

The many forms of forest management are characteristic of our 'forest culture'. A distinction can be made between, for example, even-aged and uneven-aged high forest management, coppice, and coppice with standards, as well as other forms, such as agroforestry.

Special attention is given to the promotion and preservation of extraordinary trees (e.g. dead standing trees, ancient trees, tree-related microhabitats (e.g. polypore fungi, tree cavities) and epiphytic cover of trees (e.g. mosses, lichens, climbing plants, or unusual root forms) (figs 5–6).

Within a short distance from the forest lab there are historically interesting sites including, for example, a burial mound from the Iron Age (Hallstatt period) and the relict of the so-called 'Plan Wahlen' where agricultural production was intensified during World War II.

Fig. 3. Coppice with standards (applied at the forest lab) (Photo: Andreas Bernasconi).

Fig. 4. Different forest management types are shown to convey better understanding of their origin and purpose (Photo: Andreas Bernasconi).

Table 1. Communication oriented principles of the Zürich Forest lab.

Principles	Explanations
New knowledge regarding forest ecosystem services	The most recent knowledge and findings from practice and research can be observed and experienced in an exciting format on the 150 ha of forest. The results are available online.
Silviculture and forest management	Many visitors to forests are unaware of, or do not understand, the connection between silviculture and the forests they see. In the forest lab, visitors can experience current, historical, and also potential future forms of forest management.
Allow for a travel through time	Forest management choices can have effects that can be seen decades and centuries later. By combining management, and visitor information, such developments become more tangible; forest visitors can in this way travel both back in time and into the future.
Forest owners are trustworthy	Forests in Switzerland are freely accessible; forest owners and forest managers act in the spirit of sustainability; they ensure that numerous objectives and interests are integrated into their management.

Fig. 5. Extraordinary tree trunks (Photo: Andreas Bernasconi).

Fig. 6. Unusual root forms (root buttress cavities) (Photo: Andreas Bernasconi).

Kocanda – an example of multifunctional forest management during forest stand transformation

C 16

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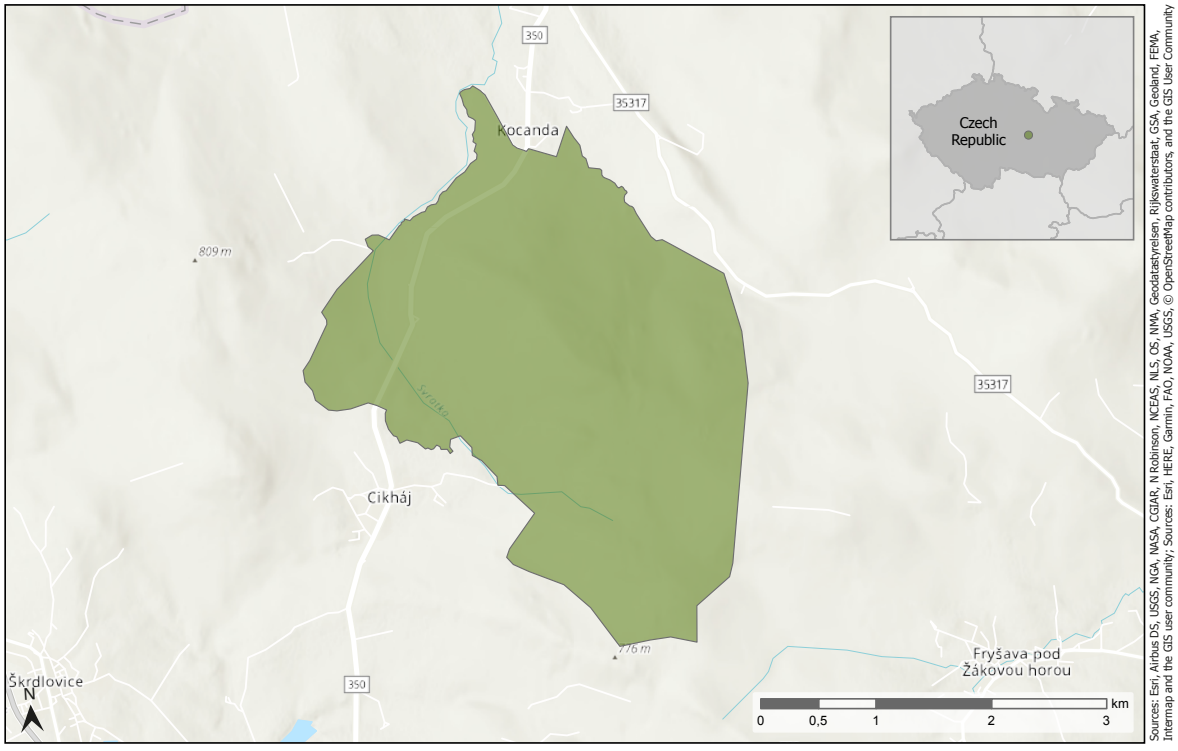
Context, legal frame, and ownership structure

The Kocanda Forest District (FD Kocanda) is a part of a private family estate. The total area of FD Kocanda is 932.34 ha (while the area of the whole forest estate is 5775 ha). FD Kocanda is located in the administrative areas of the Kocanda and Cikháj villages (district of Žďár nad Sázavou) in the central part of the Czech Republic. The villages of Kocanda and Cikháj are the only human settlements within the perimeter of the area. FD Kocanda lies in the



< Fig. C16.1. This is where everything starts. An atmosphere of microclimate in the forest of Kocanda (Photo: Jiří Bína).

Statement

"Conversion of pure, coniferous and even-aged forest stands is nothing all-new because its necessity was clearly formulated already in nineteenth century, but there are not many examples of (mid-)advanced stages of forest transformation in Central Europe – one of them is Forest District Kocanda in the Czech Republic."

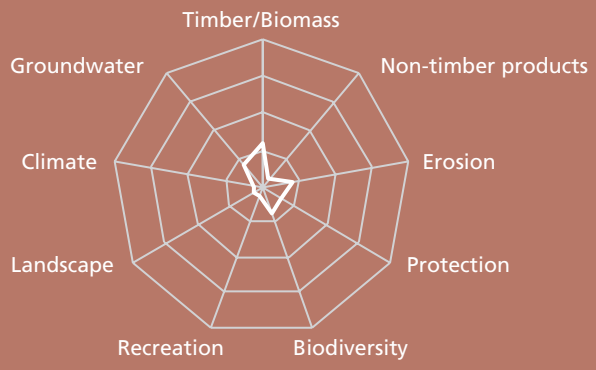


Table C 16.1. General information of Kocanda forest district.

Forest community (main types)	Acidophilous montane beechwood *(Lazulo-Fagetum montanum)* changing locally into the floriferous beechwood *(Eu-Fagion)* in the area surrounding Žákova hora; spruce-fir beechwood *(Fageta piceoso-abietina)*
Total forest area	932.34 ha (17.46 ha where forest management and human interventions are strictly prohibited)
Forest Management	Conversion into uneven-aged forestry with parallel conversion of tree species composition by underplantings; irregular shelterwood system with maximally extended regeneration period within every particular spatial entity (from the level of a tree cohort to the level of a forest stand)
Total volume	ca. 440 m³/ha (402 805 m³ for the whole FD Kocanda)
Annual growth	ca. 11.9 m³/ha (not based on the statistical inventory methods but based on the algorithms of the age-class forest, and thus calculated with highest possible precision)
Annual use	ca. 12.8 m³/ha
Deadwood (standing and lying)	Unknown; this factor has not inventoried yet; however, deadwood is retained locally
Altitude	647 to 810 m a.s.l.
Geology	Ancient (Proterozoic) metamorphosed two-mica bedrocks: muscovite-biotite migmatites or orthogneisses of Svratka Crystalline (southern part of the Bohemian Massif)
Ownership	Private; Kinský Žďár, a.s. (joint stock company), Zámek 1/1, 591 01 Žďár nad Sázavou; ID 46901523
Protected area (total)	103.47 ha (38.1 ha = the category of the forests of National Natural Preserve – core zone and expanded part + an overlap with the category of the forests for biodiversity enhancing and genetic sources protection; 62.4 ha = the category of the forests for biodiversity enhancing and genetic sources protection; 2.97 ha = I. zone of the Žďárské vrchy Protected Landscape Area – special importance of the ecosystem for the birds´ protection) + 39.03 ha of Natura 2000 (overlapping with above described areas)
Nature protection area (Natura 2000)	39.03 ha; CZ0610401 – Žákova hora
Protective function	National Natural Preserve – core zone and expanded part; forests for biodiversity enhancing and genetic sources protection; I. zone of the Žďárské vrchy Protected Landscape Area – ecosystem of special importance for the protection of birds

Svratka River basin and it extends from 647 to 810 m a.s.l. and is characterised by a continuous complex of forests. The summit of the hill, Žákova hora (the highest point in the area at 810 m a.s.l.), is approximately in the middle of FD Kocanda.

Since 1994, these forests have been undergoing a process of conversion from pure Norway spruce *(Picea abies)* stands shortly after the restitution of the forest property (in 1993). There were two categories of the forest stands within the whole forest estate after the restitution as a consequence that two different State Forest Enterprises had managed the estate before that applying different forest management approaches. FD Kocanda lies in the part which was managed by a clear-felling system until 1993. In the other part of the property, a shelterwood system had been applied. A clear decision was made in 1993 to convert the forest management from the clear-felling system and from pure Norway spruce stands towards more stable, diverse, mixed forest managed by the shelterwood system, and at later (more developed) stages to convert it continually further into a close-to-nature forestry. Two people were largely responsible for application of the new management approach – Forest Administration Director Dipl. Ing. Pavel Bednář (senior; died 2000) and the local forester Jiří Bína. Assoc. Prof. Jaroslav Švarc (died 2002) also influenced the implementation of the new system.

At the beginning of 2009 and then again at the beginning of 2011, the area of FD Kocanda expanded beyond the original borders. When comparing the new areas to the original FD Kocanda, the lower level of both transformation advancement and forest stand structure development have been realised.

The mean annual total precipitation is 740 mm, and mean annual temperature ranges from 5 °C to 6 °C (Tolasz *et al.* 2007). According to the geo-botanical standardisation, the area is characterised by two main forest communities: the dominant forest community is the acidophilous montane beechwood *(Lazulo-Fagetum montanum)* which changes into the floriferous beechwood *(Eu-Fagion)* in the area surrounding Žákova hora (Mikyška 1971). The geological basement is made up from the ancient (Proterozoic) metamorphosed two-mica bedrocks (muscovite-biotite migmatites or orthogneisses) of Svratka Crystalline that represents the southern part of the Bohemian Massif. On these acidic to neutral bedrocks medium deep, sandy and loamy-sand oligotrophic Dystric Cambisols and Cryptopodzols, with a lack of bases, are mainly formed (Rejšek 2009; Janík *et al.* 2016). Thus, the area consists of mainly acidic sites where the main biogeocoenoses are *Fageta piceoso-abietina* and *Piceeta abietina sphagnosa inferiora* et *superiora* (Bednář and Bína 2018).

Portrait of the Kocanda Forest District

"Our mission is to manage the forest with respect to the forest ecosystem stability, vitality and biodiversity encouragement and parallel with the full utilisation of the production potential of the forest sites and forest stands. Our long-term target is to achieve supreme possible stability, vitality and biodiversity of managed forest stands in the future and maximal employment of the nature automation within all silvicultural measures and interventions after (and with limited extend also during) the forest stand transformation process."

Forest history and cultural heritage

This territory at the boundary between Bohemia and Moravia was difficult to travel through because of the large forests and abundant peat bogs and swamps. The Cistercian monastery in Žďár nad Sázavou was established in 1252 to support settlement in this region. Soon after that, silver and iron mining began, and the first, primitive, metal works started to develop. These required a large amount of charcoal, and the extensive forests supplied the wood needed for this. The forest area soon began to decrease, and the tree species composition began to change, as well. By the first half of the sixteenth century, it had become difficult to supply the charcoal to new ironworks as the available wood reserves were close to being exhausted (Novotný and Horák 1968).

While in the areas near rivers, the forests were heavily devastated due to the increasing consumption of wood, the forest complex near Žákova hora was spared thanks to its remote situation; at the beginning of nineteenth century there was on one access road to the area (Švarc 1993 cited in Vrška *et al.* 2002). The structure of forest stands near Kocanda were described in 1797 as:

Fig. C 16.2. The core zone of the Žákova hora National Nature Preserve represents 17.46 ha of the natural forest that has been influenced only slightly by human activities in the history due to difficult accessibility and other factors (Photo: left, Eckart Senitza, 2018; right, Pavel Bednář, 2019).

Norway spruces with silver firs and a lot of European beeches between them, sycamore and Norway maples here and there, and elms and aspens are dispersed. The majority of the forest district consists of over-aged coniferous and broadleaved trees; other forests stands are between 80 and 100 years of age. The regeneration looks good, except for the parts browsed by cattle (Novotný and Horák 1968).

However, it is also mentioned that despite the very swampy soil at the hillside of Žákova hora, random cuts were done in these originally virgin forests, and thus some parts of the forest stands were sparse (Nožička 1957; Novotný and Horák 1968). Sycamore *(Acer pseudoplatanus)* trees were distinctively present in the mixture of tree species around Žákova hora. The sycamores were used for production of maple sugar, especially during the Napoleonic wars; and thus additionally plantings for this purpose took place (Nožička 1957; Švarc 1993 cited in Vrška *et al.* 2002).

In general, the forests in the Žďár region at that time had been devastated and misused in many other ways – cattle grazing, cutting grass, raking of the forest floor, harvesting and removal of stumps, and illegal logging. Forest management was fully under the influence of ironworks, and the forests were over-exploited. It became evident that the forests were no longer able to supply the ironworks, and in 1886 the last blast furnace in the region was closed (Novotný and Horák 1968).

Significant changes of the forest management took place after the 1850s (Švarc 1993 cited in Vrška *et al.* 2002). Pure and even-aged forest stands of Norway spruce were gradually established under the direction of the chief forester Havránek. This was also connected with age-class forest management and a use of the clear-felling system. As in many places, the forest managers hoped for highly productive forest stands and easy and simple management (Novotný and Horák 1968). However, within the area immediately surrounding Žákova hora, the forest stands remained largely untouched (Vrška *et al.* 2002).

In 1920, when a forest management plan was prepared, the forests were managed by the Forest Director Antonín Bakesh and his son, Dipl. Ing. Karel Bakesh. The plan clearly indicated an attempt for a transformation into the shelterwood system and a retreat from clear-felling system; it was very important that, following from a recommendation by Antonín Bakesh, a part of the forests near Žákova hora were excluded from common forest management, and thus the nature conservation of today's Žákova hora National Nature Preserve (NNP) was purposefully started (Novotný and Horák 1968).

When Antonín Bakesh died in 1926, his son, Karel Bakesh, took over the mission of his father. However, a large part of the forest was totally destroyed by a large windstorm on 26–27 October 1930. The storm ravaged the forest stands and by

July 1931 a total of 463 000 m³ of salvage wood (on an area of 5624 ha of the forest property) had been processed; sparse forest stands were repeatedly damaged over the course of the following years by snow and wind damage, and thus those disturbances in the period of 1930–1933 caused large-scale clearings covering an area of 1600 ha (i.e. the sudden deforestation on nearly 30 % of the area of the forest property). The total volume of salvage felling within the property reached more than 1 million m³, while in the administration of Cikháj (representing 2015 ha including forests of FD Kocanda), the salvage felling was 304 916 m³ (i.e. 151 m³/ha on average for the Cikháj-area) (Novotný and Horák 1968).

In 1941, the estate was put under Nazi receivership; when WWII ended, the property was owned by the Kinský family until February 1948. On 1 January 1949, the forest property was incorporated into the Forest Enterprise (FE) Žďár nad Sázavou of the State Forests; later it was split into FE Přibyslav and FE Nové Město na Moravě. In the forests of FE Přibyslav there was a clear effort to follow the pre-war management using the shelterwood silvicultural system. However, in FE Nové Město (where FD Kocanda was located) diverged from this approach and to a large extent the clear-felling system was employed (Novotný and Horák 1968).

The entire property was returned to the ownership of the Kinský family in 1992. As of 1 February 1993, the operation and administration of the revived estate was restored and Dipl. Ing. Pavel Bednář (senior; died 2000) was appointed Forest Director; the forester in FD Kocanda had been Jiří Bína since that time until his retirement in February 2020.

Aims of the Kocanda Forest District

It was necessary to establish long-term forest management within the newly restituted forest property in 1993. Although entire spatially, the newly formed forest estate was rather incoherent with respect to the stand structure and tree species composition. In about half of the area (that part managed by the shelterwood system within FE Přibyslav in the previous decades), the forest stands achieved certain forest stand structure heterogeneity (more or less developed; initial stages of structural encouragement prevailed) and tree species composition was also slightly shifted from pure composition towards mixed composition mainly by admixture of silver fir and European beech. By contrast, the forest stands in the administration of Cikháj (the part managed by clear-felling system within FE Nové Město na Moravě) had homogeneous age-class structure and pure species composition. It was very important to unify the silvicultural treatment across the whole property. With regard to the situation (pure, even-aged Norway spruce monocultures on the half of the property) and considering all risks and threats of such forest stands – a clear decision was made to transform tree species composition and, at the same time, to convert clear-felling system to shelter-wood system with future prospect of conversion to further follow-up uneven-aged forestry forms in the later stage of the transformation process (Bednář 2009).

The transformation was initiated by Pavel Bednář (senior). In addition, it was also supported by Assoc. Prof. Jaroslav Švarc and Prof. Vladimír Tesař as independent authorities from the outside of the company. The incorporation of these concepts into a forest management plan was made by Dipl. Ing. Jiří Fišera through a pioneering forest management plan for the 1999–2008 period (Bednář 2009).

In general the goals defined in 1990s (described above) about the forest transformation into close-to-nature forestry have been met and fully employed only in FD Kocanda. In the remaining part of the forest property, a departure from those goals since ca. 2010 has taken place. It means that the prevailing silvicultural approach in all other forest districts of the forest property is a wedge felling system combined with elements of both the clear-felling system and the shelterwood system (through a two-phase shelterwood cut). By contrast, the forest management in FD Kocanda has been continuing with long-term forest transformation – i.e. by the transformation under a continuous cover scheme (fig. C 16.3).

Applied management system

The forest management approach is characterised by the main target of the forest stand transformation, i.e. parallel conversion of tree species composition and conversion of the forest management; thus, transformation under a continuous cover scheme is strictly implemented. Applied silvicultural

Fig. C 16.3. The transformation process has its own silvicultural technique that is implemented through specific interventions within particular part of a forest stand space and has its specific schedule, as well. A typical element is the so-called 'foundation of the regeneration felling system' represented by a strip shelterwood cut where areas for underplanting by absent tree species are combined with areas prepared for natural regeneration of Norway spruce (growing under the more closed overstorey canopy shelter to control its growth and vigour). This photo shows an example of European beech underplanting with subsequent natural regeneration of Norway spruce (location: 206 Cc 10/1) (Photo: Jiří Bína, 2020).

treatment is represented in particular by the main principles as follows: (i) maximally extended regeneration period (not only a regeneration period of the entire forest stand, but of any particular small spatial forest area, aiming at maximal forest structure encouragement); (ii) long-term individual quality selection in the overstorey aiming mainly at enhancement of the quality of the target trees; (iii) underplanting of the absent tree species – mainly European beech *(Fagus sylvatica)* and silver fir *(Abies alba)* (fig. C 16.4) – and their growth beneath the canopy for their proper growth, morphological development and structural development over many decades; combined with (iv) a natural regeneration of Norway spruce under the canopy (controlled in it growth and vigour by sequential overstorey canopy opening); (v) a maximal possible employment of the nature automation; (vi) encouragement of any naturally regenerated tree species admixture; (vii) strict avoidance of creation of any larger gaps or even clearings; (viii) maximum enhancement of the forest stand vitality, stability and biodiversity, and encouragement of various forest functions and services.

If an admixture, as shown in Figure C 16.5, is present it is used for natural regeneration. The natural regeneration of Norway spruce and European beech, which were present in this forest stand has been combined with artificial regeneration of silver fir (which was absent in the initial stand). This creates a stand with the desirable, target composition of the tree species, the Hercynian mixture. The successful development and growth, as well as the full (both productive and ecological) employment of each species is enabled by appropriate silvicultural treatment. This creates sufficient and favourable ecological conditions for development of all species and allows each to grow vigorously without any one species out-competing the others.

Fig. C16.4. A view into the interior of the forest stand and the 'foundation of the regeneration felling system' at the point where the mixed underplanting (silver fir and European beech) connects to the subsequent natural regeneration of Norway spruce; one foundation consists of many underplantings within its length jointly connected by naturally regenerated areas (it is possible to see another underplanting in the upper right corner). Various light conditions have to be created within a forest stand to encourage the forest structure as much as possible when the long regeneration period (both at stand and any partial spatial level) is essential (location: 202 Bb 7/1) (Photo: Pavel Bednář, Jiří Bína 2018).

Fig. C16.5. A very rare case is when a valuable admixtures of any other tree species is present in the forest stand overstorey because there were dominating pure Norway spruce stands before the transformation started. (location: 210 Ee 9/1b) (Photo: Jiří Bína, 2018).

Economics

The total yearly harvest ranges from 11 000 to 12 000 m³ when the long-term share of the roundwood (quality III. A–C) is stabilised as ca. 60 % with the long-term average price of 75 €/m³ in the last decade. The remaining share of 40 % (represented mainly by pulpwood for various purposes and low-quality roundwood) has been sold at an average price of 37 €/m³ for the last decade (short-term price oscillations are neglected). The costs for a harvest and a wood extraction to a wood dump have ranged between 15 €/m³ and 19 €/m³ for a long time.

Costs for tending of young forests (at the growing stage up to 2 m in height) coming from natural regeneration must be considered, as well. When the 'nature automation', as a process of close-to-nature forest management, is used to the greatest extent possible, the individual selection prevails, applying mainly positive selection from above (supressed tree cohorts are left to self-thin). This approach represents ca. 70–90 % of the area that is tended (being actually only an addition to self-thinning especially where the shelter of the overstorey canopy is not optimal). Schematic measures represent the remaining 10–30 % of the total area for tending (where approx. 1.8–2.0 m cut strips are altered by 0.5 m strips of remaining natural regeneration) and it is applied in those areas where the shelter of the mature canopy is not optimal (mainly because of disturbances etc.). The individual treatment represents costs of about 70 €/ha and the schematic measures about 500 €/ha when the area was about 70 ha in the last decade (forest management plan 2009–2018); because of the further development of the forest transformation process, the area has increased to about 130 ha that is planned for the current decade (forest management plan 2019–2028). Regeneration of Norway spruce accounted for 74.9 % of the regenerated area in the last decade (2009–2018) and 25.1 % of the regeneration was made up of other the target tree species: silver fir – 6.3 %; European beech – 18.3 %; Sycamore – 0.3 % and black alder *(Alnus glutinosa)* – 0.2 %). However, when the natural regeneration of Norway spruce was dominant (98 %), other tree species usually had to be planted

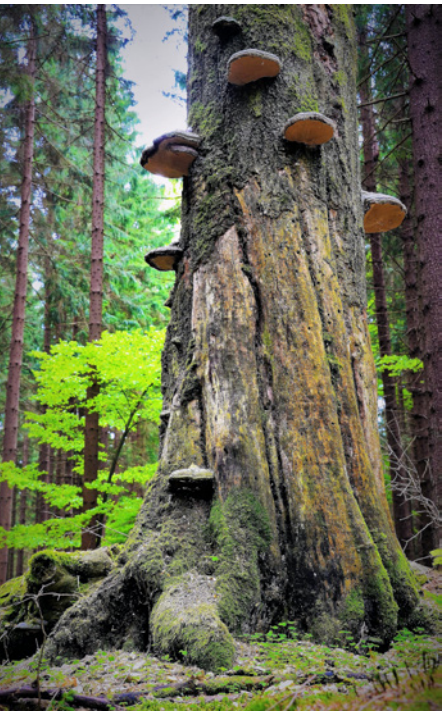


Fig. C 16.6. Any opportunities to enhance biodiversity in the managed forest stands are purposefully used for this target (location – left: 206 Dd 7; right: 210 Bb 12) (Photos: Jiří Bína, 2017).

when they were absent in the forest stands (all of the silver fir and black alder were planted, and 60 % of European beech was planted with the remaining 40 % being natural regeneration coming from the rare valuable mature admixture of European beech or seed from the Nature Preserve).

The conversion of tree species composition represents substantial costs in those forest stands where the artificial regeneration is essential (because of the lack of seed sources) when the total costs range from about 7500 to 8000 €/ha for planting and fencing (and fence disposal) of European beech and silver fir underplantings. As a consequence, within FD Kocanda, there are currently 290 fenced underplantings of European beech and silver fir (total fenced area of 31.2 ha and total fence length of 38.5 km).

However, natural regeneration represented 81 % (regardless of tree species) of the total regeneration in the last decade. This has a significant positive impact on the economics. Considerable savings are created mainly by natural regeneration of Norway spruce compared to its artificial regeneration that represents about 3700 €/ha (in comparison with the much lower costs for tending of Norway spruce natural regeneration as described above).

Ownership structure

The private owner is the Kinský family through the joint stock company Kinský Žďár where Constantin Norbert Kinsky has owned a 68.80 % stake, and his brother Charles Nikolas Kinsky a 31.20 % stake of shares in the company since 2018 (Šebestová 2019).

Important services and products

The most important products and services of the forests of FD Kocanda are:

i) wood production;
ii) nature conservation in the Žákova hora NNP;
iii) water protection and hydrological function as it is the source of the Svratka River and many small springs;
iv) biodiversity encouragement and genetic sources protection because of the forest stand transformation towards close-to-nature forestry and the occurrence of the Žákova hora NNP that is managed in its expanded part through implementation of the ecological forestry;
v) importance for microclimatic and ecosystem regulation functions and as a migration corridor in the landscape – it is a part of the large compact complex of the forests in the central part of the Czech Republic;
vi) scientific importance where many studies have been done in the NNP about the dynamics of the nature forest and where in the managed forests stands various silvicultural issues have been observed (e.g. several diploma theses; one PhD thesis) and where permanent research plots aiming at various silvicultural, eco-physiological, hydrological and others issues have been established;
vii) educational and enlightenment purposes – many seminars and workshops both at national and international levels have been arranged, and these events have been covered by the local and national media; universities from within and outside the Czech Republic used the area for practical training;
viii) a wide range of forest practitioners have attended various events and there have been many articles about applied forest management in forestry journals; potentially, there will be many more as an Exemplary Forests and Exemplary Forests of Pro Silva (containing also an inventory plot for repeated inventories) were established here in 2017;
ix) tourist importance – the area is popular with tourists and there are marked trails supplemented even by educational panels containing information about the area;
x) importance for a hunting – hunting is another important activity in the landscape and important heritage, as well.

Conservation of rare species

Žákova hora NNP is one of the most valuable (within the top 10) natural forests that have been preserved in the Czech Republic (otherwise characteristic by cultural landscape); it is unique because of its history when it was established within the private forest property based on the recommendation of Antonín Bakesh in 1929 (with subsequent official Ministry declaration in 1933) (Vrška *et al.* 2002). There are many rare species both from fauna and flora, including: *Dentaria enneaphyllos; Circaea alpina; Veronica montana; Leucojum vernum; Cara-*

bus coriaceus; Sinodendron cylindricum; Aglia tau; Triturus alpestris; Ficedula parva; Ficedula hypoleuca; Aegolius funereus; Columba oenas; Nyctalus leisleri; Sorex alpinus and others (Staněk 2009).

Nature conservation

FD Kocanda covers the Žákova hora NPP (figs C 16.2 and C 16.5). The whole area of FD Kocanda is also a part of the Žákova hora Supra-regional Bio-centre (within the Net of Ecological Stability of Landscape in the Czech Republic – ÚSES), the largest supra-regional bio-centre in the entire Žďárské vrchy Protected Landscape Area. An area of Natura 2000 was established there (CZ0610401 – Žákova hora; 39 ha). Within 17.5 ha of the core zone of the Žákova hora NNP all human activity is prohibited, and within the surrounding of about 21 ha of the expanded part an ecological forestry has been being applied. There are 86 ha of the special-purpose forest stands that are managed though different special-purpose forestry approaches (for a biodiversity enhancing and genetic sources protection; or in the I. zone of the Protected Landscape Area for the protection of birds; or by an employment of the ecological forestry in an expanded part of the Nature Preserve). The nature conservation was started here based on the recommendation of the Forest Director Antonín Bakesh. Over 20 % of biomass in the core zone is made up of deadwood (Vrška *et al.* 2002). The Nature Preserve represents extraordinary value for biodiversity and genetic resources protection, and it is also the main source of findings about forest dynamics (in the right picture C 16.2. there is fungus *Hericium coralloides*). Stem position maps of trees with DBH ≥10 cm were carried out in the core zone in 1974, 1995, and 2011 (Janík *et al.* 2016). For instance, the constant increment of sycamore share has been observed for the last many decades; however, sycamore recruits are not spatially associated to individual gap makers and have a highly clustered distribution when the number of individuals grew mostly through the increase of existing clusters. Thus, an increment of its share can be spatially and temporally limited process (Janík *et al.* 2016).

Figure C 16.7 allows a view into the interior of the forest stand, under the crown canopy layer of the homogeneous and even-aged stand of Norway spruce being regenerated by means of a large-scale shelterwood cut, with European beech natural regeneration differentiated by age and space and spread (from the core zone) under the Norway spruce shelter, completed with a mosaic-like and cluster-formed natural regeneration of Norway spruce. The specific features of ecological forestry in the expanded part of the Žákova hora NNP are reflected by the distinctively higher proportion of deadwood left in the forest.

Recreation

The area is well used by tourists and there are marked trails supplemented even by a few of educational panels. The locality is very popular for many different reasons (e.g. large forest complex; well-known National Nature Preserve; important historical events during WWII; close location to larger ponds; Žďárské vrchy Protected Landscape Area; well-developed tourist infrastructure; the top of Žákova hora is one of the highest points in the region, etc.). Thus, the importance for the tourism is significant. There are a few small villages in the surrounding area.

Strengths and weaknesses

A potential problem for the near future is that the forest management plan is based on the methodology designed for management by age-classes, and this is currently the only possible alternative according to the Czech Forest Act; a change to the legislation has been widely discussed at many different levels (including at ministerial level) for a long time. However, even the legislation change will not provide a full solution to the problem. The reason is because, potentially, the distinction between FD Kocanda and the rest of the forest property will gradually increase in the future (if the current different approaches continue) – the longer the time that different forest management is applied, the more distinct the differences of forest structure (and other forest entities) will become. This can start to be a problem when the forest management plan is prepared for the whole forest property. Thus, for the rest of the forest property the recent methodological approach will be used effectively in the future while the enhanced forest structure in FD Kocanda will require a different methodological approach based on the statistical forest inventory where, among others, the harvest maturity will be determined by target diameter rather than based

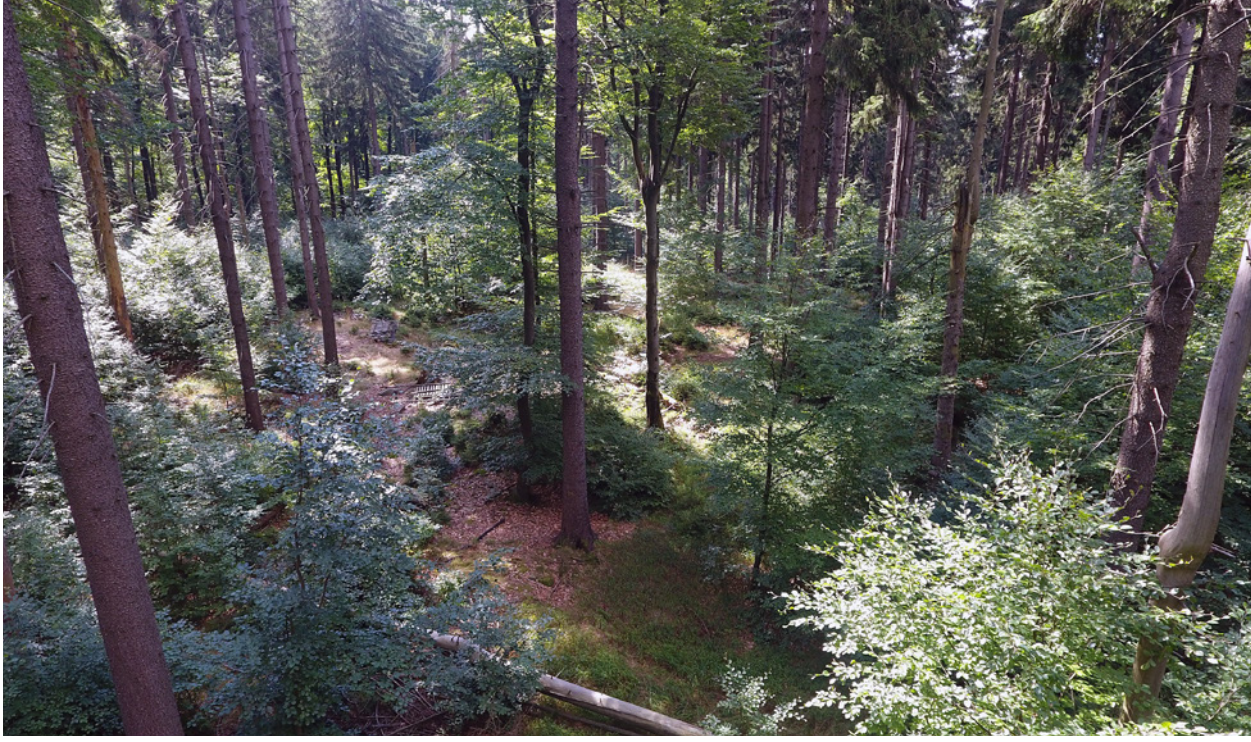


Fig. C16.7. An example of ecological forestry in the expanded part of the Žákova hora National Nature Preserve (location: the border of 207 Cc 11/1a on the left-hand side and 207 Cc 15/3b/1b on the right-hand side) (Photo: Pavel Bednář, Jiří Bína 2018).

on age, etc. A second potential threat is represented by the 'human factor' after retirement of the local forester (working here for many decades) in 2020 and when the all-new top management was simultaneously engaged at the same time; however, recent short-term employment of a new forestry staff brings a general optimism with regard to this issue. Considering that there have been other similar examples of forest stand transformations, and as Souček (2018) analysed, if such transformations fail it has been because of their interruption most often caused by the fact that forest owners or newly coming foresters deflected the forest management from the previous transformation.

Conclusion

FD Kocanda is an important and valuable example of a large forest area under long-term forest transformation (parallel tree species conversion and forest management conversion). This is an issue mainly in the Czech Republic, but also to a certain extent in other parts of Europe. The transformation has been applied here for more than 25 years and during this period many forest functions and services have been being fulfilled and even deliberately encouraged (such as biodiversity and nature protection as forest functions in the expanded part of the Nature Preserve where the ecological forestry has been applied). These functions are also encouraged in production stands when the vitality, stability, biodiversity, and production of the forest stands have been enhanced under the applied forest management system. FD Kocanda is an important area from the viewpoints of research, forestry production, and public education. The main threat are the hypothetical future decision of stakeholders to convert the forest management back to simplified management systems and subsequent sudden forest structure unification and nature automation losses which both have been so intensively enhanced in recent decades. Forest management within FD Kocanda is an extraordinary example of how large areas of pure, even-aged, coniferous secondary monocultures can be progressively transformed and how fairly advanced stages of this process can be achieved over a relatively short time; in addition, it is magnificent example of how uneven-aged silviculture corresponds well with enhancement of multiple forest functions/services.

Funding

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Box C 11

A novel TRIAD approach to increase resilience of the forest landscape to global change: or how to make a better omelette without cracking too many eggs

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Forest management: a balancing act

Forest management today aims at striking a balance between (a) maximising timber and fibre production, and (b) protecting biodiversity and allowing for other uses of the forest. This division of often conflicting objectives is normally achieved by either 'land sharing' where all objectives are achieved on the same piece of land at the same time, or 'land sparing' where different objectives are achieved on different pieces of the land at the same time (fig. 1). Numerous variants of these two contrasting management strategies may be found in different parts of the world, and discussions still rage over the advantages and disadvantages of each strategy (Phalan 2018). For many, however, such a balancing act is impossible to achieve and can be summarised metaphorically as:

It is impossible to make an omelette (i.e. in the case of forest management, produce timber and fibre) without cracking some eggs (i.e. without compromising biodiversity or multiple uses of the forest).

In this box, we present the TRIAD functional zoning approach to forest management as currently used or advocated as an effective strategy to minimise conflict among various users while achieving varied forest management objectives on different parts of the land (i.e. land sparing) (Tittler *et al.* 2016; Betts *et al.* resubmitted). We then discuss how this approach could be improved to actually increase the resilience of a forest landscape to global threats such as climate change and invasive exotic pests and diseases. To continue the metaphor:

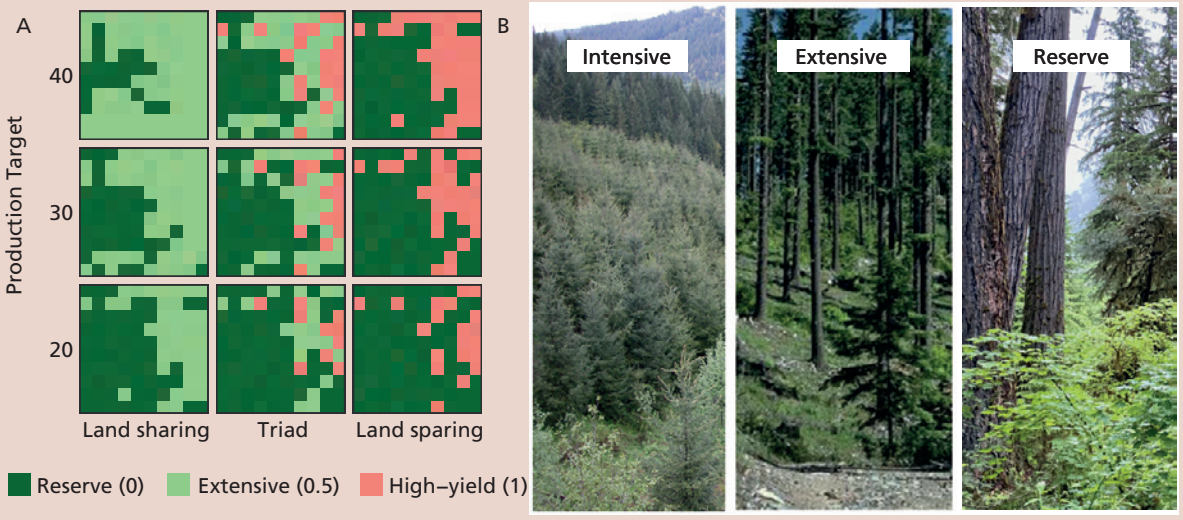

Fig. 1. Conceptual illustration of a forest landscape under various management approaches and production targets. In (A), each of the nine panels is a schematic map of a region with unmanaged/protected/reserve forest (dark green; 0 units of wood production per pixel), extensive forestry (light green; 0.5 units of wood/pixel), and high-yield forestry (red; 1 unit of wood/pixel). Region maps in the same row all produce the same quantity of wood, but use different proportions of unmanaged/protected, extensive and high-yield forestry to provide the production target. The three rows show results for low (20), medium (30), and high wood production targets (40). In (B), examples of each type of forest management implemented: high-yield intensive forestry (a plantation), extensive forestry (variable retention or close-to-nature forestry), and protected (old-growth forest). Adapted from Betts et al. (Resubmitted).

It is possible to make a better omelette (i.e. produce timber and fibre while enhancing the resilience of the forest landscape to global change uncertainties) without cracking too many eggs (i.e. without compromising biodiversity or multiple uses of the forest).

The TRIAD forest management approach: or how to make an omelette without cracking too many eggs

The TRIAD approach to forest management was first proposed by Seymour and Hunter (1992) as a means to achieve the various objectives of ecosystem management in the state of Maine (USA) while reducing land-use conflicts. It basically involves the division of a forest landscape into three zones with specific management objectives. First, there is a conservation zone where the main objective is to protect biodiversity and where forest harvesting is prohibited or reduced to a minimum (this zone can be associated with, and often indeed is, a reserve area). Second, there is a multi-use or extensive management zone where timber harvesting occurs but at a reduced level such that the negative impacts on biodiversity and other uses are minimised. Finally, there is a third zone where the loss of timber and fibre production afforded in the first two zones is compensated for through intensive wood production. In Europe, these three zones could be compared to forests being protected, managed under the close-to-nature forestry approach, or managed with high-yield species such as Norway spruce *(Picea abies),* Douglas fir *(Pseudotsuga menziesii),* or pines (*Pinus* spp.). Thus, one can argue that such an approach is already being implemented in most of Europe and, in fact, in many parts of the world. The main difference between this and a true TRIAD functional zoning approach is that, in true TRIAD zoning, the location and extent of each of these three zones are fully or partially controlled by different forest managers and that no global analysis is done to optimise the location and extent of each zone. Ideally, the location and extent of each functional zone would be calculated to maximise benefits to all. There is no optimal proportion for each of the three functional zones for all situations, and depending on the extent, type, and spatial distribution of both extensive and intensive forestry, various scenarios can be envisioned.

To best fulfil the production goal without negatively impacting the conservation goal, the production zone should be located on productive, accessible land (to minimise transport and road building) with relatively low conservation value, far from protected areas (Tittler *et al.* 2015). Although ecological issues such as biodiversity are considered, they are subordinate to the objective of producing timber and fibre. There now exists, however, means to substantially increase productivity while minimising negative impacts on biodiversity using multi-species plantations (Paquette and Messier 2010).

In the multi-use or extensive management zone, the focus is on balancing timber production and extraction with ecological and social goals (Seymour and Hunter 1992). This maintains multiple uses of the forest (recreation, hunting, trapping, extraction of non-timber forest resources, etc.) as well as native species, ecosystems, and evolutionary and ecological processes. Thus, forest management activities in this zone must tread lightly, focusing less on timber production alone and more on maintaining a basket of services as well as the self-organising and adaptive capacity of the forest and habitat for biodiversity. Although stands may be logged and replanted or regrown naturally, these activities should be carried out with the idea of maintaining a diverse forest structure and composition, rather than simplifying it to optimise timber production in the short term. Partial cuts and variable retention logging, natural disturbance-based management and close-to-nature forestry may all be used in this zone (Harvey *et al.* 2002; Gustafsson *et al.* 2012), although attempts should also be made to limit road construction as much as possible. These practices are all attempts to limit the negative effects of conventional forestry practices on the natural functioning of the forests. Thus, economic goals may be met, but the focus is on balancing these with social and environmental objectives.

The proportion of the forest designated to each zone may vary from case to case, depending on the relative value placed on conservation, timber production, and non-timber forest uses. However, even in a system focused largely on profit from timber production, the proportion of land designated as conservation or extensive management may be increased with the successful implementation of an intensive management zone. In other words, the faster the timber can be produced in the intensive management zone, the larger the

proportion of the forest that may be set aside for the other two zones (Tittler *et al.* 2016).

Implementing TRIAD to increase the resilience of a forest landscape to global change uncertainty: or how to make a better omelette without cracking too many eggs

Increasingly in the past few years, many forest managers and scientists have been advocating for the need to consider resilience (or adaptability) as an important new objective in forest management (Seidl *et al.* 2016; Messier *et al.* 2019). This new objective is rendered necessary as the number and level of environmental and societal uncertainties associated with global changes are increasing. One approach being advocated to increase the resilience of forests to global uncertainties is to maximise the diversity of tree species with different biological characteristics (i.e. functional traits) in a network of strategically located stands within a landscape. The aim of the approach is to allow impacted stands on the landscape to naturally recover through seed sources from the enriched stands having unaffected tree species. This new 'Functional Complex Network' approach to forest management (Messier *et al.* 2019) could be implemented using a modified TRIAD approach.

In this novel TRIAD approach, silvicultural interventions implemented in any of the three functional zones, but particularly in the extensive and

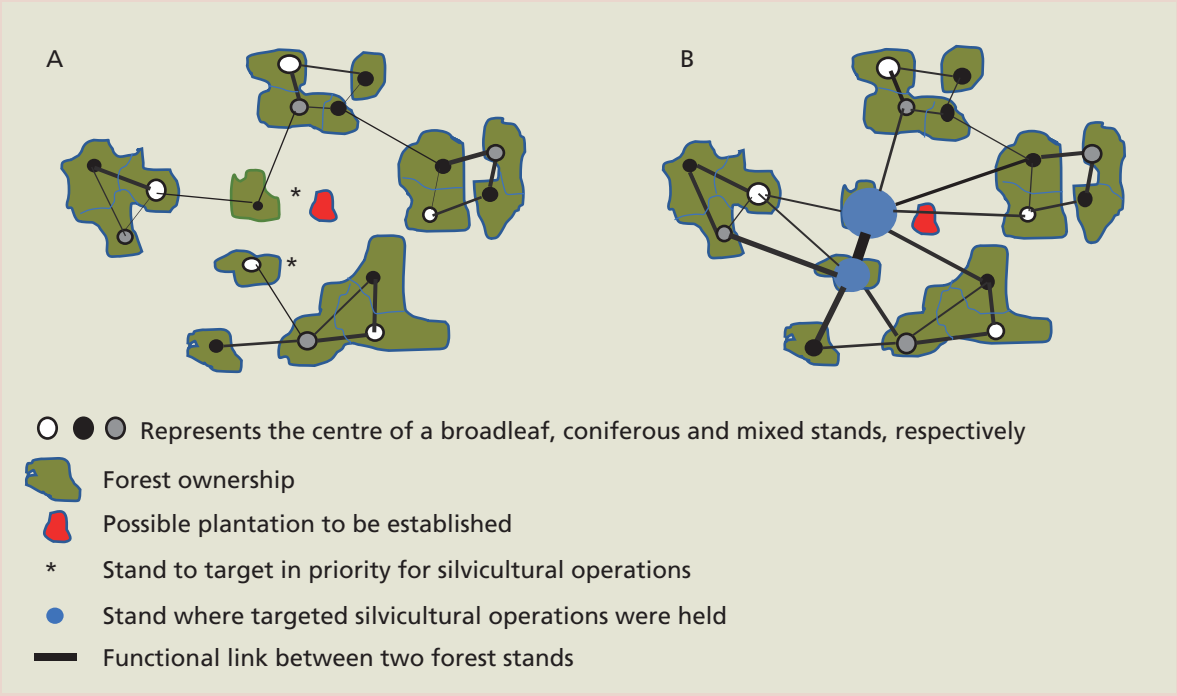

Fig. 2. Schematic representation of the analysis of a possible fragmented central European forested landscape before (A) and after (B) targeted silvicultural interventions. Three attributes related to the resilience of the landscape are represented: (i) the functional diversity of a stand (related to the average size of the dots within each stand), (ii) functional connectivity (related to the total number and the average thickness of the links among stands), and (iii) centrality (related to the average number of links per stand). By prioritising silvicultural interventions aimed at increasing functional diversity on the well-connected and centrally located stands (shown with an asterisk) or by adding a new multi-species plantation with key functional traits in a central location within the landscape (red stand), it is possible to switch a landscape with a relatively low resilience (A) to one with a higher resilience (B). Thus, by promoting a diversity of tree species, through forest cutting or planting in either or both of the extensive and intensive zones, with key missing functional traits in the central stands (blue dots) or newly planted areas (red stand), it is possible to increase the functional diversity, connectivity, and centrality of the landscape. B illustrates the situation before the possible dispersion of species to adjacent stands. The different functional attributes, and distribution of those attributes, may change over time. Adapted from Messier *et al.* (2019).

intensive zones, are aimed at not only maintaining the natural diversity of tree species found in the area (as in the ecological forestry or close-to-nature approach) or maximising wood production of a few tree species (as in the classic plantations of high-yield tree species), but also at increasing the functional diversity and connectivity (in terms of seed dispersal) of centrally located stands in key areas across the whole landscape to ensure that the forest will be able to recover without interventions following unexpected disturbances. This approach makes use of two recent developments in ecology: (1) the use of functional traits to evaluate tree functional diversity and redundancy in forest stands or landscapes (Aubin *et al.* 2016), and (2) the use of network theory that describes the spatial connectivity of forest stands in terms of seed dispersal and establishment to favour the natural regeneration of stands (Dale and Fortin 2010; Aquilué 2020). Network theory can then be used to evaluate where and how silvicultural interventions should be carried out within the landscape to most efficiently enhance key network properties (fig. 2), namely functional connectivity and centrality which both increase the resilience of the forest landscape (Aquilué *et al.* 2020).

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Ireland – It's native woodland resource

C 17

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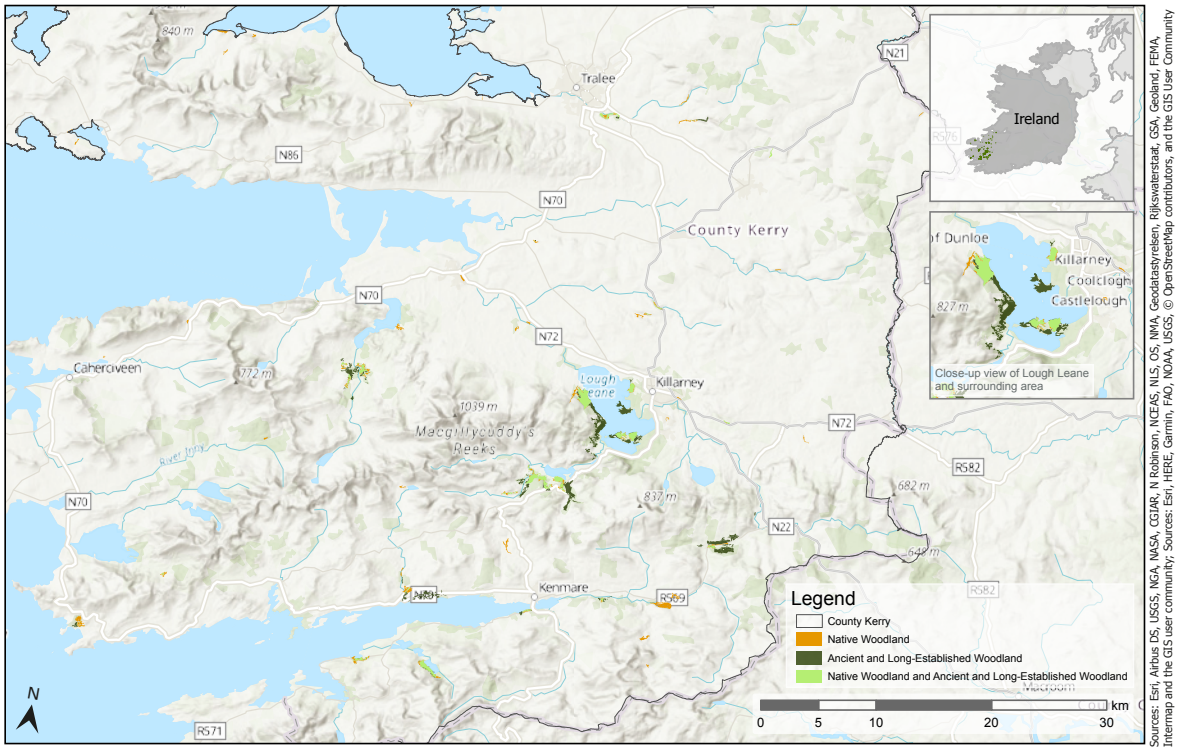
Native woods: context and ownership structure

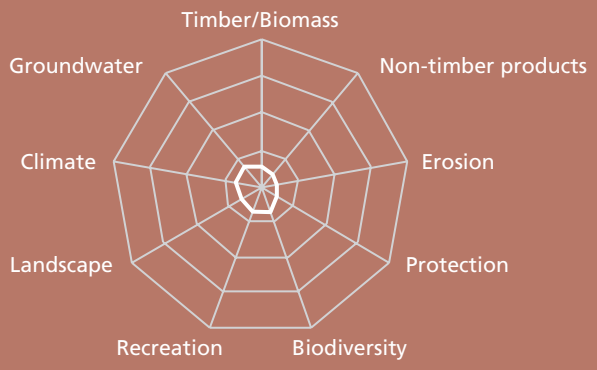
Our school days in Ireland taught us that trees such as oak *(Quercus robur, Q. petraea),* ash *(Fraxinus excelsior),* elm *(Ulmus glabra),* hazel *(Coryllus avellana),* holly *(Ilex aquifolium),* alder *(Alnus glutinosa),* birch *(Betula pendula, B. pubescens)* and a wide range of associated plants once covered most of the Irish countryside. Such species represent the natural vegetation type that much of open areas in Ireland would revert to in the absence of human interventions. Small areas of these most valuable habitats remain as scattered remnants through the



< Fig. C 17.1. Riparian woodland as one of natures solutions to improve biodiversity conservation in Irelands forests (Photo: Tom Houlihan).

Statement

"Native woodlands represent one of Ireland's most important and enduring national treasures. Protection and sensitive management of our existing resources combined with nurturing of a growing interest in new woodland establishment will leave an enduring legacy to be enjoyed for future generations."



Irish countryside; many of these areas are in private ownership.

Native woodlands represent much more than just native tree species. They are havens containing unique communities of both plants and animals living either on or beneath the trees, and providing a wide range of ecosystem services for society. They contribute greatly to Ireland's indigenous ecosystems, species, and genetic diversity. Such valuable ecosystems are rare and are endangered by development, grazing pressure, and invasive species (e.g. rhododendron, *Rhododendron ponticum*). In this chapter, we explore the range of services that Irish native woodlands provide and the ongoing endeavours to protect and enhance this resource for the future.

A little bit of history

Native tree species are those that arrived in Ireland over thousands of years following the end of the last ice age (approximately 15 000 years ago). It took another 4000 years before conditions became suitable for colonisation by pioneering plants and animals from southern and central Europe. Pollen records provide a clear picture of the developmental progression of vegetation. First juniper *(Juniperus communis)* scrub and dwarf willow (*Salix* spp.) appeared followed by mixed birch, Scots pine *(Pinus sylvestris),* and hazel woodland (Cross 2012). The arrival of hazel and pine altered the characteristics of woodlands around 9500 years ago as reflected in increasing accumulation of the pollen of these species in peats around that time (Hall 1997).

By the time the first humans arrived (about 9000 years ago), Ireland was mostly covered in woodland (fig. C 17.2). The woodlands comprised species such as oak on the more acid soils of the south and northeast, with elm and hazel dominant on more fertile midland soils. Scots pine was confined to drier locations and birch was found on poorer soils. The role of land bridges and possible marine inundation of former land areas has been the subject of much debate (e.g. Devoy 1985, 1995,

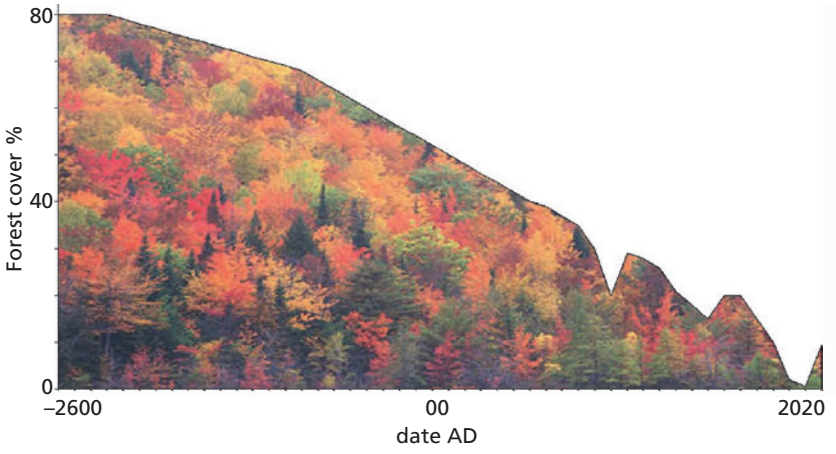


Fig. C 17.2. Decline of Ireland's native woodland resource over time (Neeson 1991).

Figs C17.3 (left) and 4 (right). Examples of native woodland at Clonkeen, Killarney, southwest Ireland (Photos: Tom Houlihan).

Brooks *et al.* 2011; Furze *et al* 2014). In drawing on experience from more remote islands, e.g. in the mid Pacific Ocean, Mitchel (2000) describes how trees are capable of long distance migration over water but that the mechanisms are rarely observed. In the Irish context, he concludes it is probably more reasonable to consider our surrounding seas as filters rather than barriers to tree migration; in other words, some trees get across the sea while others do not. Such filters prevented the arrival of species such as beech *(Fagus sylvatica),* sycamore *(Acer pseudoplatanus)* and hornbeam *(Carpinus betulus)* other species.

Humans began to have a major impact on woodland cover about 5500 years ago (during the Neolithic period) when woodlands were cleared to accommodate tillage and pasture (DAFF 2008). While there is some evidence of cycles of land clearance and woodland recovery in the later prehistoric period, the history of our native woodlands is one of progressive decline.

From the seventh century AD, early law tracts indicate that the great woods were often confined to marginal land and upland areas. As populations increased over the following centuries, the exploitation of woodlands increased under the Anglo Normans and then successive English monarchs. There is no single reason for the ultimate decline of Ireland's forests but it is generally agreed that there were several contributory factors, beginning around the mid-sixteenth century (DAFF 2008). Key factors included industrialisation (shipbuilding, along with iron, glass, and barrel production) and 'plantations' (i.e. the parcelling out of large tracts of land to settlers who cleared large areas of woodland for agriculture). Subsequent population increases between 1700 and 1840 again placed high demand on agricultural resources. By 1928, only 1.2 % of the country was covered in woodland (DAFM 2020).

The current woodland resource

Native woodlands are to be found scattered throughout Ireland with many occurring on upland areas (fig. C17.3), slopes (fig. C17.4) and also on cutaway bogs in the central part of Ireland. Most woodland is fragmented and small. In a national audit, Perrin *et al.* (2008) surveyed 1320 sites and found 50 % of these were 6 hectares (ha) or less in size with only 3.3 % of sites exceeding 50 ha.

Cross and Collins (2017) describe four categories of native woodlands: (1) Ancient woodland – land under woodland cover since 1660 based on the oldest reliable national records; (2) Long-established woodland – land that has remained continuously wooded since at least the first edition Ordnance Survey maps of the 1830s and 1840s; (3) Recent woodland – woodland likely to have originated since the first Ordnance Survey maps; and (4) New woodland – woodland dominated by native species and created within the last 20 years or so through their establishment on open land.

The precise area of Ireland's native woodland is difficult to quantify, as stands often contain a mix-

ture of native and non-native species. Bullock and Hawe (2014) estimate an area of 100 000 ha or 1.2 % of the land area of the Republic of Ireland as native woodland. In its assessment of 'nativeness', the Third National Inventory (DAFM, 2017) reports an area of 128 000 ha of native forests (i.e. forest where native species occupy 80 % or more of the canopy) or about 19 % of Ireland's stocked forest area. Mixed forests (i.e. forest where native species occupy 20–80 % of the canopy) account for 85 600 ha (12.7 % of the forest area). Cross and Collins (2017) point out that mixed and non-native forests also incorporate a range of stand types which include naturally regenerating birch in older conifer and commercial reforestation areas. Though not strictly considered native woodlands, these still merit consideration as part of our overall native woodland resource.

Management of native woodlands

Management planning geared towards conserving and restoring existing native woodland needs to be fully cognisant of all factors contributing to its current status and condition (Byrnes 2007). These include underlying factors such as climate, soil type, and elevation, as well as the ecology and natural dynamics of woodland types. The former woodland management regime(s) that pertained should be considered in this regard. Factors such as owner's objectives and the threats to the woodlands posed by invasive exotic species and high deer population levels are also highly significant for management. Cross and Collins (2017) describe the principal national management objectives to enhance the conservation status of all native woodland types. These include:

- conservation of valuable habitats, associated species, and genetic variation;
- conservation and enhancement of species diversity;
- improvement of woodland structure;
- encouragement of natural regeneration;
- regulation of grazing;
- control of invasive species;
- increasing the amount of deadwood in forests.

Priority sites of high conservation value are identified as a focus for management efforts in the context of limited resources. Cross and Collins (2017) also highlight the importance of retaining the essential elements of the existing woodland environment when there is a focus on restoring native woodlands that were previously neglected or subject to inappropriate management. For example, the existing levels of shade, humidity, and shelter onsite are regarded as vital for woodland flora and fauna diversity, even if such attributes are afforded by a current non-native canopy. The appropriate application of close-to-nature systems such as coppicing and continuous cover forestry is regarded by the authors as highly relevant. These systems can enable gradual change in woodland species and structure as appropriate through harvesting of single or small groups of trees and follow–on regeneration. This will help maintain the overall canopy cover as well as the existing woodland environment.

Ecosystem services

Ireland's native woodlands have the capacity to provide a flow of timber and non-timber products and services. The protection and expansion of these woodlands will deliver benefits including reversal of wider habitat fragmentation and the protection/enhancement of biodiversity and water quality. Other important functions include landscape enhancement and provision of locations for recreation, tourism enterprises and education. Woodlands are also of importance as resources for carbon sequestration and flood control. Compatible wood production from native woodland can also help replace hardwood imports used in making high-value furniture and craft-related products.

Innovative Government supports are facilitating native woodland protection and expansion. Table C 17.1 outlines the measures in place, collaboratively developed and administered by the Department of Agriculture, Food and Marine (DAFM). Support is also available for woodland improvement and the provision of forest roads as appropriate.

Natural capital

Natural capital is a concept that frames the world's resources (such as land, plants, animals, habitats and water) as assets or stocks that yield a flow of

benefits to society. The Natural Capital approach involves measuring and valuing natural capital assets (Irish Forum on Natural Capital 2020). In their report prepared for the Woodlands of Ireland, Bullock and Hawe (2014) quantify the economic value of ecosystem good and services provided by the natural capital of Ireland's native woodland resource. These include provisioning, regulating, cultural, and supporting services. The authors describe the importance of integrating such values into national accounting and reporting systems. They provide baseline estimates of the annual economic value for Ireland's native woodland resource in the range € 100–143 million. Of this, the annual value of amenity use of native woodlands is estimated to be in the order of € 35 million. Annual expenditure on woodland-related tourism is estimated at € 50 million. The annual value of carbon sequestration is estimated at € 8 million. This is likely to increase considerably in line with future carbon price

Table C17.1. Department of Agriculture Food and the Marine incentives for native woodland creation.

Measure/Scheme	Descriptor	Available Funding
Native Woodland Establishment[1]	Supports the establishment of new native woodland on 'greenfield' sites	Grant aid and annual premia
Deer Tree Shelter and Deer/ Hare Fencing Scheme[2]	Supports landowners growing broadleaves in areas where there is a risk of deer/hare damage	Funding supports for new deer fencing, deer fence upgrades and hare fencing
NeighbourWood Scheme[3]	Supporting the development of attractive close-to-home woodland amenities for public use and enjoyment	Grants aid plus additional fencing allowance
Woodland Creation on Public Lands[4]	Establish new native woodland on suitable state-owned lands	Grant aid plus fund for trails and signage as well as forest playgrounds
Native Woodland Scheme Conservation[5]	Supports the restoration of existing native woodland and the conversion of non-native forest to native woodland and opportunities for management of emerging native woodland	Grant aid and annual premia
Woodland Environment Fund[6]	Provides an access point for individual businesses to help expand Ireland's native woodland resource, by providing additional incentives to encourage landowners to plant new native woodlands where appropriate	Potential grant top up on existing grant aid

[1] See: https://www.teagasc.ie/crops/forestry/grants/establishment-grants/native-woodland-establishment
[2] See: https://www.teagasc.ie/crops/forestry/grants/management-grants/deer-tree-shelters-and-deerhare-fencing-scheme
[3] See: https://www.teagasc.ie/crops/forestry/grants/management-grants/neighbourwood-scheme
[4] See: https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/2020/CreationofWoodlandsonPublicLandsFINAL310720.pdf
[5] See https://www.teagasc.ie/crops/forestry/grants/management-grants/native-woodland-conservation
[6] See: https://www.teagasc.ie/media/website/crops/forestry/news/DAFM-WEF-leaflet-14Sept18.pdf

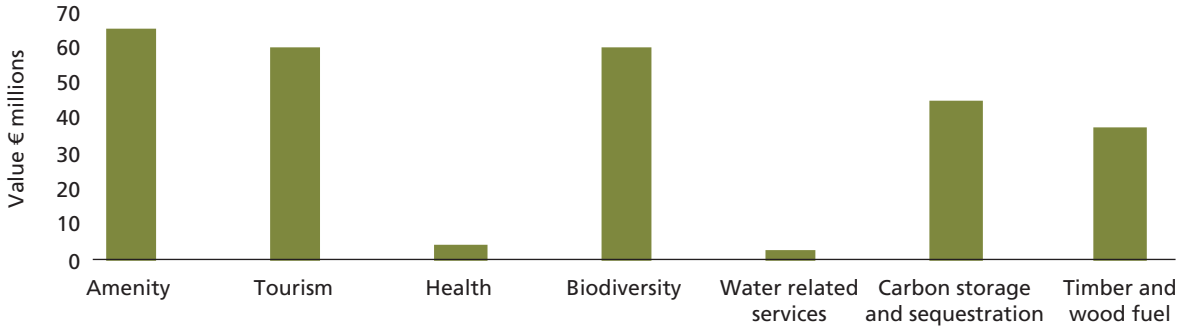


Fig. C17.5. Estimated annual ecosystem service values based on future expansion of native woodland cover.

increases. As new information and metrics become available, estimates for the value of water-related services are likely to be significantly higher than previously estimated (Bullock pers. comm.).

In looking to the future, Bullock and Hawe (2014) also provide indicative values of potential benefits realisable through native woodland expansion. For example, expansion of Ireland's native resource to 25 % of total forest cover is expected to yield an overall annual ecosystem service value in the order to € 274 million (fig. C 17.5).

The purpose of assigning a financial value is not to change the fundamental and intrinsic value of nature – which is arguably priceless – and many ecosystem services are irreplaceable. Having a financial value for natural capital shared by society at large, as distinct from being perceived as 'free', can shift behaviour away from degradation to restoration (Irish Forum on Natural Capital 2020).

Case study on Native Woodland Establishment Scheme: southwest Ireland

'Trees are a natural part of this area and it's great to see them return'. Pat O'Connor and his family farm 74 ha in a beautiful wooded valley in Clonkeen, Killarney (fig. C 17.6). Pat remembers the bleakness of the landscape after World War II when 'there wasn't a tree left standing'. In 2005, Pat examined his options and decided to incorporate 16 ha of his farm into the Native Woodland Scheme. Work was completed in 2006 and Pat never regretted his decision. Pat was subsequently featured in the Teagasc bi-monthly magazine 'Today's Farm' in 2007 (fig. C 17.7 and C 17.8).

Pat has a great affinity with nature and has very positive views on the Native Woodland Scheme. His native woodland – which incorporates oak, alder (fig. C 17.9 and C 17.10), birch, and moun-

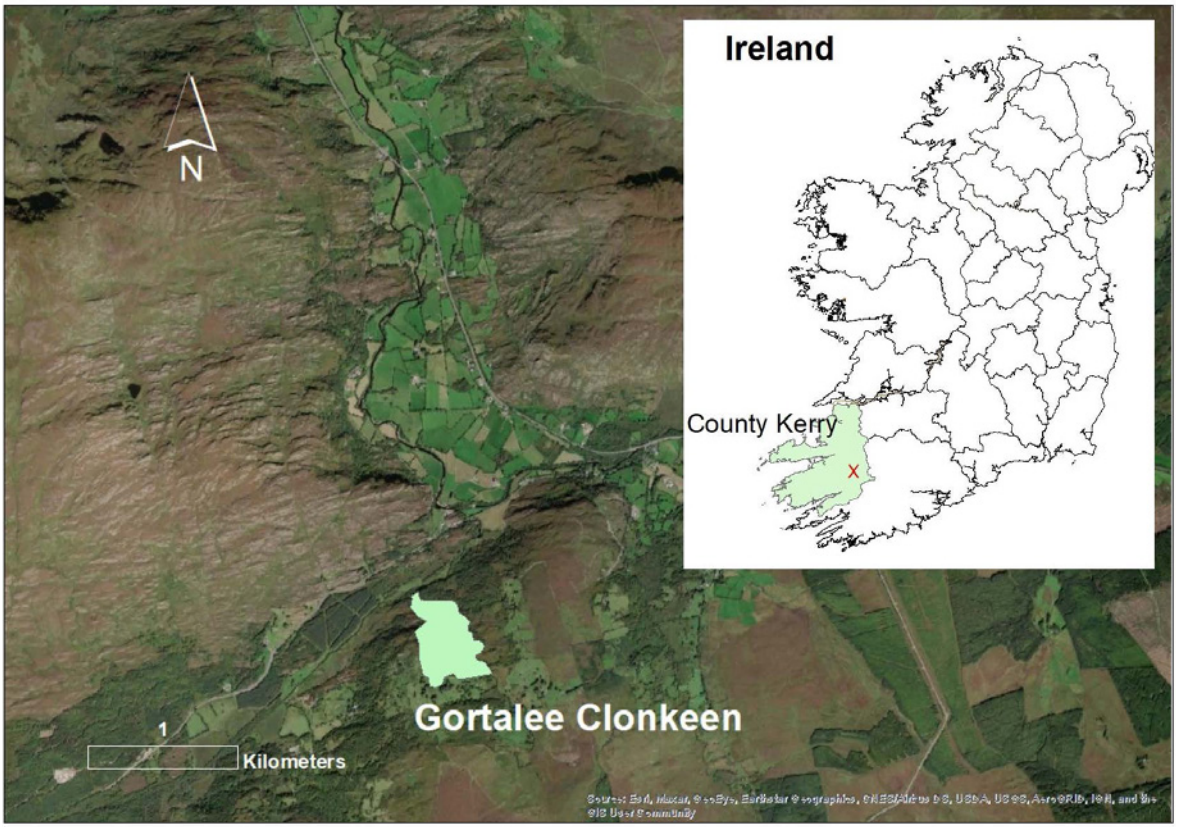


Fig. C 17.6. Indicative extent of native woodland at Clonkeen, Killarney, Co. Kerry.
(Sources: World Imagery – Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Ordnance Survey Ireland – open data)

Today's farm

Beauty
Biodiversity
Profit

Tom Houlihan, Teagasc (left) with Pat O'Connor, who farms in Clonkeen, Killarney.

Tom Houlihan,
Teagasc Forestry Development Officer covering the Kerry area

// rees are a natural

tive views on the woodland scheme. He had already planted many trees under REPS, and his native woodland, protected by fencing from deer and stock, is flourishing. Planting has enhanced the

Scheme, reduced costs for both owners. Pat took a hands-on approach, getting involved in the establishment work himself. He is very proud of the sturdy deer

Fig. C17.7. Pat planted initially in 2006.

Fig. C17.8. Pat in 2019, considering more planting (Photos: Tom Houlihan).

tain ash *(Sorbus aucuparia)* – is flourishing in the absence of threats from deer and livestock. Pat describes how planting enhanced the amenity and recreational value of his farm, created additional habitat value, improved biodiversity, and provided a legacy that will be enjoyed by future generation.

All woodland establishment costs incurred were covered by the Native Woodland Grant and the annual premium payments were a welcome bonus. A co-operative approach with an adjoining landowner, who established 12 ha under the Native Woodland Scheme, resulted in economies of scale and reduced costs for both owners. Pat took a hands-on approach, getting involved in the establishment work himself. Pat's woodland is now well established (fig. C17.10). He undertook further planting of mixed commercial forest (22 ha) of his farm in 2013. Pat is now considering further native woodland establishment on 7 ha of land that he inherited, a strong endorsement of the Native Woodland Scheme.

Biodiversity

Ireland's native woodland resource constitute a genetic resource and a huge reservoir of biodiversity, including both plants and animals. Cross (2012)

Fig. C17.9. Post-planting in 2006.

Fig. C17.10 Well-developed woodland, 2020 (Photos: T. Houlihan).

describe how 20 % of our plants, 28 % of breeding birds, and 50 % of invertebrates are woodland species in the broadest sense. In the National Survey of Native Woodlands, Perrin *et al.* (2008) identified four principal woodland types based on the associated species assemblage. Each woodland type is named according to the dominant tree and herbaceous species. The four woodland types are: oak/woodrush *(Quercus petraea/Luzula sylvatica);* ash/ivy *(Fraxinus excelsior/Hedera helix);* alder/meadowsweet *(Alnus glutinosa/Filipendula ulmaria);* and birch/purple moorgrass *(Betula pubescens/Molinia caerulea).* Further analysis divided these four groups into 22 vegetation types.

Irish native woodlands are also diverse in structure with typically five recognised layers or tiers of diverse vegetation in a vertical profile. The tree layer comprises taller tree species such as oak and birch and is called the canopy; the tallest trees may extend above the general canopy as 'emergents'. Cross (2012) also describes a secondary canopy made up of smaller trees. The shrub layer is formed by small trees and shrubs and may include species such as holly, hazel, hawthorn *(Crataegus monogyna),* and emerging trees of the canopy species. A dwarf shrub layer may also be found on acidic soils and containing low-growing woody species such as bilberry *(Vaccinium myrtillus)* or ling heather *(Calluna vulgaris).*

Biodiversity case study: Ballyseedy Wood

Ballyseedy Wood is situated near Tralee, County Kerry in the southwest of Ireland (fig. C17.11). The property was purchased on behalf of the local com-

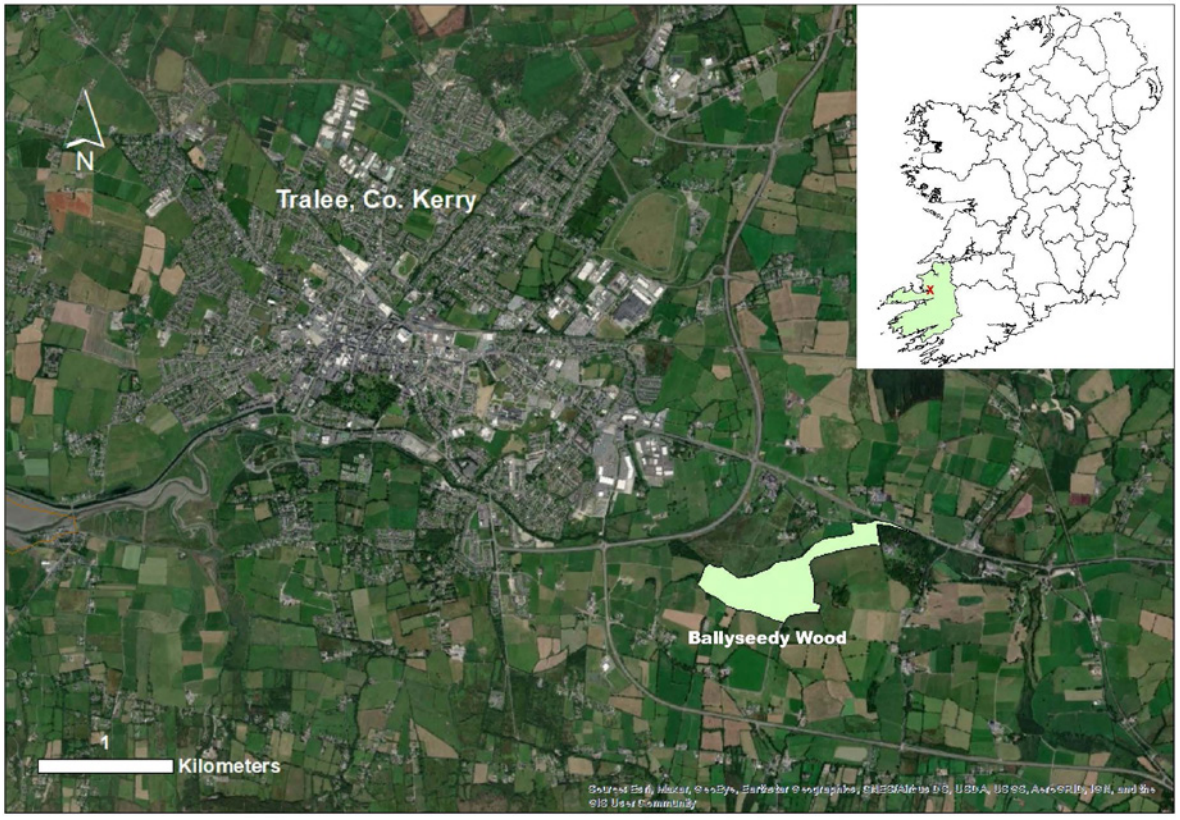


Fig. C17.11. Ballyseedy Wood, County Kerry, Ireland (Sources: World Imagery – Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Ordnance Survey Ireland – open data).

munity in 1993 following work by the Ballyseedy Woods Action Group and is held in trust and managed by Kerry County Council. Ballyseedy Wood has a long and distinguished history, being first recorded on a map made by English adventurer Sir Edward Denny in 1587. Various recordings of tree planting are documented over the centuries (McMorran 1991). Today, Ballyseedy contains a number of highly valuable woodland types. The site is a Special Area of Conservation (SAC) under the Habitats Directive, selected for its residual alder/ash-dominated woodland which conforms well to the woodland type 'Alluvial Forest' (figs C17.12 and 13).

Alluvial forest is listed with priority status under Annex I of the EU Habitats Directive (Natura Code 91E0) and is a habitat type that is rare in Europe (NPWS 2018). The very large alder trees present are likely to have been planted. However, much of the secondary regeneration is also quite mature, being up to 100 years of age.

Studies of flora and fauna in Ballyseedy Wood are indicative of the biodiversity potential of such valuable habitats. The National Survey of Native Woodlands (Perrin *et al.* 2008) report a total of 196 vascular and 45 bryophyte species recorded in Ballyseedy Wood during previous field visits, with 22 native tree species, including some locally less common tree species. Studies recorded over 100 species of Lepidoptera (including seven noteworthy species) and 12 species of Diptera. Ground invertebrate surveys included nine species of carabid beetle and 40 species of staphylinid beetle, three of which indicate ecologically well-developed deadwood microhabitat, and a fourth that indicates well-developed wetland habitat (O'Neill *et al.* 2008, citing WM Associates 2003).

A bird survey in 2002 recorded 33 bird species within the woodlands of which 23 were deemed to be breeding. In addition, the woodland has been noted as a nesting site for long-eared owl *(Asio otus)* and woodcock *(Scolopax rusticola)* have been recorded in winter. Badgers *(Meles meles),* foxes *(Vulpes vulpes),* common frogs *(Rana temporaria)* and Irish hares (*Lepus timidus* subsp. *hibernicus*) also have been recorded at Ballyseedy. Both salmon *(Salmo salar)* and trout *(Salmo trutta)* have been recorded in the River Lee along the northern boundary of the woodland. Non-native tree species are present within the site but account for less than 30 % of the woodland (NPWS 2019).

Figs C17.12 and 13. Alluvial woodland Ballyseedy; a rare and threatened habitat type in Europe (Photos: Tom Houlihan).

Carbon sequestration

There is a growing interest in the establishment of new native woodland in Ireland. Woodland establishment can play an important and complementary role in combating climate change. Based on current available data, the indicative average annual sequestration rates for (long-term retention) native species in Ireland can range between 1.7 and 5.5 t CO_2-e/ha depending on species, growing conditions, and management (Black pers. comm.). The establishment of new woodlands and forests in Ireland has a particularly important and beneficial role to play beyond 2030. Forests provide a range of raw materials for industry as well as services to society. To sustain service provision, a

well-balanced age structure is needed at national forest level. In the Irish context, maintaining the climate change benefits of Irish forests will require a significant and sustained national planting programme over the next two decades, including native tree species. Achievement of this goal is, therefore, a key component of national climate change and land use policy (DAFM 2015, Woodlands of Ireland 2016; and DAFM 2020).

Amenity and recreation

Ireland's native woodlands offer strong potential as recreational and educational resources. Ballyseedy Wood is an exemplar woodland recreational amenity offering a unique and tranquil experience (figs C17.14–17): 'Such a beautiful place at any time of day… get lost under the trees… smells of the wood… lovely in the sunshine but even nicer after a fall of rain… paths mark out such a piece of heaven just outside the town of Tralee' (Tripadvisor 2019). The wonderful amenity that exists today is the fruitful result of collaboration between by Kerry County Council, the National Parks and Wildlife Service, DAFM, Ballyseedy Woods Action Group and a range of other local groups and agencies. Ballyseedy Wood was one of the pilot sites funded by DAFM under the 'NeighbourWood Scheme' (Table C17.1) which supports the development of attractive close-to-home woodland amenities.

Water-related services

Well-sited, well-designed, and sustainably managed woodlands deliver many services associated with the aquatic environment. The 'Woodland for Water' measure (DAFM 18b, fig. C17.18) combines the establishment of new native woodland in conjunction with undisturbed water setbacks (buffers of natural ground vegetation to protect water and aquatic ecosystems) and can be effectively applied alongside streams, rivers, and lakes to form permanent semi-natural landscape features. This measure has been developed by DAFM to deliver meaningful ecosystem services that protect and enhance aquatic ecosystems and water quality (fig. C17.18).

Figs C17.14–17. Ballyseedy Wood: A haven for recreation and tranquillity (Photos: T. Houlihan).

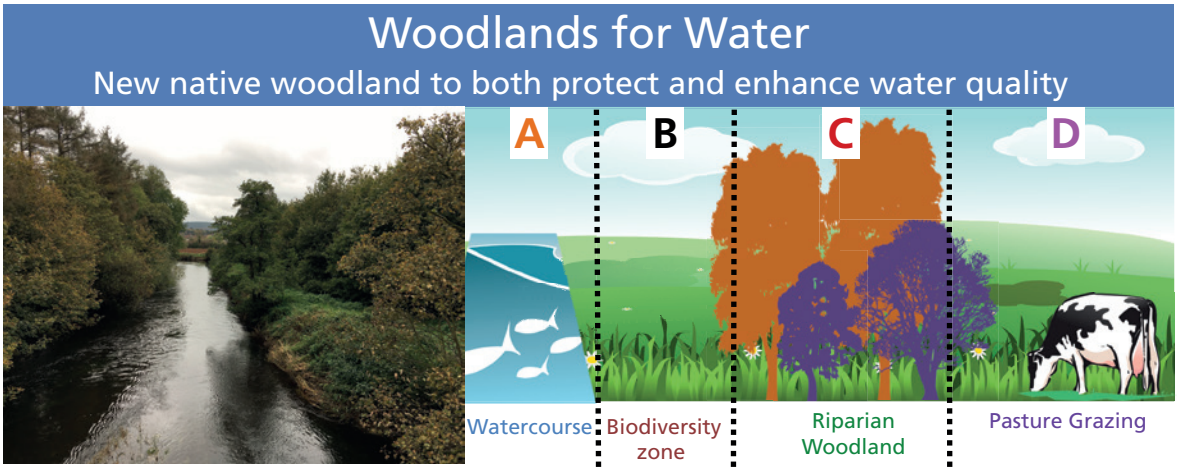


Fig. C17.18. Elements of the Woodland for Water Measure (DAFM 2018b).

These services include protection and buffering of watercourses from sediment and nutrient runoff, bankside stabilisation, and provision of conditions for shading, cooling, and regulation of floodwater. The provision of detritus and food input into aquatic ecosystems and the protection of protected aquatic species is also very important. The Woodland for Water measure may be realised using the Native Woodland Establishment Scheme, available from the DAFM.

Resilience of Native Woodlands

The Strategy for Native Woodlands in Ireland (Woodlands of Ireland 2016) highlights the need to ensure the future resilience of Ireland's woodland resources. The report describes the implications of climate change across a wide range of woodland-related interests. These include woodland dynamics, water quality, invasive alien species, and tree pests and diseases. The need to address the impact of climate change and develop robustness of new and existing native woodlands is highlighted, especially with regard to the adaptability of native tree species and the suitability or otherwise of non-indigenous provenances. The potential impact of invasive species as well as pests and diseases on our native woodlands is also a significant issue related to climate change (coupled with increased international trade) that needs to be prioritised.

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Woziwoda – Educational and social functions of forests in northern Poland

C 18

S. Konczal[1], A. Konczal[2]

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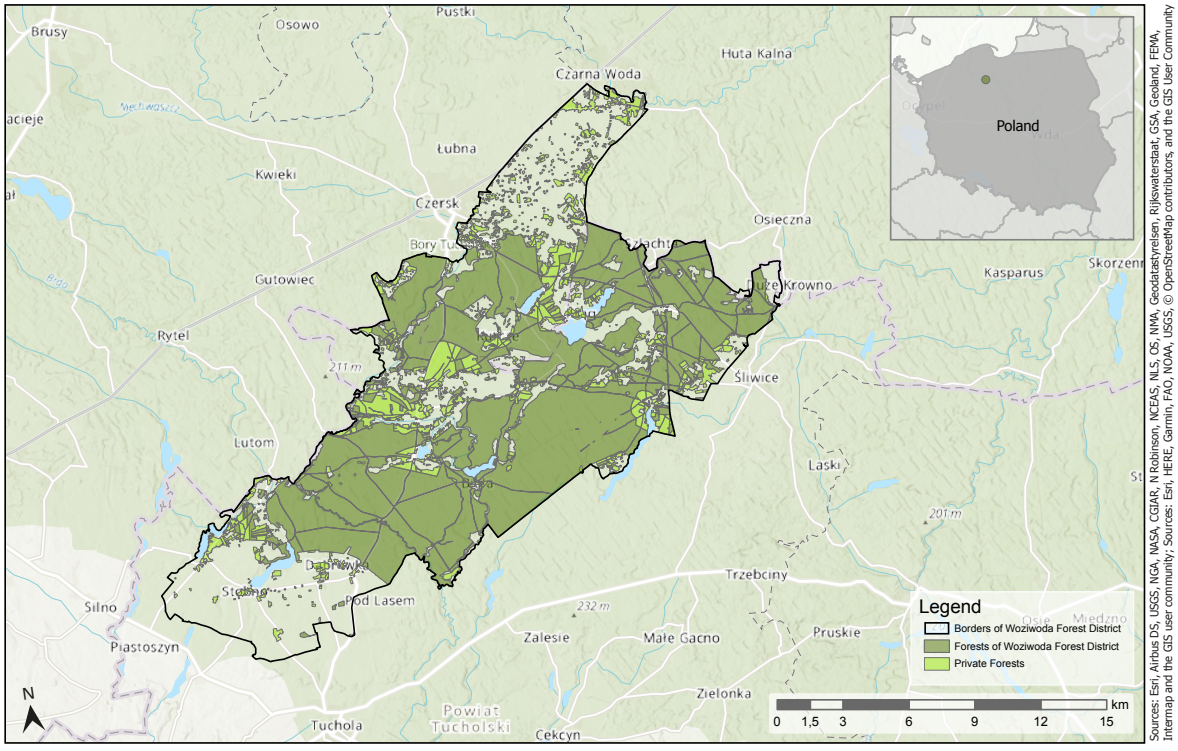
[2] European Forest Institute, Bonn, Germany

Context, legal frame, history, and ownership

The Woziwoda Forest District is located on the administrational territory of the Kuyavian- Pomeranian Voivodeship and the Pomeranian Voivodeship in northern Poland. Geographically, forest stands of Woziwoda Forest District are part of the largest continuous forest area in Poland – the Tuchola Forest (Bory Tucholskie). This forested region has been frequently mentioned in written documents, as far back as the Middle Ages. Therefore, forest develop-



< Fig. C 18.1. Forests in Woziwoda, dominated by Scots pine and characterised by intensive management. The open water bodies show the great potential for nature conservation (Photo: Woziwoda Forest District).

Statement

"Nature protection through moderate and rational use."

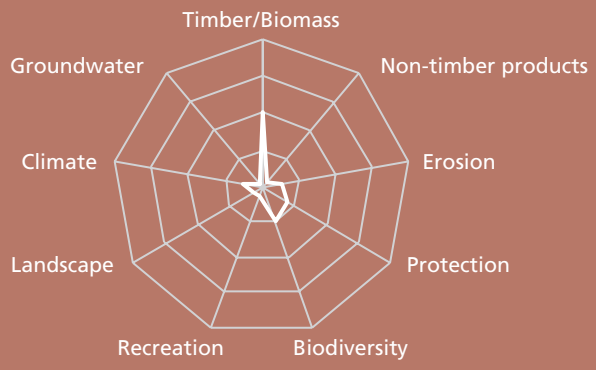


Table C 18.1. General information on the forests of Woziwoda Forest District.

Total forest area	13 830 ha
Organisational structure	12 forestry units
Main management types	Mainly Scots pine forest managed according to multifunctional principles
Total standing volume	3 745 000 m³
Annual growth	7.7 m³/ha
Annual cut	74 000 m³ or 5.4 m³/ha
Deadwood (standing and lying)	45 925 m³ (3.3 m³/ha) of which 14 822 m³ is lying and 31 103 m³ is standing
Altitude	60–100 m a.s.l.
Ownership	85 % state forests
15 % private forests, church forests, and municipal forests	Small scale mosaic of sandy, marly or clayey soils, mostly nutrient rich; 50 % of soils are largely impenetrable for fine roots, 75 % are sensitive to soil damage by forestry machines
Geology	Predominantly acidic soil (glacial sands)
Protected areas	Six nature reserves (254 ha) 42 nature monuments Special designated ecological areas (321 ha)
Nature protection area (Natura 2000)	14 815 ha
Protective function	776.6 ha

ment and management are well-known and described as compared to other forest districts in Poland, especially in the northern part of the country.

After the Polish state regained these areas from the Teutonic Knights in 1466, the forests became part of royal estates and were managed by the Mayor of Tuchola. As a result of the First Partition of Poland in 1772, the entire royal forests were expropriated for the benefit of the Prussian king. The end of the eighteenth century is then regarded as the beginning of an organised forest management in Tuchola Forest. In 1782, the Prussian king issued a decree 'on the development of the Tuchola Forest' – creating eight administrative areas each about 6000 ha in size, including Woziwoda District. The Woziwoda Forest District was then established in 1833, in the course of forest administrative areas being transformed to forest districts. After Poland regained independence in 1918, the Council of Ministers transferred forest areas in 1922 to the Minister of Agriculture and State Property to be supervised by the Forestry Department. Following numerous reorganisations, the Forest District of Woziwoda has remained unchanged since 1993 (fig. C 18.1 and C 18.2).

Fig. C 18.2. The Woziwoda Forest District Office (Photo: by Daniel Janczyk).

Portrait

"The main goal of our forest enterprise is to manage our forests sustainably so they will provide all needed forest functions. Alongside timber production, it is at the heart of our work to ensure a broad range of ecosystem services; this will guarantee that the forests are resilient, rich in biodiversity, and are a place for recreation. Special emphasis is given to education and interaction with the public for creating a better understanding of the forest and their wide range of services".

Forest in figures

Woziwoda Forest District covers an area of 14 830 ha, of which 95 % are covered by forests. The forest district is divided into 12 forestry units. The district also has its own forest nursery.

Forests are dominated by coniferous forests, mostly Scots pine *(Pinus sylvestris);* this species accounts for 92 % of the forest area (fig. C 18.3.). These Scots pine stands produce high-quality timber. The soil of Woziwoda Forest District is predominantly acidic and derived from glacial sands. In terms of altitude, it belongs to lowland areas.

The forests of Woziwoda Forest District are managed according to multifunctional principles. The main functions are economic, protective, ecological, and social with an emphasis on education. Revenue is generated mainly by timber harvesting with an average annual cut of about 74 000 m³. Despite mainly being composed of a single tree species, the forests are rich in terms of nature and their protection value. The entire area of the district coincides with the Tuchola Forest Biosphere Reserve which was established in 2010. Natura 2000 areas cover almost the entire area of the Woziwoda Forest District. Apart from the Natura 2000 areas, the district also includes six nature reserves with a total area of 254 ha, a landscape park, 42 nature monuments (mostly single veteran or magnificent trees [Fig. C 18.4.]), as well as designated ecological areas covering 321 ha.

Fig. C 18.3. Typical pine forest in the Woziwoda Forest District (Photo: Stefan Konczal).

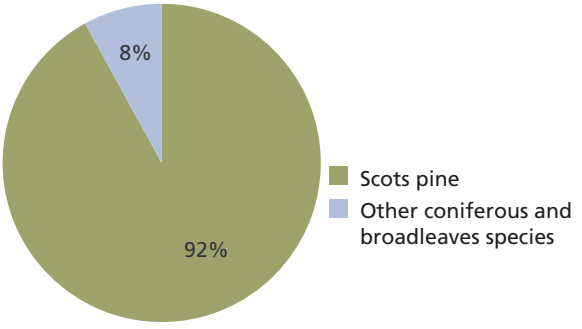


Fig. C 18.4. Tree species distribution Woziwoda Forest District.

Economy

There are several factors that mean the harvesting and management costs in Woziwoda Forest District are lower than in other regions of the country. These include: the relatively uniform species composition and habitat structure; the large proportion of protected forest areas mean that maintenance and management costs are in general low; and the topography. Other economic factors of importance are the risk of natural disturbances such as forest fires, the costs incurred for forest protection, and the road network.

Nearly all income is generated via economic function. Only 0.1 % is provided by social functions. With respect to the costs, the economic function accounts for 94.6 %, the environmental function for 0.9 %, and the social function for 4.5 % of the entire costs of the Woziwoda Forest District.

During the period 2017–2019, the average harvested timber volume amounted to about 79 000 m³ (not including small-sized timber). The average selling price of wood was about 40 €/m³ (168 PLN/m³). Wood sales accounted for approximately 94 % of the total annual revenues. The remaining 6 % are mainly from selling seedlings, leasing of land and buildings, and subsidies from the Regional Fund for Environmental Protection and Water Management. A total annual revenue of € 3 016 360 (13 272 000 PLN).

About 40 %, or 31 600 m³ is large-sized timber of which 90 % is coniferous. It is usually made available in the form of long-sized logs. Logs of medium dimension are mainly sold as pulp wood, for pallet production, or in the so-called 'garden programme' (medium-sized timber processed into garden products). Low-quality timber of larger dimensions is sold as firewood to the local population. The main recipients of harvested timber are large pulp mills, sawmills producing for domestic and foreign needs, companies processing medium-sized wood and exporting their products to countries such as Germany, France, and the UK. In the wake of the hurricane of 11th–12th August 2017, a significant share of the harvested wood was actually exported as logs to China and Scandinavia. Every year in the Wozi-

woda Forest District, about 200 m³ of wood is exported as electricity poles to Italy.

The average annual administrative costs average about € 1 636 360 (7 200 000 PLN), while the costs for forest management, wood harvesting, and removal amount to € 1 140 909 (5 020 000 PLN). The total annual costs are about € 2 777 273 (12 220 000 PLN). The cost/income ratio in the Woziwoda Forest District is 0.92.

Other ecosystem services

There are two Natura 2000 areas in the territory of the Woziwoda Forest District: (1) Bory Tucholskie (PLB 220009), was established as a Special Protection Area under the Birds Directive and covers almost the entire area of the forest district (14 815 ha); and (2) Dolina Brdy i Stążki w Borach Tucholskich (PLH 040023) includes many important nature reserves and was designated under the Habitats Directive.

Since 1996, 2770 ha (about 20 %), have been designated as protection forest in Woziwoda Forest District by the Ministry of Environment. The main function of these forests is the conservation of water and the prevention of soil erosion or degradation. These protection forest should not be mistaken for nature protection units such as nature reserves, Natura 2000 areas, landscape parks, or ecological areas.

In 2019, Woziwoda Forest District established two Marteloscope sites: (1) Ustrone, a lowland mixed conifer-broadleaved forest; and (2) Zielonka – a lowland pine forest. The Marteloscope sites will be used during practical vocational training classes for students of the Adam Loret Forestry Technical Secondary School in Tuchola, as well as for the education of the wider society. Also, the employees of the district will be involved in training events and hands-on workshops.

Importance of Woziwoda Forest District for recreation and education

Woziwoda Forest District is part of the Forest Promotion Complex of Tuchola Forests (FPC). FPC is an area of ecological, social, and educational importance, created for promoting multifunctional, sustainable forest management and for supporting innovative research. Tasks of the FPC are carried out within the 'Economic and Protection Programme'. The FPC activities are overseen by the FPC Social and Scientific Council, which is composed of researchers, local decision-makers, regional stakeholders, and members of local community.

The Woziwoda Forest District is one of two locations in the region where practical vocational training classes take place for students of the Adam Loret Forestry Technical Secondary School located in Tuchola. In the Woziwoda Forest District considerable emphasis is given to environmental and forestry education. The main objectives are: conveying information and knowledge about forest ecosystems, the concepts of sustainability and multi-functionality, and how to manage forests to ensure the full range of forest ecosystem services. Various forms of educational activities are implemented.

Fig. C 18.5. Magnificent tree approx. 350-years-old in Woziwoda Forest District (Photo: Stefan Konczal).

Fig. C 18.6. Educational event for the public (Photo: Robert Piątkowski).

These include outdoor activities for children and adults, and presentations and lectures at schools or thematic events such as: mushroom picking, Earth Day, Beekeeper's Day, active/outdoor holidays and camps, the 'Clean Up the World' initiative, the 'Festival of the Tree', and the delivery of the Christmas trees to local schools.

There is a dedicated infrastructure for the environmental and forestry education of the Woziwoda Forestry District, which includes the 'Educational Centre', the 'Green School', the 'Educational Barn', a 'Green Classroom', nature and sports trails, the 'Glass Beehive', and natural beehives in an old-growth stand, as well as a number of reference stands for thematic forest excursions.

Special focus in education on forest tree beekeeping

An example of a targeted educational activity of the Woziwoda Forestry District are animations related to forest tree beekeeping. Their aim is to draw attention to the importance of insects and especially bees in forest ecosystems (fig. C 18.7 and C 18.8). In the Educational Centre, in a specially designed 'oak hut', visitors can watch live bees in a glass hive. On a nearby nature trail one prominent stop describes and explains the characteristics, life, and importance of insects in forests. Near to the Green School and Educational Centre, foresters have artificially created beehives in an old pine

Fig. C 18.7. Excursion during 'Beekeeper's Days' (Photo: Robert Piątkowski).

Fig. C 18.8. Artificial tree beehive in an old pine tree (Photos: Robert Piątkowski).

stand. The purpose is to both demonstrate bees as forest insects and the profession of tree beekeeping (Polish: bartnik) where bees were bred in the past in artificial cavities of living trees (often large pine trees) for honey production. This profession largely disappeared from Europe by the end of the nineteenth century. In this context, educational 'Beekeeper's Days' are organised on an annual basis (fig. C 18.7). During these events, the public can learn about the role and significance of bees, their products, and the role of bees in the past and today.

Since 2018, the State Forest Enterprises have been implementing the 'bees return to the forest' programme. Within this programme, 100 tree beehives have been established in living trees across Poland (fig. C 18.8). They are run by foresters and supported with experience and practical knowledge by professional beekeepers.

All tree beehives are equipped with special scales that monitor the weight of a hive in connection to the timing of the flowering of particular plant species. The results of these investigations will be applied in forest management instructions to ensure the protection of the honeybee *(Apis mellifera)* in managed forest stands.

Conclusion

In our activities and management we try to connect all aims listed in the Forest Act: (1) the preservation of forests and their beneficial impacts on the climate, air, water, soil, human life and health conditions; (2) the protection of forests, especially forests and forest ecosystems which are natural parts of native nature or particularly valuable forests; (3) protection of soils and areas particularly vulnerable to pollution or damage and of special social importance; (4) protection of surface and underground water reservoirs; (5) the production, on a rational management basis, of wood and raw materials and by-products of forest use. We do it while maintaining sustainable forest management principles.

‘Gut Poitschach’ – Nature-based forestry with single tree fellings

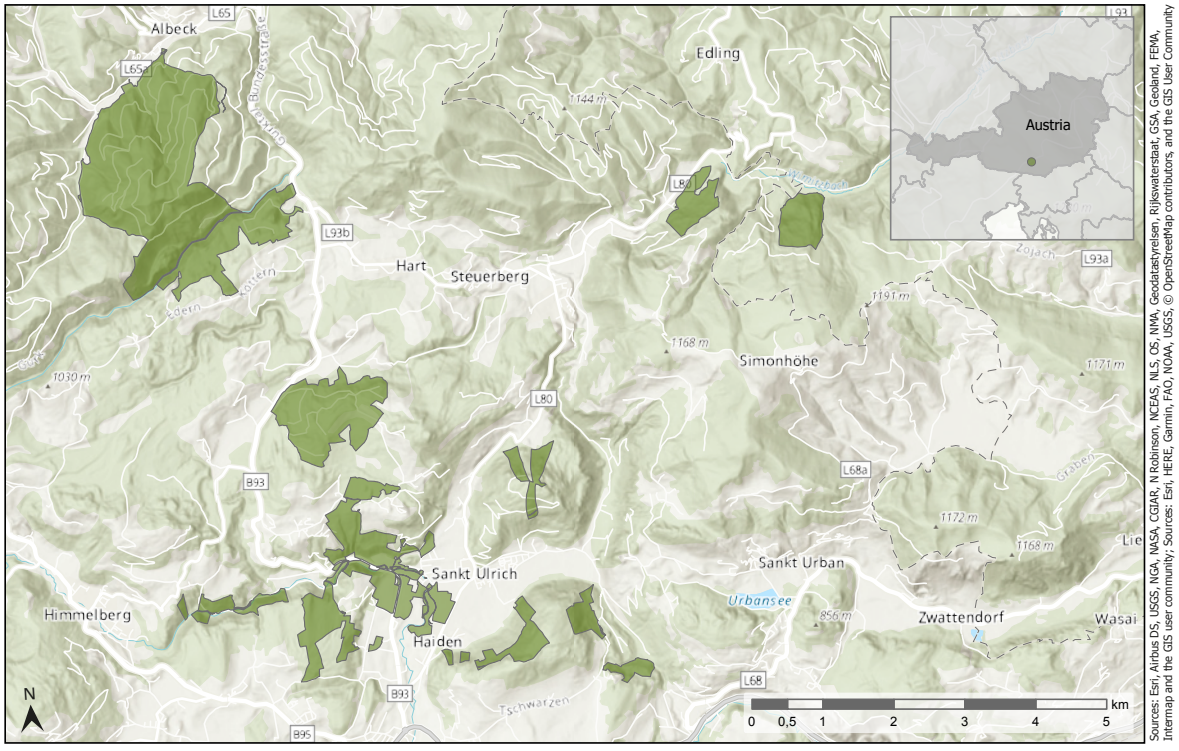
C 19

E. Senitza

Gut Poitschach, private owner and manager, Austria

Context, legal frame, and ownership structure

The private forest enterprise of ‘Gut Poitschach’ is located in the centre of Carinthia (Kärnten), one of Austrians federal states (Bundesland) in the south of the Alps with borders to Slovenia and Italy. The estate Gut Poitschach has been owned and managed by the same family (Senitza) for five generations. The enterprise covers about 840 ha of productive forest at an elevation between 600 and 1200 m a.s.l. Forestry is one branch of a broad



< Fig. C 19.1. Light and shadow – both serve biodiversity (Photo: Eckart Senitza).

Statement

"Light and shadow – both serve biodiversity."

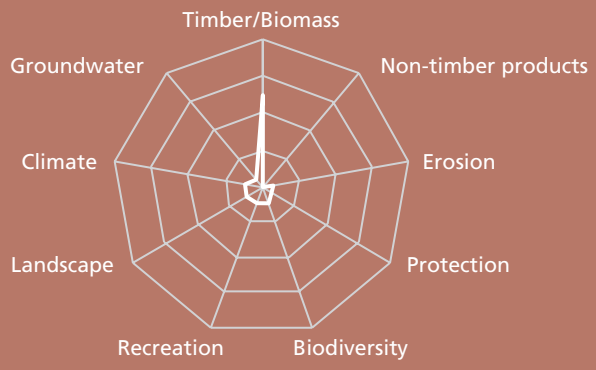


Table C 19.1. General information on the Gut Poitschach.

Forest community	Mixed mountain forests with spruce *(Picea abies),* beech *(Fagus sylvatica),* silver fir *(Abies alba),* larch *(Larix decidua),* pine *(Pinus sylvestris),* and several broadleaves
Total forest area	852 ha
Organisational structure	2 forest districts – 60 % of one forester (40 % external work) forested
Ownership	Private property
Main management types	Selection cutting system with single tree selection
Total volume	> 400 m³/ha
Annual growth	10 m³/ha
Annual harvested volume	7–8 m³/ha
Deadwood (standing and lying)	No inventory yet, many biotope trees (mainly old beech)
Altitude	Between 580–1200 m
Climate	Moderate climate of the southern intermediate alps, annual precipitation 1200 mm
Geology and soil types	Quartzphyllite and mica slate, Quaternary, bogs – Soil types mainly brown earth to podzol
Protected area (total)	Over 5 ha swamps and bogs and surrounding forest protected by own decision
Nature protection area (Natura 2000)	No
Protective function	Protection forest 75 ha

mixed enterprise; the other branches include, farming, hunting, a fishery, energy production, renting/leasing of flats and industrial buildings (former pulpmill, sawmill, etc., timber logistics and transport, and an office for forestry consulting. The property area has been extended step-by-step with acquisitions of forest and farmland (1885–1989) of the former iron processing industries and is in one family's hands just since about 100 years. Since World War II, forestry has become the main income source of Gut Poitschach. Because of the favourable terrain conditions and the intensive system of tractor and skidding trails, logging can mainly be done by tractor and cable winches. Around 80 % of the annual harvesting and maintenance work can be done with four forest workers that are employed on the estate. Since 2015, management interventions have aimed to encourage natural regeneration and a more diverse forest structure. The selection and harvesting of trees depend on market conditions and the individual maturity of the single trees. The entity aims at promoting a (semi-)automatic wood production, where the need for planting, plant protection, and tending of young stands

Fig. C 19.2. From trees to saw logs to quality sawn wood – product cycle (Photos: Eckart Senitza).

is minimised as much as possible. However, no general formula will work as the changing site conditions require a differentiation in treatment and management. Finally, the timber is sold according to a diversified assortment made up of: large-diameter timber, long lengths of wood for construction, high- and low-quality roundwood (fig. C 19.2), and also thin stems. Timber is sold to about ten small- and medium-sized sawmills of the region. Silver fir *(Abies alba),* larch *(Larix decidua)* and pine *(Pinus sylvestris)* are sold separately to specialists.

Portrait

"The forest will stay in the main focus as a managed ecosystem for the production of timber, providing biodiversity and recreational amenity as the basis for new economic opportunities".

Forest history and cultural heritage

The historical context of the enterprise and of the forest utilisation and the changing framework has had a strong influence on the forest development and current forest composition and structure. The history of the forest area dates back to before 1600, when iron processing developed into an important activity; key factors for this development were the availability of energy from charcoal and mechanical hydropower. This led to clearcutting of forests in the area with corresponding development of low growing stocks. In addition, many forest areas were characterised by use as woodland pasture and litter use; consequently, the sites became impoverished. From 1880 onwards, the conversion from iron processing to the production of paper and cardboard took place and in 1890 and especially around 1920 the hydroelectric power stations were expanded and equipped according to the state-of-the-art of that time. In 2003 they were completely renovated and equipped with electronic control and monitoring.

From 1920 onwards, many acquisitions were made and around 120 ha of former agricultural land (grassland and arable land) were bought up and afforested (fig. C 19.4). Of course, these areas were also not built up in a near-natural way. With intensive use in the period between the two world wars, the stock had fallen to an average of around 150 m³/ha in 1951. Since that time, stocks have been continuously built up and forest stands have been systematically improved. By the 1940s, the grandfather of the current owner had already recognised the importance of ecology in the forest and so many of the looted stands were underplanted with beech and enriched with a mixture of other broadleaf and coniferous species. Until 1992, between 3000–7000 m³ of wood were harvested annually and the stock had gradually increased to an average of 290 m³/ha. The objective at that time was to achieve an average stock of about 330 m³/ha. The following inventories confirm that stocks increased to around 320 m³/ha in 2001 and to an average of 420 m³/ha by 2016.

This means that the original target has already been exceeded, and the question now is how to manage the forest on a permanent basis, and how to adjust to an appropriate average harvesting level in order to ensure constant stock renewal. About 100 years ago, farmland was planted mainly by Norway spruce and transformed into forest. As a consequence, there were several large clearcuts between 1850 and 1930 to supply the pulp and papermills. Up until 1975 the enterprise also ran its own sawmill. Since that time, forest management has been carried out using natural regeneration and supplementary planting and, since 1992, there has been no clearcutting.

Aims of the enterprise

The objectives in forest management are to establish stable, resilient, and highly productive forest stands with maximum flexibility of harvesting in the time distribution and yearly amount of harvesting.

The aim was to achieve the best possible rationalisation of forest management:

– Through further use of natural regeneration, the annual number of planted trees could be reduced to about 3000; a saving of about € 5–7per sold m³. The planted trees are moCtly mixed tree

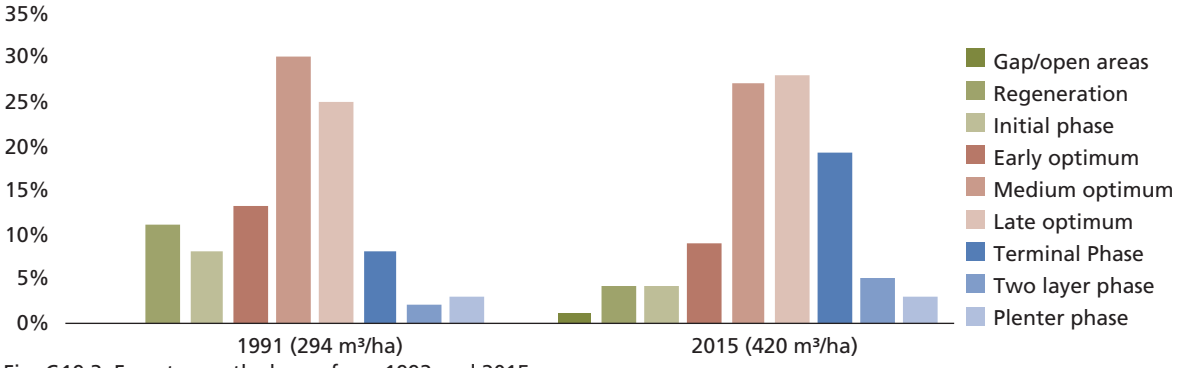


Fig. C 19.3. Forest growth classes from 1992 and 2015.

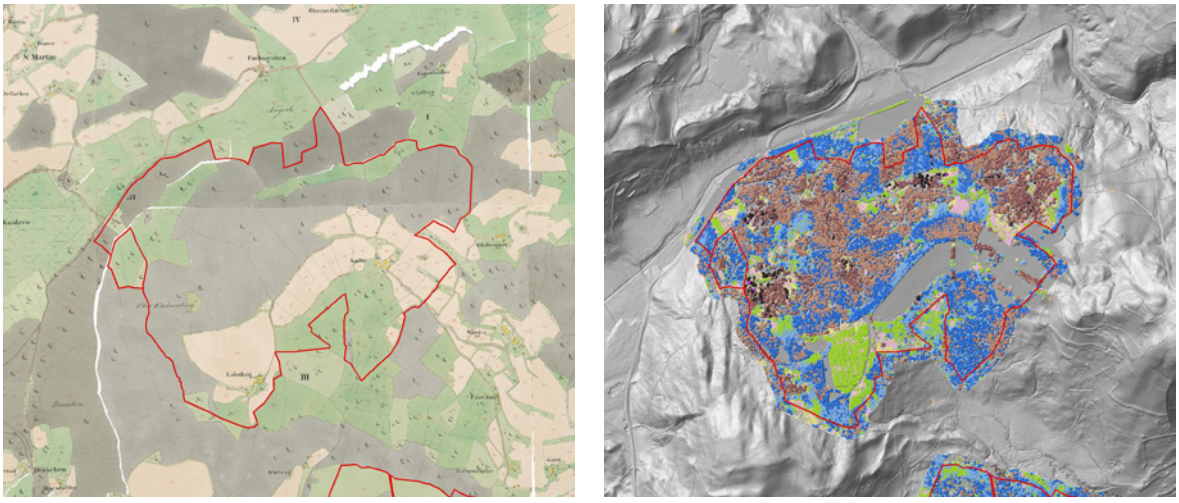


Fig. C 19.4. Historical map on the left of one forest district (about 1860) shows high portions of arable land (beige) and pastures (light green) which is now forest. The individual tree height model on the right, generated from LIDAR data shows diverse tree height structure as a result of selection fellings. Yellow, rose and green areas are the last plantations (green under 20 m height former pasture), and there is a gradient from blue (mid-size trees) to brown (taller trees); the darker colours indicate taller trees. The black indicates trees with a height >40 m and most have been harvested since the data was collected (Map by Gut Poitschach).

species, which are planted in small disturbance areas (after windthrow, bark beetles, snow break) to supplement natural regeneration. In this way, it has been possible to largely retain the proportion of larch and pine as light-demanding tree species.
- The spectrum of mixed tree species was largely preserved and even significantly expanded. The proportion of spruce *(Picea abies)* is about 70 %. The proportion of fir and, especially sycamore *(Acer pseudoplatanus),* has increased, especially in the younger stands. Unfortunately, the recent loss of ash *(Fraxinus excelsior)* because of 'ash dieback' (caused by *Hymenoscyphus fraxineus*) has led to a narrowing of the tree species spectrum.
- By shifting the age classes of the main stands to higher proportions under constant use within these stands, an automatic stand renewal could be achieved. The cost-intensive tending of young stands could be significantly reduced. In contrast, the proportion of stocks over 60 years of age has now increased from 20 % to 60 % (fig. C 19.3).
- In the growth classes, the proportion of 'young growth/pole wood' classes has been reduced from 32 % to 18 % and the proportion of 'tree wood (Baumholz >20cm)/uneven-aged stands' has increased from 38 % to 55 %.
- The proportion of already regenerated stands has increased from 25 % of the total forest area in 1992 to 52 % in 2016. Thus, the insurance for possible damaging events is already established.
- Today forestry is the most important economic activity of the enterprise: on the forest area of 840 ha an annual harvest of 4000 to 5500 m³ is cut. These fellings are thinnings and small-scale or single cuttings of mature trees. Forest regeneration occurs naturally where possible and is sometimes complemented with plantings on small disturbed areas.
- With regard to the species composition, spruce is dominant (74 %), but there is also fir, pine, larch, and especially beech, sycamore maple, and ash according to the site conditions.

Fig. C 19.5. Self-differentiation of young trees in light patches (Photo: Eckart Senitza).

Fig. C 19.6. Silver fir needs deer populations to be controlled (Photo: Eckart Senitza).

Management

Within the forest enterprise the growing stock of former young stands of lower stockings (1951: growing stock 150 m³/ha) has been transformed within three manager generations (about 50 years) into a forest with a diverse structure and high growing stock (mean stocking: 420 m³/ha). Years of massive snow break (1975 + 1979: 20 000 m³) and windthrow (1990: 6000 m³, 1998: 7500 m³) have partly destroyed the stands, but often irregular thinning has provided the impulse for more diverse stand structure.

Fig. C 19.7. Uneven patches of shadow and light provide high structural differentiation (Photo: Eckart Senitza).

Economy

Since 1945, the proportion of sawlogs (>20 cm) has increased from the original 35 % to over 80 % compared to pulpwood and low-diameter logs. Among the harvested assortments, the share of large (>45 cm) and long timber (5–9 m) has stabilised at about 15–20 %. These assortments usually have a premium of 5–10 % above the normal timber price. In addition, special assortments of larch, silver fir, and spruce for log-house construction or other construction purposes are offered on a case-by-case basis. By shifting to the harvest of large-diameter timber, in favourable cases the costs for timber harvesting and transport (by chainsaw, tractor and cable winch up to the forest road) are about 15–18 €/m³.

There is a comprehensive network of forest roads for trucks of around 65 m/ha and additional network of haulage routes for tractors of about 60 m/ha. These are the prerequisites for small-scale silviculture and also for avoiding soil damage in the stands. In this case the important lever are cost reduction through natural regeneration (figs C 19.6 and C 19.7), self-differentiation to avoid pruning and thinning operations (fig. C 19.5) and the piece per part momentum for harvesting costs, logging and loading for transport, and revenue increase by the shift of assortments to higher diameter classed and special assortments with better prices.

There are more than 400 permanent sample plots and the area is inventoried every decade with additional support of growth models for simulation of increment.

Because of the wide range of business activities (forestry, agriculture, rental, energy production, timber trade, and forest consultancy services for external customers), the proportion of income from the forest has been reduced to around 50 %. Service sectors now account for around one third of turnover.

Factors affecting the economic success include the good location, relatively favourable sites with a low proportion of terrain requiring use of cable cranes, and an average/good water supply. Other reasons are motivated employees who, in collaboration with external service providers, ensure efficient and largely damage-free timber harvesting (fig. C 19.11). Flexibility in terms of the timing and quantity of timber harvesting is also important.

Ownership structure

As mentioned, the forest of Gut Poitschach is now in the hands of the fifth generation of the family. The last owners were grandfather, father, and grandson. A further handover is pending. The payment of the heirs and further financial burdens always pose new challenges. Close and good relations with the immediate neighbours and local partners are very important. Local demand for firewood and other forest products (e.g. resin use for larch – today for wellness products, larch oil for sauna etc.) can also be met.

Most important services/products

The most important products are sawlogs from spruce (fig. C 19.9), but also from fir and larch, mainly for the regional market. It is particularly important to note that solid construction timber of larger dimensions is also needed, especially for roof renovations of churches and old houses in Italy.

Specialities/Rarities

There is a high diversity (with respect to stand structure and species composition) of forest sites over a wide range of altitudes from 600 m.a.sl. to 1200 m.a.sl.. In particular, dry sites at about 1100 m.a.sl. are an example of a rare habitat. There are also some very old beech stands. Species-rich swamp areas with various Sphagnum species and insectivorous plants have been voluntarily included in a protection and maintenance programme. A 10-ha lake is a natural jewel and is managed as part of a strongly ecologically-oriented fishing operation.

Nature conservation

Even without a prescribed nature conservation concept, old trees, especially old beech and other broadleaved trees, have been left in the forest areas for 50 years until they die naturally, and gradually decompose. Branches and tree-tops always remain scattered in the stand after harvesting and they form another component of deadwood, in addition to the stumps. On the edges of the former

Fig. C 19.8. Overmature Norway spruce should have been harvested earlier (Photo: Eckart Senitza).

agricultural areas, numerous old trees have also been left, mainly oaks (*Quercus* spp.) (fig. C 19.9), sycamores, and also ashes. These provide further small biotopes for bats and rare bird species.

During the construction of the tractor tracks, small ponds, or wetland biotopes have been created at suitable locations (fig. C 19.10). Forest edges are left stepped and the edges and slopes of the forest roads offer additional niches and small biotopes. Hazel grouse *(Tetrastes bonasia)* is common, but capercaillie *(Tetrao urogallus)* is unfortunately rare, although special biotope maintenance has also been carried out to create capercaillie-suitable habitat in the appropriate locations. In the forest, there are several species of woodpecker, including black woodpecker *(Dryocopus martius),* and great spotted woodpecker *(Dendrocopos major),* as well as hobby *(Falco subbuteo)* and several species of owls (e.g. *Glaucidium passerinum, Strix aluco, Asio otus*). At the forest border with old broadleaves the Eurasian Hoopoe *(Upupa epops)* and green woodpecker *(Picus viridis)* are also frequent.

Population/Recreation

There is no direct provision of recreation, but in areas close to settlements the forest is used by a lot of walkers and joggers. This use of the forest occurs without conflicts. In the future, theme trails and

Fig. C 19.9. Biotope tree oak with a lot of tree related microhabitats (TREMs) (Photo: Eckart Senitza).

information boards may encourage further understanding of forest management. For decades, the farm has offered about 5–7 excursions per year for different interest groups.

Strengths and weaknesses – or, where is the potential to improve certain issues?

Management: The management is based on detailed knowledge of the forest and a very flexible approach to decision-making. All trees selected for cutting and as biotope trees are marked. Structural thinnings are made with only 100–150 future trees/ha to convert homogeneous stands to uneven-aged forests. The detailed knowledge depends on committed managers (fig. C 19.11) and a certain degree of patience and time spent in the forest, which are payed back by the results.

Policy: Forest management under the Austrian forest law allows a great freedom as long as you care for the forest and keep it healthy. The law requires immediate reaction to respond to bark beetle outbreaks and favours natural regeneration. There are no limits concerning harvesting, although clearcuts are restricted to 0.5 ha; however, in Gut Poitschach no clearcuts are carried out.

Science: The forest inventory has been designed specifically for the area; there are permanent plots and the inventory is based on several results from science as well as the use of growth models. There is one permanent reference stand (>5 ha), which is part of the European-wide AFI (Association Futaie Irrégulière) network within the RESYNAT-Project in Austria. An inventory of the biotope trees is in the pipeline. More scientific projects will be implemented in the future.

Communication: For decades, the enterprise has served as a location for excursions for school classes, expert groups, farmers, forestry teachers, etc. In the year 2014 the enterprise was given the 'State Award for Exemplary Forestry' by the Austrian Federal Ministry for Agriculture, Forestry, Environment and Water Management. Several articles have been

Fig. C 19.10. Swamps and bogs are voluntary protected (on the left). Biotope trees are left until they gradually decompose (on the right) (Photos: Eckart Senitza).

published in regional papers and national forest magazines. Information boards will be placed at the entrances to the forest, but this has not yet been implemented.

Network

Examples of good forest management should be communicated and timely information should be provided to educate the public and enable interested people to get involved; this might prevent unrealistic expectations while providing the public access to the forest and to learn about the balance between economic activities and other services in the forest. This is especially true for this example (C19) Gut Poitschach, but also for two other examples presented in this book, i.e. (C6) Pahernik and (C22) Langau. For many years these belong to the network of ProSilva demonstration sites (www.prosilva.org), and have followed ProSilva principles. and serving within a network of about 65 practice examples across Europe as good case examples.

Nature conservation is of course part of the ecosystem approach of forest management as also promoted by Pro Silva. There is a strong conviction that the elements like deadwood or biotope trees, and also the mixture of species and structures lead to an improved balance between diverse antagonists (e.g. bark beetle) for a greater forest stability and resilience. Well-managed forests can provide a wide variety of ecosystem services (timber production, nature conservation, provision of clean water, carbon sequestration, recreational opportunities). Stakeholders and in particular nature conservation should not remain stuck at a level of pure self-purpose with sometimes, very theoretical approaches unrelated to practice.

Forester's Statement

"Continuous cover forests need consistent management following the same guidelines and principles over decades. This is the precondition for achieving 'rapid' changes in a slowly-developing system. Such forests provide more flexibility and adaptability to changing environmental and socioeconomic conditions!"

Fig. C19.11. The hero: he knows how to fell big trees without damage (Photo: Eckart Senitza).

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Throughout the chapter, the author refers to the following documents and websites:

AFI – Association Futaie Irrégulière: https://www.prosilva.org/activities/afi/

Frank G.; Lipp S. *et al.* 2016: project report ReSynatWald (german) https://bfw.ac.at/cms_stamm/100/pdf/ReSynat_Endbericht_klein.pdf

Pro Silva Austria, 2018: Grundsätze (German) https://www.prosilvaaustria.at/naturnahe-waldwirtschaft/

Pro Silva Principles, 2012: https://www.prosilva.org/close-to-nature-forestry/pro-silva-principles/

Pro Silva Exemplary Forests, 2019: https://www.prosilva.org/close-to-nature-forestry/examplary-forests/

Pro Silva – European Exemplary Forests Network, 2019: https://www.prosilva.org/information-news/news/exemplary-forests-network/

RESYNAT 2016: https://bfw.ac.at/rz/bfwcms.web?dok=10483

Staatspreis für vorbildliche Waldwirtschaft 2014: https://docplayer.org/70318680-Ministerium-fuer-ein-leb-enswertes-oesterreich.html

Susse, R.; Allegrini, C.; Bruciamacchie, M.; Burrus, R., 2011: Management of irregular forests AFI. Besancon 144 p.

Box C 12

Large-scale projects in support of education in forest science and management: the example of the EMEND Project

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The EMEND Project (https://emend.ualberta.ca) is an internationally renowned controlled experiment in environmental science and forestry located in northwestern Alberta, Canada. The upland merchantable forests of this region are a coarse- and fine-grained mixture of stands comprising both broadleaved hardwoods–mainly trembling aspen *(Populus tremuloides)* and balsam poplar *(P. balsamifera)* – and coniferous softwoods–mainly white spruce *(Picea glauca)* and black spruce *(P. mariana)* with some lodgepole pine *(Pinus contorta)* (see Rowe 1972). The mixed-wood character of these forests is maintained largely by natural disturbances, especially wildfire (Cumming 2001) and occasional insect outbreaks. In general, the Populus species re-establish quickly after fire, either as suckers from living root stocks or from wind-blown seeds, and grow quickly to become the initial post-disturbance forest canopy. Depending on availability of seed, shade-resistant white spruce establishes and grows slowly in the understorey, gradually moving stand composition towards domination by coniferous trees through natural stand dynamic processes until succession is reset by the next disturbance (Lieffers *et al.* 1996; Bergeron *et al.* 2014). Industrial forestry in Alberta uses the hardwoods, especially aspen, for pulp, while the conifers of later successional stands are valued mainly for high quality lumber. Thus, the western boreal mixed-wood forest is an economically valuable and renewable natural resource.

The EMEND project was designed to support use of this resource through implementation of sustainable forest management (SFM) specifically designed for the western Canadian boreal mixed-wood region. The project title, EMEND, is an acronym for the phrase 'Ecosystem-based Management Emulating Natural Disturbance', which summarises the central hypothesis of the experiment, i.e., that forest harvests designed to retain landscape patterns similar to those left in the wake of natural disturbance will be more sustainable than those, like traditional clearcutting, intended mainly to maximise economic efficiency. EMEND research is relevant to all six SFM assessment criteria outlined by the Canadian Council of Forest Ministers (CCFM 2007), but specifically addresses the four related to the ecological state of the forest: (1) biological diversity; (2) ecosystem condition and productivity; (3) soil and water; and (4) role in global ecological cycles.

Given its broad whole-system focus, research at EMEND has been attractive to ecologically-minded students and researchers, and from the start the project was coupled to significant educational objectives. In addition to providing research to support improvement in woodland management, EMEND is well suited to support hands-on education for both undergraduate and graduate university students seeking to apply principles of environmental science in modern forest management.

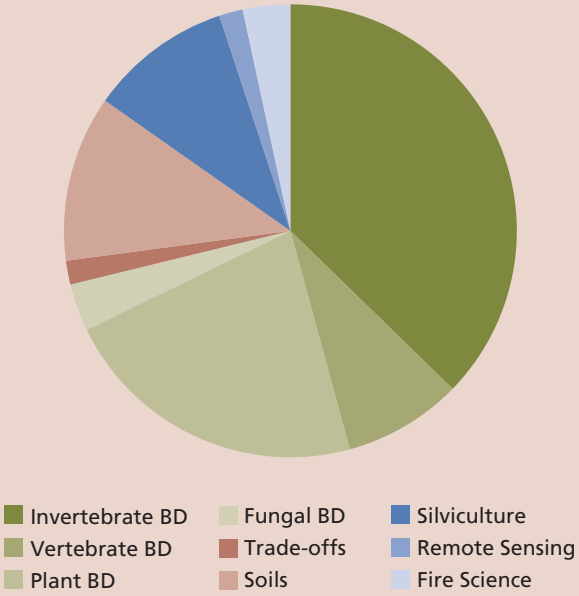

Fig. 1. Distribution of EMEND student projects classified by general subject area. More than 70 % of projects have dealt with how biodiversity (BD) of various taxa responds to the disturbance treatments across the four basic cover-types.

Furthermore, EMEND has been used to inform public understanding of how an industry based on natural resources is adapting to public pressures to be more sustainable. In this short description we summarise the basic aspects of the project and then focus particularly on how it has met its educational objectives during the first twenty years of its existence. Following retirement of the initiating principal investigators (J. Spence and J. Volney) and changes in forest industry alignment (sale of Daishowa-Marubeni interests to Mercer International in 2018) shortly thereafter, the project is on hold. At present the academic and educational strategy of EMEND is in the process of being revised and renewed by a new leadership team. Although it is expected that the project will continue to have both educational and scientific objectives, the methods and linkage of their delivery are expected to change. Thus, in this paper we deal with what was accomplished in the first 20 years of the project (1997–2017).

Background and context

Commercial forestry in Alberta is conducted mainly on public (i.e., 'crown') lands, with the Government of Alberta (GOA) allocating the exclusive rights to harvest and responsibility to regenerate forests in defined Forest Management Areas (FMAs) to particular forestry companies. The GOA sets out objective-oriented ground rules for woodland management that all FMA holders are obliged to meet. Companies may hold spatially overlapping tenures for different forest types on the same land base. This was the case for a large area (P1, >1.7 million ha) in northwest Alberta, where Daishowa-Marubeni International Ltd. (DMI) was, at the start of EMEND, the FMA holder for harvest of early-successional broadleaved trees (*Populus* spp.), while Canadian Forest Products Ltd. (Canfor) held the rights to harvest the late-successional merchantable conifer volume (mainly *Picea glauca* and *Pinus contorta*). Public concerns about ecological impact of forest harvest that surfaced in Alberta during the early 1990s (e.g., Pratt and Urquhart 1994) prompted both the government regulators and forward-looking companies to develop new management approaches that would meet with public approval.

Against this background, the two companies mentioned above approached researchers at the Canadian Forestry Service (CFS) and the University of Alberta (UA) to develop the scientific understanding required for transition from the then widely used two-pass clearcutting harvest system to the more ecologically sound approach of variable retention (VR) forestry. This overall mission was defined by industry to meet their broad needs and resulted in the development of the EMEND project. Specifically, the research aimed to compare the ability of VR forestry and traditional clearcut harvesting to meet the Canadian criteria for sustainability and thereby favourably address many public concerns. The work was especially appealing to researchers because these two independent companies where challenged to cooperate in developing the most sustainable plan for joint use of the forest land designated to provide wood volume to feed their mills and meet their commercial objectives. Until this time, most traditional forestry research had focused narrowly on timber production and silviculture. However, with the shift to criteria-based SFM, such understanding had to be much better integrated with other forest values such as biodiversity, forest health, and ecological cycles. Thus, addressing sustainability concerns demanded a whole forest ecological perspective that accommodated the prevailing succession of forest cover types.

Following 18 months of in-depth consultation and planning that involved all founding partners (Canfor, DMI, GOA, CFS, and the UA) in bi-monthly meetings to define and organise the project, EMEND was launched. The project was planned from the start to include educational objectives with the goal of training a new generation of forest scientists well versed in the philosophy and methods of sustainable management. Initial fieldwork in 1997, accomplished with a supervised crew of undergraduate forestry students, was employed to select the stands to be used for EMEND from candidates identified in the provincial forest inventory for mixed-wood forest in the FMA now held by Mercer Peace River Pulp Ltd (MPRP). The overall project design, a two-way factorial cross of four commercially harvested cover-types by disturbance (both retention harvest and prescribed fire) treatments (see Spence et al. 1999; Work et al. 2010; Pinzon et al. 2016), was applied using 10-ha compartments as replicates for all treatment combinations during the winter of 1998–1999, following a summer of pre-harvest data collection and layout of experimental compartments within stands in 1998.

The EMEND Management Team (EMT), comprising representatives of the five founding partners, divided research to be conducted at EMEND into three categories: (1) core research to address the overall, experiment-wide objectives of EMEND as defined above; (2) graduate student research to include approved projects aiming to enhance scientific understanding of specific core issues and outcomes as they develop; and (3) tangential scientific work that effectively employed the unique nature of the EMEND template to answer process-oriented questions about mixed-wood ecology. The EMT committed to funding all research in category 1 and to support applications for competitive grants to fund work in category 2. The main educational objectives of EMEND were developed within these two categories of research. The Sustainable Forest Management Network (SFMN), a member of Canada's Networks of Centres of Excellence programme, provided considerable opportunity to win funding for category 2 projects, and it is fair to say that availability of such funding was a central inspiration for the founding and initial success of EMEND. Funding required for approved category 3 projects was to be provided by those wishing to pursue the work. In addition to generating new knowledge through EMEND research, the EMT also planned and funded various public outreach and technology transfer activities as contributions to public education. These are outlined below.

Connections to university-level education

From its beginnings, EMEND research was planned to engage both undergraduate and graduate students. The EMT envisioned that undergraduate students employed on the EMEND 'core crew' would be engaged in periodic monitoring of the overall experiment, while graduate student projects were seen as the backbone of the creative scientific effort at EMEND. From the start, the EMT hoped to involve all EMEND students in a vibrant and interactive culture of SFM that could contribute to a positive shift in the Canadian attitude towards forest management.

The core-crew. Each summer, six to ten senior undergraduate students pursuing degrees in environmental science or forestry were chosen from applicants from across Canada to constitute the core crews. Specific training on data collection associated with planned summer work was provided to the core crew by experienced academics and technicians. The day-to-day work of these students was supervised by a senior student with previous EMEND experience who served as the crew leader for the summer. Pairs of core crew students visited the six permanent plots in each of the 100 EMEND compartments to collect data about aspects of the experiment prioritised for focus. Crew members also assisted graduate students with data collection in projects that involved experiment-wide monitoring when time was available beyond that required for the overall experiment monitoring planned for the summer.

Because the EMEND field site is remote and located on the edge of a large wilderness, it was crucial to provide well-organised support for student work. This included the construction and operation of a field camp with basic facilities to feed and house students, and to support limited laboratory work. In addition, the EMT ensured that the field site was well-mapped and laid out with well-maintained trails, signage and base-lines to guide those engaged in fieldwork. Furthermore, all core crew students were given detailed training with respect to safety and the skills required for effective work in remote forested sites. Funding to meet these objectives was provided through collective effort by all founding partners as well as a successful application to the Canadian Foundation for Innovation. Through these efforts EMEND students were able to live reasonably close to the experimental site, find their way around the site safely and efficiently, and a collective EMEND culture based on shared camp experiences was encouraged.

Between 1997 and 2017, a total of 117 young men and women have served on the EMEND core crew. Some individuals were employed for multiple years. Through hands-on work these students gained experience in many aspects of field work germane to issues in SFM, and many have gone on to pursue graduate level research of their own at EMEND or elsewhere, or to take their experiences into the Canadian work force in industry or government.

Graduate student programmes. As of 2018, 46 graduate thesis projects (35 MSc, 11 PhD) and nine postdoctoral fellowships had been completed in association with EMEND. National and international graduate students working on the project have pursued topics in a wide variety of areas relevant to SFM (Fig. 1). More than 70 % of student projects have dealt with forestry impacts on various

elements of biodiversity to meet CCFM criterion 1 because this aspect had been relatively unstudied with respect to forest management in Canada (fig. 1). Although the design of EMEND is an alternative silviculture experiment only about 10 % of student projects over the first 18 years focused on traditional silvicultural topics. These, of course, are highly relevant to the overall EMEND design, but such projects have also investigated the long-term effects of silvicultural treatments themselves. For example, Gradowski *et al.* (2009) investigated aspen and balsam poplar regeneration from root suckers nine years after logging in a variable retention experiment. Solarik *et al.* (2012) investigated factors affecting white spruce and aspen survival ten years after partial harvest, while Xing *et al.* (2018) reported on the effects of retention level, and original wood cover type on the long-term survival and growth of residual trees of various species included in the EMEND retention harvests. Most recently, Xing *et al.* (2019) published allometric equations for local estimation of biomass of aspen, balsam poplar, and white spruce and demonstrated that greater accuracy flowed from use of such locally developed equations as opposed to those developed for national use. These projects have depended on the multi-year data base possible given the long-term nature of the EMEND project.

EMEND graduate programmes over the first 20 years were supervised by a total of 19 academics representing nine universities, mainly from Canada and the USA. Many graduate projects also included co-supervisors from additional partner institutions such as the CFS and GOA. In addition, EMEND has provided the working space and project context for a number of visiting students from Europe seeking to gain international experience through their programmes of study. Virtually all EMEND graduate students have had paid undergraduate assistants dedicated to their projects during each of their two to four summers of fieldwork at EMEND, adding an additional 124 summers of research-based education for undergraduate students. Thus, in combination with core crew experiences, research at EMEND has provided educational experience to nearly 250 undergraduate students and introduced them to a culture of applied SFM as fostered by multiple cooperating agencies.

Over the first fifteen years (1997–2011) of EMEND, when generous funding was available through the SFMN, a large graduate program was mounted. Interactions among graduate students and project sponsors as well as representatives of other agencies with interest were facilitated mainly by an annual two-day research meeting. All sponsored students were required to present an account of their research progress and findings. These meetings were highly interactive, provided much constructive feedback to graduate students, and included a scheduled half-day general discussion of overall project development in relation to project goals. A high point of the EMEND year, these project meetings remained a continuing aspect of the project as long as there were a significant number of graduate students involved in EMEND work. With closure of the SFMN in 2009, funding available for graduate work declined precipitously and number of graduate students declined. Given that the main driver of the annual research meetings was interactive exchange between students and project sponsors, the meetings were discontinued. Of course interactions and joint planning among sponsors and senior researchers continued at the EMT meetings.

Recognizing that reduction in graduate student work was a problem for EMEND, the EMT supported an application for a Collaborative Research and Development grant from the National Science and Engineering Research Council of Canada, which was funded in 2011. Under the terms of this agreement, the EMT sought to intensify the EMEND experience for the smaller number of students that could be supported by exposing them to a broader range of both industrial- and government-sponsor personnel through research presentations delivered at sponsor facilities. Between 2011 and 2017 these site visits provided students the experience of tours of sponsor facilities and supported development of a more in-depth understanding of issues faced by non-university personnel seeking to adopt research results in the context of developing improved SFM programmes.

Student research programmes have contributed the great majority of published work from EMEND. Of 92 peer-reviewed journal publications resulting from EMEND work at the time of this brief review, 68.4 % have resulted from thesis work at EMEND and another 21.7 % have resulted from postdoctoral research. Collectively, this body of work makes a significant contribution to understanding the scientific basis for SFM in the boreal mixed-wood of western Canada. As the project

matured, the EMT additionally encouraged development of a series of research notes, known as EMEND Insights, addressing issues relevant to forest managers in less formal scientific terms and specifically targeted at forest practitioners. All students have been encouraged to contribute at least one note to this series from their projects. To date, 29 EMEND research notes have been produced. The 22 EMEND Insights printed to date and 7 SFMN Notes are available on the project website, serving to facilitate application of research results in the Alberta forest industry.

Connections to Public Education

The initial concept of EMEND included a knowledge exchange and technology transfer programme as an important pillar of the project. These efforts, of course, are intended to be primarily educational, but the focal audience is the public. Under this programme, EMEND has also expanded the information available to forest practitioners beyond efforts connecting directly to student research, underscoring the EMT's intention to provide a channel for communication between the public and other institutions engaged in forestry in Alberta.

A central part of this programme has been the delivery of field tours, organised in most years by CFS personnel with expertise in the area of technology transfer. These well-subscribed tours included exposure to the site, a general review of how the experiment was organised, and summary of overall progress with the work conducted at the EMEND field camp. Key members of sponsor institutions, members of the forestry community in western Canada, and members of the public advisory communities of the main industrial sponsors were invited to participate. Participants were given opportunities to see first-hand interesting aspects of site development along carefully designed tour trails accompanied by students who explain their research in the field setting. Some tour participants were additionally taken on guided helicopter flights over the site to provide a narrated 'big picture' view. Non-governmental organisations also invited graduate students and post-doctoral fellows to visit local schools, public talks, and science fairs to provide information about the project.

Finally, to facilitate transfer of information to the public, the Abele Pavilion was developed at the junction of the Mercer International and Canfor forestry roads (56°46'13.6"N 118°22'29.0"W), located centrally among EMEND treatments, to showcase permanent descriptions of the history of the project, its main objectives, purpose and spatial layout of experimental treatments, and updated information about research progress. At the Pavilion, visitors can also find directions to three self-guided trails through examples of treatments on broadleaved, conifer, and mixed-wood forest stands.

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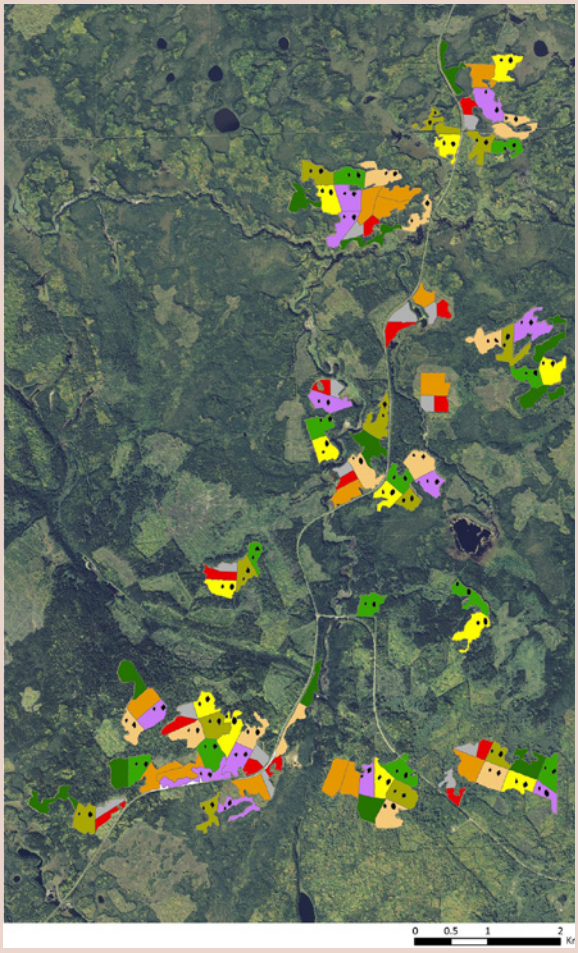

Fig. 2. Plots and transects for the EMEND project (Photo: EMEND project).

Fig. 3. Autumn impressions of the EMEND plots. The picture shows the impressive dimensions of this research setup (Photo: EMEND project).

Zvolen – Multifunctional broadleaved forests in a university forest enterprise of Slovakia

C20

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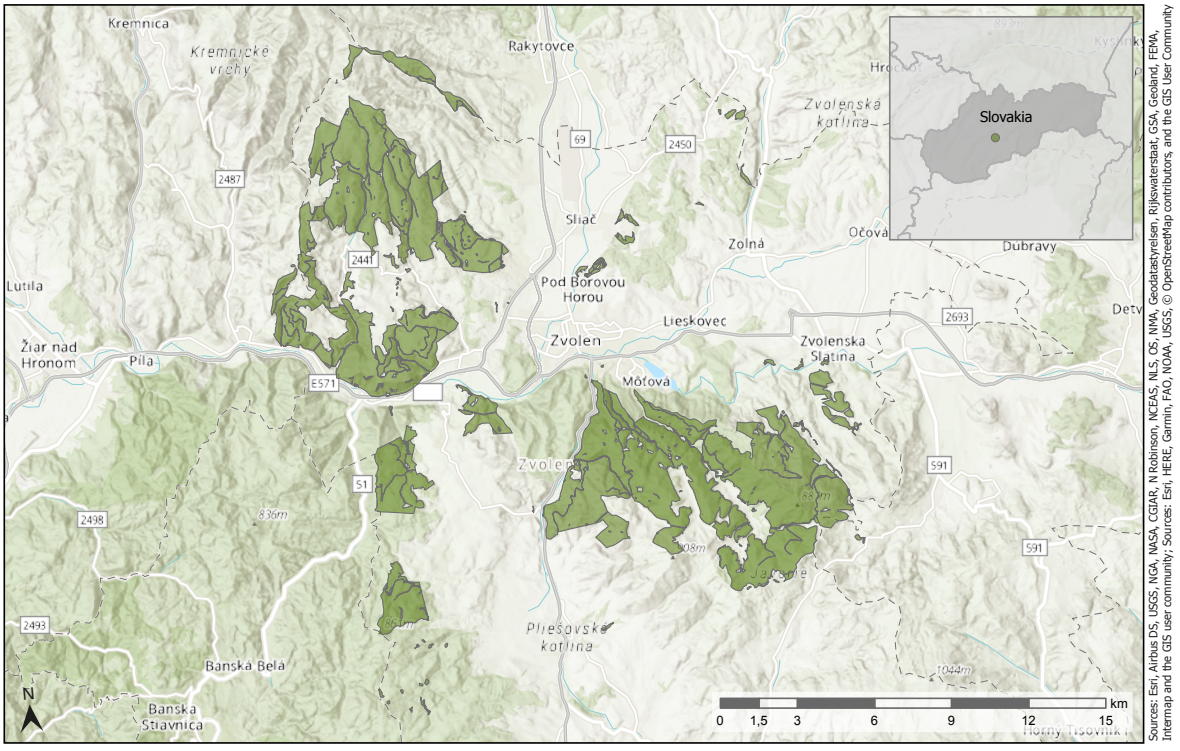
Context, legal frame and ownership structure

The main mission of the University Forest Enterprise is to provide the objects and infrastructure for the education of forestry students, the research activities in the various disciplines and the application of innovative approaches in the forestry practice. At the same time, the forests should be managed in the way that ensures the providing of wide spectrum of ecosystem services and the production of valuable timber.



< Fig. C20.1. Landscape of the mountains of Kremnica in the northern part of the University Forest Enterprise Zvolen (Photo: Milan Saniga).

Statement

"Production, ecological and environmental functions are the basis foreducation, science and society in the University Forest Enterprise Zvolen."

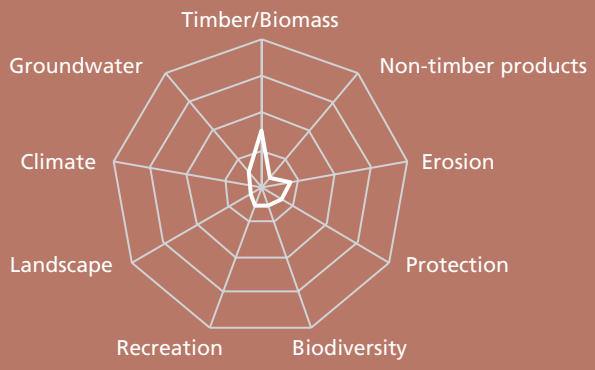


Table C20.1. General information on the forests of the University Forest Enterprise Zvolen.

Total forest area	20418 ha (all)
9 716 ha (University Forest Enterprise)	Irregular group shelterwood, group and single-tree selection systems
Main management types	small-scale shelterwood system, irregular shelterwood system
Total volume	292 m³/ha
Annual growth	6.5 m³/ha
Annual use	5.4 m³/ha
Deadwood	9.2 m³/ha (standing – 2.8 m³/ha; lying – 6.4 m³/ha)
Altitude	250–1026 m a.s.l.
Ownership	state forests
Geology	andesite, pyroclastic parent rocks
Protected area (total)	Nature reserves – 450.8 ha
Nature protection area (Natura 2000)	1329.53 ha
Function of the forests	80 % of the University Forest Enterprise has the status of special purpose forests, 14 % of protection forests, and 6 % are forests with production function

The University Forest Enterprise (UFE) of the Technical University in Zvolen is located in Zvolenská kotlina basin with its forests situated in the geographical units of the mountains of Kremnica, Javorie, and Štiavnica (fig. C20.1). UFE is an institution with a special purpose. Its aim is to maintain the practical education for study programmes at the Faculty of Forestry of the Technical University in Zvolen. Moreover, it serves as a research laboratory for the departments of the Faculty of Forestry as well as for other departments of the university. UFE is an educational object for close-to-nature silviculture in Slovak Republic. It was founded on 1 January, 1958. The original area of 5375 ha was later enlarged to the current 9716 ha. Of this area, 92.8 % is state-owned, 6 % have unknown owners, and 1.2 % is the property of the university. The altitude of the UFE forests ranges from 250 m to 1026 m, and they have variable geological, climatic, and soil conditions. According to the categories of the Forestry Act of the Slovak Republic, special purpose forests account for 80 % of the area, protection forests account for 14 %, and commercial forests with a primary production function account for 6 %.

Aims of the enterprise

The forests are used for three main purposes: educational, scientific, and commercial. Aside from production, ecological, and environmental functions, there is a specific complex of forest stands around the Sliač Spa which has a designated health function.

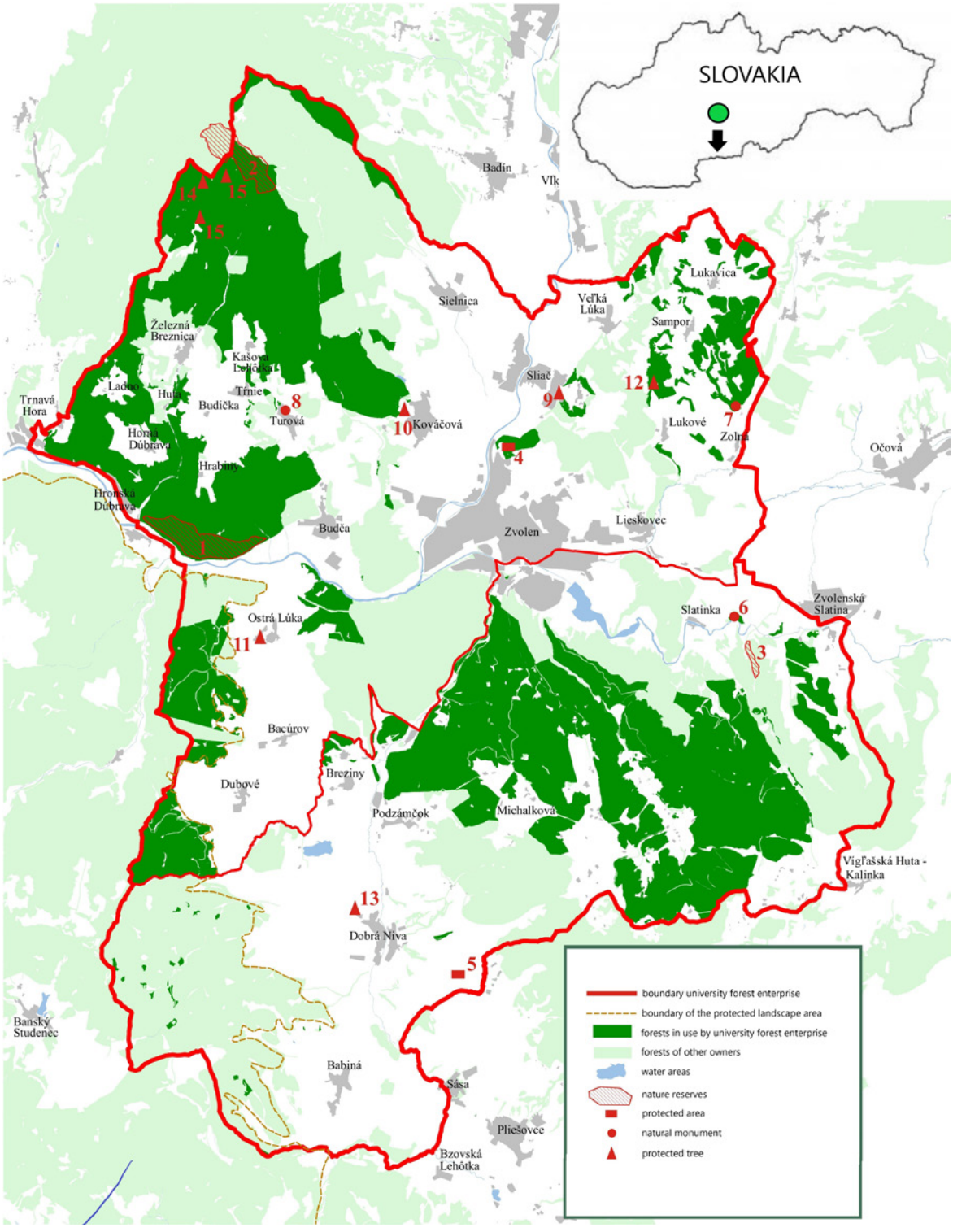


Fig. C20.2. Map of the University Forest Enterprise Zvolen.

Ecological conditions and trees species composition

The average annual temperature in UFE ranges from 4 to 8 °C and total precipitation ranges from 600 to 1000 mm. Specific measurements conducted by a network of biometeorological stations show that certain sites of UFE located at lower altitudes should be considered as deficient regarding the soil water regime during the hot and dry periods (Šulek and Ivan 2018). UFE is divided into the two forest districts of Budča and Sekier.

The tree species composition in UFE is dominated by broadleaved trees. The most abundant is beech *(Fagus sylvatica),* covering 52 % of the area. The second most abundant are oaks – sessile oak *(Quercus petraea)* and Turkey oak *(Quercus cerris)* that reach the proportion 20 %. Other broadleaved tree species include hornbeam (*Carpinus betulus,* 8 %), sycamore (*Acer pseudoplatanus,* 3 %), and ash (*Fraxinus excelsior,* 3 %). The most abundant coniferous species is Norway spruce *(Picea abies)* with 8 %, followed by Scots pine (*Pinus sylvestris,* 3 %), silver fir (*Abies alba,* 3 %), and European larch (*Larix decidua,* 1 %).

Flora and fauna

Because of its location, climatic, and soil conditions, UFE creates a suitable environment for an immense variety of plant and animal species. The southern part is more suitable for thermophilic species of steppe zone that spread from Podunajská nížina Lowland. Here in the National Nature Reserve (NNR) Boky, the steppe zone meets the broadleaved deciduous forest zone. The main habitats include forests, forest-steppes, steppes, meadows, and wetlands and water areas.

The UFE manages forests in three separate geographical units in the immediate vicinity of the city of Zvolen. All these mountain ranges have a stratovolcanic structure, formed by andesite and pyroclastic parent rocks. Their relief is considerably eroded and denuded. The diverse parent rocks, climatic, and vegetation conditions determines the diversity of plants ranging from thermophile and xenophile species on extremely dry sites, through the communities on nutrient-rich sites, and up to the elements of the montane flora. UFE forests are rich in flora and home to many protected species including: Cornelian cherry *(Cornus mas)* on the slopes of the steppe NNR Boky; grey-sheathed feather grass *(Stipa joannis)* on the steppes and rocky hillsides NNR Boky; European feather grass (*Stipa pennata* subsp. *austriaca*) rarely on rocky steppes NNR Boky; grass-leaved iris *(Iris graminea)* on rocky forest-steppe hillsides NNR Boky; rose campion *(Lychnis coronaria)* abundant on the steppe and forest-steppe hillsides of NNR Boky; Turk's Cap Lily *(Lilium martagon)* in broadleaved deciduous humid forests in the locality of Jagerka (fig. C 20.3); yellow monkshood *(Aconitum anthora)* in Turkey oak forest in close vicinity to Hronská Dúbrava; wolf's-bane *(Aconitum lycoctonum)* particularly in NNR Boky; lesser butterfly-orchid *(Platanthera bifolia)* in broadleaved and mixed forests; Mahaleb cherry *(Prunus mahaleb)* on rocky hillsides (Šulek and Ivan 2018).

Regarding the environmental demands, fauna is mostly bound to forests, forest-steppes, meadows, and aquatic habitats. Forest wildlife is mostly represented by red deer *(Cervus elaphus),* roe deer *(Capreolus capreolus),* fallow deer *(Dama dama),* and wild boar *(Sus scrofa).*

Characteristic birds in higher-altitude forests include hazel grouse *(Tetrastes bonasia)* and western capercaillie *(Tetrao urogallus)* on the northern border of the territory. The red fox *(Vulpes vulpes)* is the most abundant predator. The European badger *(Meles meles)* occurs only sporadically, and the European wildcat *(Felis silvestris),* common weasel *(Mustela nivalis),* and short-tailed weasel *(Mustela erminea)* are also rarely seen. As for protected species, 10–20 individuals of brown bear *(Ursus arctos)* (fig. C 20.4) and Eurasian lynx *(Lynx lynx)* are permanently present in these locations. In recent years, wolves *(Canis lupus)* have been observed in the northern part of UFE. These observations have found one to two packs consisting of three to five individuals, as well as one to two lone wolves. There are a larger number of protected bird species present in the area. Thermophilic species, such as common rock thrush *(Monticola saxatilis)* can be found in the southern part of Kremnické Mountains. Higher altitudes of the northern part are home to mountain species, such as the spotted nutcracker *(Nucifraga caryocatactes).* Rare species, like the lesser spotted eagle *(Aquila pomarina),* Eurasian eagle-owl *(Bubo bubo),* common raven *(Corvus corax),* black stork *(Ciconia nigra),* and others are also present. Some of the rarely seen

Fig. C20.3. Turk's Cap Lily *(Lilium martagon).* Location: Jagerka (Photo: Milan Saniga).

Fig. C20.4. Brown bear *(Ursus arctos)* (Photo: Tibor Pataky).

species of reptiles occur on southern parts of rocky hillsides in the valley of the River Hron. These include the common wall lizard *(Podarcis muralis),* green lizard *(Lacerta viridis),* Aesculapian snake *(Zamenis longissimus),* and European adder *(Vipera berus)* (Šulek and Ivan 2018).

Nature Reserves

There are two National Nature Reserves (NNR) and one Nature Reserve (NR) located in different environmental conditions that serve especially for the teaching of environmental science:

– NNR Boky – vegetation zone of oaks – thermo and xerophilous communities (147.09 ha);
– NNR Mláčik – vegetation zone of fir and beech (147.2 ha);
– NR Prosisko – vegetation zone of beech and oak with the pre-glacial relict species *Geum ternatum* (20.8 ha).

NNR Mláčik was established in 1982 with the aim to protect and conserve the fir–beech forest community with the occurrence of common alder. The most abundant tree species in the forest stands of the reserve is beech (45.5 % of the NNR area). Other frequently occurring species include silver fir (24.2 %), ash (15 %), sycamore (8.3 %), Norway spruce (6.2 %). Mountain elm *(Ulmus glabra),* rowan *(Sorbus aucuparia)* and common alder *(Alnus glutinosa)* are also present.

The upper layer of forest stands is formed by beech and silver fir with an average age of 150–180 years. The oldest silver fir is about 205 years old. Mixing of tree species occurs on various levels from individual and group to areal. The middle layer is dominated by ash, beech and sycamore. The dominant species of natural regeneration is beech; on favourable sites, regeneration of silver fir and mountain elm is abundant. Many individuals of natural regeneration are damaged by ungulates (browsing). Noble hardwoods (ash, sycamore) and silver fir as well, are damaged by bark stripping by deer, even at older ages. The majority of the reserve is in the mature stage and the initial phase of the decay stage. Taking into consideration the absence of the other developmental stages and the active management until 1970, NNR Mláčik cannot be considered a secondary 'primeval forest' yet. The intention behind the cessation of management in NNR Mláčik was to conserve the original fir–beech forest community leave this to develop naturally (fig. C 20.5).

NNR Boky is situated on a steep slope at the southern border of the Kremnické Mountains, between the villages Budča and Hronská Breznica, district Zvolen (fig. C 20.6). The altitude ranges from 280 to 589 m a.s.l., the mean annual temperature is 6.2–8.0 °C, vegetation period comprises 154–164 days. The mean annual precipitation ranges from 700 to 820 mm and the number of days with snow cover is 55–80 per year (Bublinec and Pichler 2001). The main tree species are: sessile oak (40 %), Turkey oak (30 %), hornbeam (25 %), and beech (5 %). The reserve is situated at the edge of the distribution of Turkey oak. The occurrence of Turkey oak at different localities and with different admixtures of other tree species allows us to study its ecology and increment trends. The obtained knowledge can be applied in management of Turkey oak forest stands in southern Slovakia (Magic 1968). The forest stands in the reserve belong to the oak (1.), beech–oak (2.) and oak–beech (3.) altitudinal vegetation zones and to four forest type groups (FTG) and five forest types (FT). The most frequent FTG is Fageto-Quercetum (53 %), followed by Corneto-Quercetum (32 %). Areas of Tilieto-Aceretum (13 %) are present in valleys. There are also areas of Querceto-Fagetum tiliosum (2 %)[1] (Hančinský 1972).

There is a long tradition of building memorials to distinguished personalities who have contributed to the development of forestry and forest science in Slovakia (fig. C 20.7).

Economy

In 2018, 55 678 m³ of wood was harvested at UFE (Ivan 2018). The proportion of softwood was 8614 m³ (15.5 %). Hardwood accounted for 47 064 m³ (84.5 %).

[1] Typological units used in Slovakia are based on Zlatnik's phytosociological system (Zlatník A., 1953: Fytocenologie lesa, SZN Praha). The forest type groups are defined as a set of plant communities comprising also their environment (geobiocoenoses) and including their developmental stages characterised by their plant species compositions, structures of tree vegetation layers, and having a common set of species in the herbaceous vegetation.

Timber cutting and extraction was carried out by contractors (69.1 %) or by UFE workers (30.9 %). The annual income from timber sales in 2018 amounted to 3 705 738 €, the income from the sale of seedlings was 31 101 €, and the income from hunting was 47 130 €. Fishing revenues amounted to 2862 € and honey sales were 304 €. In 2018, the total annual income reached 3 787 135 €. The structure of total annual costs (3 389 156 €) included the costs of cutting and extracting timber (51.5 %), administration costs (29.4 %), maintenance and development of infrastructure (especially forest roads – 10.1 %), costs of production of planting material (2 %), tending of young stands (3.9 %), and protection of forest stands (3 %). Over the next decade (2019–2028), timber cutting will decrease by 18–20 %. The proportion of natural regeneration will increase to 85 %. The costs of cutting and extraction of timber are expected to increase, as is the income from selling timber.

Silviculture

The composition of the UFE forests is dominated by native tree species and this means that natural processes can be used to ensure the ecological stability of the forest. The basis of forest management is small-scale shelterwood system.

The predominant tree species is the beech (51.6 %) along with sessile oak (16.2 %) and Turkey oak (3.3 %). This means the stands are stable and there is potential for targeting diameter and height differentiation and increasing production of high value timber trees. Both targets can be achieved by consistent application of close-to-nature forestry. For this purpose, a new silvicultural concept of so-called 'mosaic' stands is being developed and applied in the forest stands of UFE (fig. C 20.8).

The mosaic structure of forest stands understands the forest as ecosystem, including all of its functions. The aim of the management is to make optimal use of natural processes and the ecological characteristics of the dominant tree species (i. e. beech, oak). This forest will consistently be able to perform the required functions (Saniga 2010). Beech is supposed to play a stabilising role in the forests of Slovakia in the future in connection with climate change.

This nature-based management system was created on the basis of research on broadleaved virgin forests of Slovakia. The system uses the develop-

Fig. C 20.5. Structure of the forests in NNR Mláčik (Photo: Milan Saniga).

Fig. C 20.6. Structure of the forests in NNR Boky (Photo: Milan Saniga).

Fig. C 20.7. Memorial to Prof. Štefan Korpeľ, the key figure behind the promotion of close-to-nature silviculture in Slovakia (Photo: Milan Saniga).

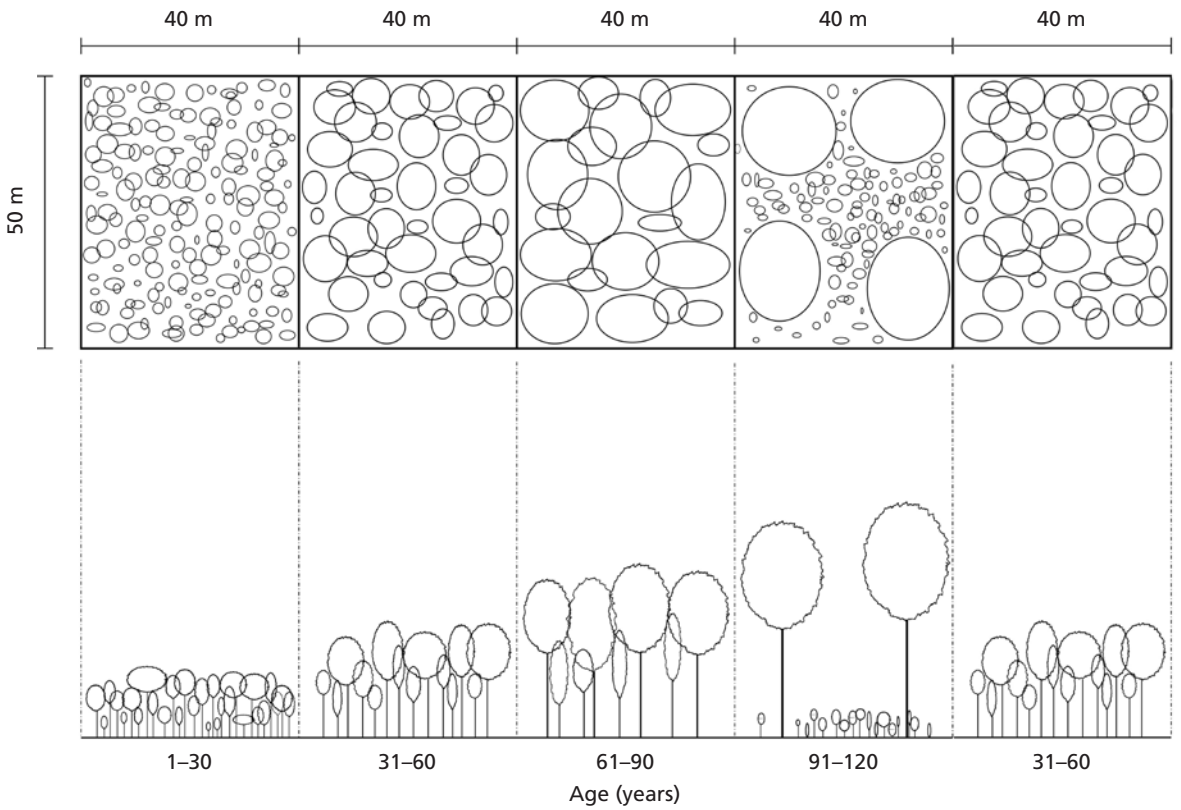


Fig. C20.8. Model of value increment management for beech mosaic stands (Saniga 2010).

mental stages of beech and oak primeval forests as a model for the management of stands. An example is the ProSilva demonstration object – mixed stands with dominant sessile oak that are concentrated in the locality of Kremenný potok (102.6 ha) (fig. C20.9). The structure of these forest stands represents different phases of conversion of forest management according to age-classes into forest management according to diameter classes. This complex serves mainly for educational purposes for students of the Faculty of Forestry and forest practitioners.

Mosaic structure of broadleaved stands with dominant of beech include the ProSilva demonstration represented by stands 585b, 513, and 515 (26.5 ha) (fig. C20.10).

Conclusion

The mosaic concept of forest stands considers the forest as an ecosystem including all its functions. It aims to form a forest that can deliver the functions in perpetuity through optimal utilisation of natural resources while taking the ecological requirements of tree species into consideration (permanent forest). The essential and dominant tree species of UFE is beech, which will be, considering expected climate change, a stabilising tree species in Slovakian forests (where it is the most abundant species) in the future. The UFE forests cross five altitudinal vegetation zones, and combined with good accessibility to the forests, this means that a variety if silvicultural methods are suitable for achieving the desired tree species composition. The small-scale shelterwood system is the main silvicultural method used; using optimum timing and extraction

Fig. C20.9. Mosaic structure with a dominant representation of oak, stand 584 (Photo: Milan Saniga).

Fig. C20.10. Mosaic oak–beech stand 585b (Photo: Milan Saniga).

Fig. C20.11. Beech stand with selection structure in University Forest Enterprise TU Zvolen (Photo: Milan Saniga).

Fig. C20.12. Excursion for forestry practitioners (Photo: Peter Gogola).

methods, this system allows maximum utilisation of natural processes in forest ecosystems as well as achieving the aim of high ecological stability. Besides this silvicultural system, the concept of mosaic stands is also gradually being applied. The principal target of forestry activities under the conditions of the UFE is an active application of the principles of silviculture based on natural processes.

Professional employees of the enterprise, in close cooperation with the teachers and scientists from the Faculty of Forestry, directly participate in the preparation of decennial forest management plans to support the application of shelterwood and selection silvicultural systems along with maximum utilisation of the natural potential of stands of native tree species (fig. C20.11). Through an optimum utilisation of natural forces and ecological laws, this forest management strategy strives to form the forest in such a way, that it will fulfil all required functions in perpetuity.

Final statement

The UFE of the Technical University in Zvolen with its tree species composition can be used as a model for the management of broadleaf-dominated forest stands in Slovakia. Silvicultural systems used in forests located in UFE are based on the principles of close-to-nature management and serve as a natural laboratory not only for students but also for forestry practitioners (fig. C20.12).

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Valle die Susa – Management of multifunctional forests in the heart of the western Italian Alps

C21

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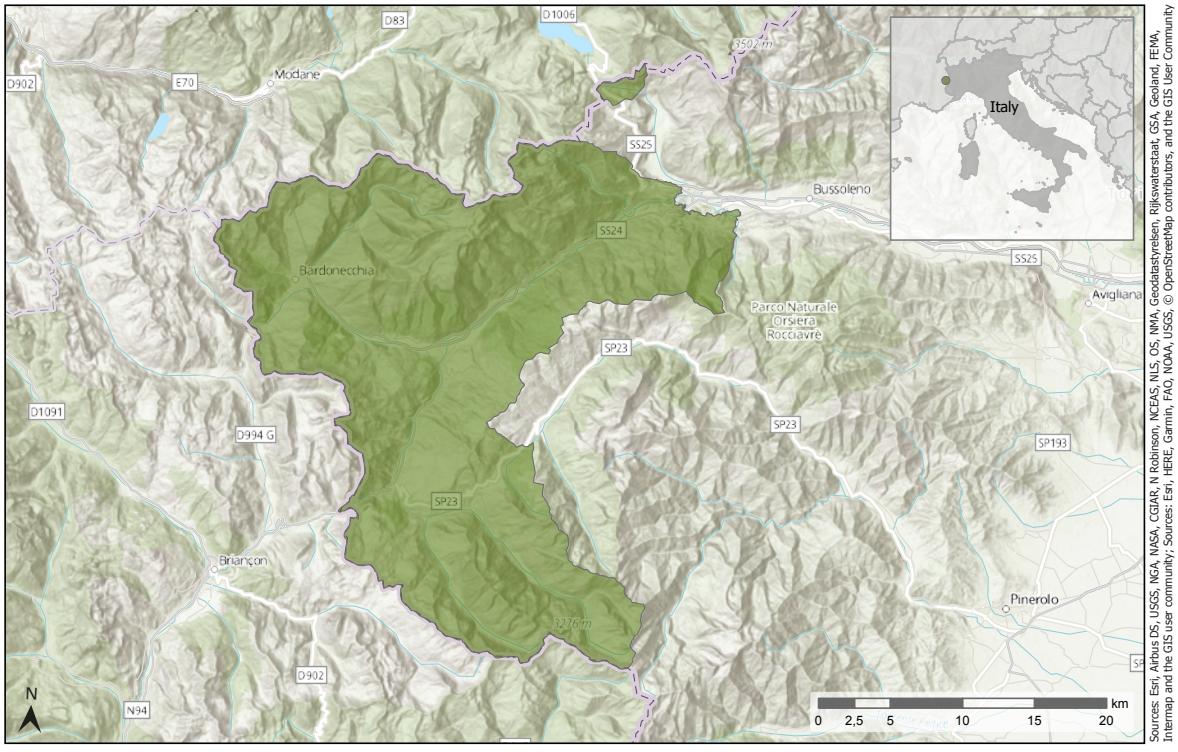
The Upper Susa Valley Forest Consortium (Italian: Consorzio Forestale Alta Val di Susa, CFAVS) was established in 1953 with the purpose of managing pastures and forests owned by the municipalities in the Upper Susa Valley (fig. C21.1). The socio-economic context in the 1950s was considerably different from nowadays, and so over time, the CFAVS has responded to the changing social and administrative context by maintaining the key objective of managing the forest–pastoral resources, and expanding its competences to the management of safety and the environment, thus responding to current needs and opportunities.



< Fig. C21.1. View over the Gran Bosco di Salbertrand Natural Park and the Alps in the Upper Susa Valley (Photo: CFAVS).

Statement

"Production and protection forests in a changing environment."

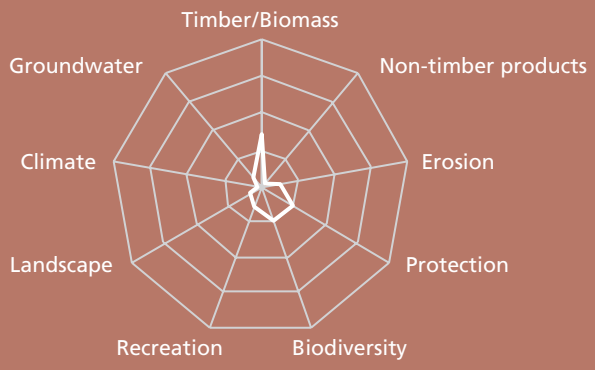


Table C21.1. General information on the forests of the Upper Susa Valley Forest Consortium.

Total forest area	18600 ha
Total volume	Up to 500 m^3/ha
Annual growth	Up to 2.2 m^3/ha
Annual cutting rate	3000 m^3
Main management types	Group and single tree selection cutting, group cutting
Deadwood	Up to 20 m^3/ha
Elevation	600–2400 m a.s.l.
Climate	Mean annual temperature 7.4°C (range 2.9–10.1 °C), annual precipitation 960 mm (range 650–1350 mm)
Soil	Predominantly brown soils, generally slightly evolved
Ownership	70 % public, 30 % private
Protected areas	3985 ha
Natura 2000 areas	9232 ha
Protection forests	4500 ha

Context

Geography

The Susa Valley (Italian: Val di Susa) lies within the boundaries of the Metropolitan City of Turin, in the Piedmont region of northern Italy, located between the Graian Alps in the north and the Cottian Alps in the south (fig. C21.2). It is one of the longest valleys of the Italian Alps. The valley is of glacial origin with an east–west course, characterised by the presence of two important and historical natural Alpine passes, Montgenèvre (1854 m a.s.l.) and Moncenisio (2083 m a.s.l.), which over the centuries have made the valley a preferred connection between France and Italy (Marincioni and Appiotti 2009; Gras and Tonini 1991).

The anthropic presence in the valley has always been quite intense, as evidenced not only by the archaeological findings, but also by the morphology of the territory, characterised by large areas enclosed by dry stone walls to allow cultivation, and the presence of ancient villages with typical local architecture (Giordano *et al.* 2016).

The Susa Valley is a transversal endo-alpine valley characterised by low precipitation. The weather systems that bring precipitation to the valley originate from the encounter of cold air masses of North-Atlantic origin with hot-humid air masses of North African origin. During winter, warm and dry foehn winds blow from the west. Winds coming from the east bring more humid air masses but, after the first stretch of the valley (up to Condove), they reach the upper valley with reduced humidity (Brun 1989).

These climatic features determine numerous environmental peculiarities, such as habitats of

Fig. C21.2. Protected species of particular interest within the areas managed by the CFAVS: alpine ibex (left) and bearded vulture (right. Photos: Davide Pittavino).

high environmental value and several endemic animal and plant species present in the Susa Valley (fig. C22.2). The Susa Valley hosts three regional natural parks (Gran Bosco di Salbertrand Natural Park, Orsiera Rocciavrè Natural Park, Val Troncea Natural Park) and one provincial park (Lake Borello – Oulx Pond), as well as 15 Special Areas of Conservation (SAC, Italian: Zone Speciali di Conservazione, ZSC) established within the EU Habitats Directive (Natura 2000).

The CFAVS manages the properties of the 14 municipalities in the westernmost part of the Susa Valley: Bardonecchia, Cesana Torinese, Chiomonte, Claviere, Exilles, Giaglione, Gravere, Meana di Susa, Moncenisio, Oulx, Salbertrand, Sauze d'Oulx, Sauze di Cesana, and Sestriere. The managed properties account for approximately 18600 ha of PEFC (Programme for the Endorsement of Forest Certification) certified forests, in both mesalpic and endalpic zones, distributed from the bottom of the Dora Riparia Valley to the upper limit of trees and vegetation. The public (municipal) property covers about 70 % of the territory and interfaces with small patches of private property. The state/demanial property is very limited (<1 %).

Landscape context

The landscapes of the area covered by the CFAVS are diverse, as they cover a climatically and morphologically varied territory that develops on slopes with prevailing north–south exposures and more limited portions on the remaining quadrants and altitudes, which range from 600 m a.s.l. near Susa to the tops of the mountains that touch 3500 m a.s.l., with pioneer subalpine forest stands reaching 2400 m a.s.l.

The bottom of the valley is urbanised and affected by linear infrastructures (highways, state roads, railways), with limited portions of land still used for agriculture. Forests occupy large areas along the slopes, while alpine pastures and rocks are found at higher elevations. Nowadays, glaciers occupy very limited parts of the territory.

The prevalent endalpic context of the upper Susa Valley favours the presence of European larch *(Larix decidua)* woods, which makes up 66 % of the forests, followed by Scots pine *(Pinus sylvestris)* forests (15 %), which dominate the south facing slopes (fig. C21.3). Other forest formations of significant interest are those dominated by silver fir *(Abies alba),* present in cool sites of the mountain plain (<10 %), and mixed maple–linden–ash (*Acer pseudoplatanus* and *A. opalus–Tilia platyphyllos* and *T. cordata–Fraxinus excelsior*) stands and chestnut *(Castanea sativa)* groves that characterise the low elevations. The remaining limited and fragmented forest areas are extremely varied, including chestnut, beech *(Fagus sylvatica),* alder (*Alnus viridis* and *A. incana*), Norway spruce *(Picea abies),* oak (*Quercus petraea* and *Q. pubescens*), riparian formations and reforestation. Some of these, however, represent sites of high interest and importance, and are in some cases protected by the Natura 2000 Network (fig. C21.3).

The forest stands are managed as high forests. Coppice stands, which have always been poorly

represented on municipal properties, are in the process of active or passive conversion into high forests.

Ownership structure

The CFAVS is a company owned by the 14 member municipalities. It does not receive public financial contributions, but participates in calls for projects and works that guarantee the annual functioning of the CFAVS, and supports the technical sectors of the mountain communities (Italian: Unioni Montane) and municipalities.

The CFAVS is administered through: the Assembly of Mayors, which dictates the political and institutional guidelines; a Board of Directors, which updates and coordinates the decisions taken; and a Technical Director who coordinates the personnel and the specific work.

The CFAVS employs about 35 people and is divided into five functional areas that meet the different needs of the territorial management:

1. Forests: active forest management, forest planning, pasture management, trail network, Natura 2000 Network, fires, Rural Development Programmes (Italian: Programma di Sviluppo Rurale, PSR) and Interreg funding.
2. Mountain basins: planning and management of land management works, maintenance, disruptions, naturalistic engineering, and forest road network.
3. Forest construction sites: implementation of works and interventions for the ordinary and extraordinary maintenance of the territory.
4. Surveillance: originally a fundamental service of the CFAVS; currently the surveillance function in the strict sense is in decline, in favour of technical roles in the territory.
5. Administrative area: economic, financial, and personnel management.

The CFAVS manages about 66 300 ha of total municipalities areas, of which about 47 700 ha are municipal land other than forest (mainly pastures, rocks, and screes), and about 18 600 ha are municipal forest areas.

Forest history and cultural heritage

The Susa Valley is an historical transit route of international importance for trade, war, and people (Marincioni and Appiotti 2009).

The war events until 1700 had a major impact on the extension and management of the forests, with strong pressure on the whole rural complex, while from 1800 the territory and the environment of the valley were mainly influenced by the industrial development (transportation system, metallurgical industries, textile industry, and mining). In this context, the CFAVS was founded in 1953 to manage a natural heritage in need of strong protection and that was still an important economic resource.

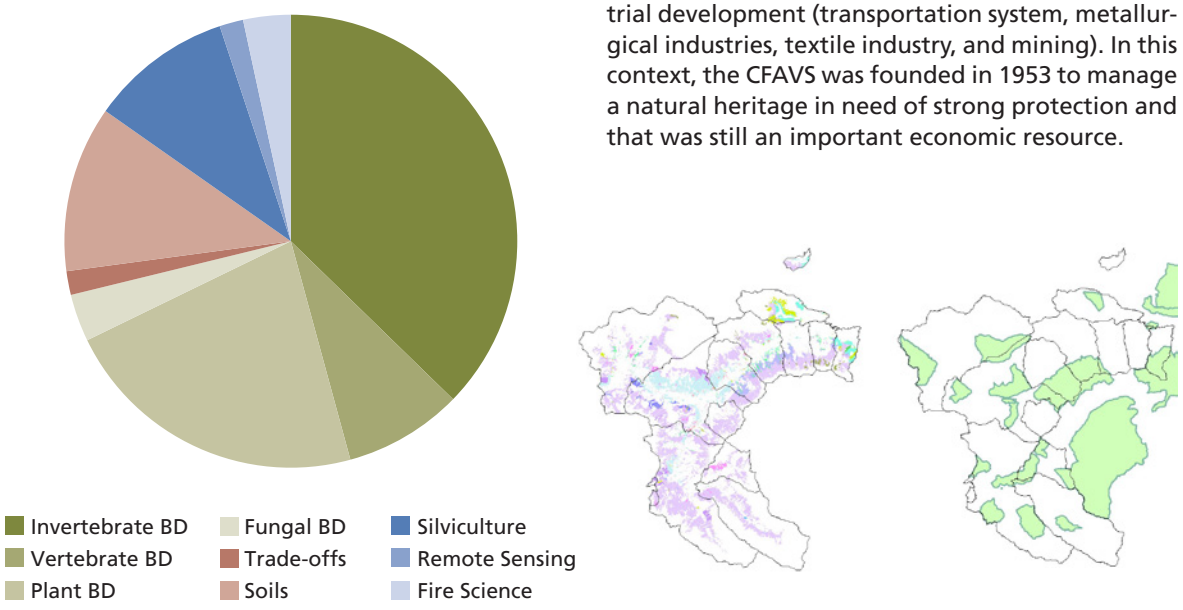


Fig. C21.3. Species composition of the forests managed by the CFAVS (left) and their location within the consortium (middle); sites of the Natura 2000 Network (in green) in the Upper Susa Valley (right).

Over time, the economic value of wood as a raw material has gradually decreased, while aspects related to the safety of the territory, guaranteed by important maintenance works on roads, watercourses, and the forest stands themselves, and the externalities guaranteed by the forest (i.e. landscape, tourism, wildlife management, environmental protection and biodiversity, carbon credits) have assumed an increasingly important role, refocusing forest resources in relation to human activities (fig. C21.4).

At the same time, the wood market has been greatly reduced in terms of volume and economic value. There has also been an increase in interventions with multiple purposes associated with the production of raw materials after disturbances (e.g. avalanches and wind), and the maintenance and improvement of the externalities offered by the forests (e.g. biodiversity, resistance and resilience, fire prevention, and water regulation).

Undoubtedly, climate change, whose effects on forests are not immediately evident and quantifiable, requires consideration and the development of new strategies to address climate threats to forest ecosystems. The increase in frequency and magnitude of natural disturbances recorded in recent decades calls for a substantial change of perspective compared to traditional forest management. New technologies, such as remote sensing (including satellite and Lidar data) are used to address these problems.

Extensive disturbances caused by Storm Vivian (February 1990) occurred in the Susa Valley; the forests have shown a remarkable ability to recover, even if the recovery has been slow because of the local climatic characteristics. The observations related to the recovery of forests after Storm Vivian have helped forest technicians to contextualise the most recent disturbances related to tree falling caused by avalanches (2008), heavy snowfalls (2012–2016), strong winds and, in the territory of the middle Susa Valley, large forest fires (2017).

Demand for forest products

The active forest management responds on a local scale to the demand for larch timber to make shingles (a typical roofing material in the Susa Valley) and load-bearing structures for flagstone roofing, in addition to the supply of different carpentry assortments of larch. Parallel to the management of larch stands, silver fir and pine forests offer discrete quantities of wood, suitable for the production of packaging. The silvicultural interventions for the production of these assortments are techni-

Fig. C21.4. Nature-based tourism and outdoor recreation are important ecosystem services in the Upper Susa Valley (Photo: CFAVS).

cally managed by the CFAVS by means of forest plots assigned to mainly local forest owners by public auction, the revenues of which remain at the disposal of the municipality owning the forests.

The forests of the Upper Susa Valley also supply small quantities of high-quality timber such as assortments of Swiss stone pine *(Pinus cembra),* much appreciated in small carpentry, or sporadically very high-quality larch beams for specific processes, such as ship masts, and Norway spruce specially selected for the trial production of violins.

Assortments of larch of lower quality are often used for naturalistic engineering works (e.g. crib walls, barriers, and tripods) that use local materials and specific operating techniques for the realisation of highly functional works, which are well inserted in the territorial context under the ecological, landscape, and environmental aspects (fig. C21.5).

Residents in the Upper Susa Valley are also entitled to request small quantities of wood for domestic heating. The CFAVS, as manager of the municipal forests, identifies suitable trees considering that the operators, in this case, are not highly qualified to carry out the cuttings. Therefore, the timber allocated must be relatively easy to cut. These operations allow the thinning of stands that do not provide valuable assortments.

Finally, the management of forests in tourist areas (e.g. ski slopes) and in natural parks requires particular attention to the social and environmental context in which such stands are located: analyses conducted by the CFAVS have shown that the application of silvicultural criteria that respect the specific needs of a given territory does not compromise the productivity or the quality of the assortments provided. These aspects must be linked to careful forest planning and continuous evaluation involving all stakeholders who interact with the work of the technicians and the forest managers.

Main products and other ecosystem services

The main wood products of the CFAVS are:
- Timber wood from larch;
- Swiss stone pine for fine carpentry (fig. C21.6);
- Larch for specialised carpentry uses (e.g. beams, matchboards, and shingles);
- Larch for naturalistic engineering (e.g. crib walls, barriers, and tripods);
- Scots pine, Norway spruce and silver fir for packaging;
- Beech and other broadleaves for firewood;
- Assignments of wood for civic use (mainly beech, ash and larch, but also Scots pine, silver fir and other species are assigned as needed).

The multifunctional forests of the Upper Susa Valley offer other services and goods in addition to timber production:
- Protective function of forest stands that directly protect towns, infrastructures, and human activities from natural disturbances (e.g. avalanches and rockfalls);
- Ecological function, protection of biodiversity, and conservation of particular habitats and species (Natural Parks, Natura 2000 Network, fig. C21.7);
- Tourist-recreational function linked to the tourist vocation of the Upper Susa Valley, with the

Fig. C21.5. Larch crib wall (left) and tripods (right) (Photos: CFAVS).

Fig. C21.6. Wood pile of Swiss stone pine, Piccolo Bosco di Salbertrand, Gran Bosco di Salbertrand Natural Park (Photo: CFAVS).

presence of ski resorts, areas of public use adjacent to the villages owned by the municipalities, forests located along high traffic roads;
– Landscape function that characterises the mountain and alpine context of the Susa Valley.

Specialities and rarities
– 3 regional natural parks (Gran Bosco di Salbertrand, Orsiera Rocciavrè, Val Troncea, belonging to the Cottian Alps Protected Areas Management Authority);
– 1 provincial park (Lake Borello – Oulx Pond);
– 15 sites of the Natura 2000 Network;
– 11 veteran trees (fig. C21.8).

Numerous protected species, of which of particular interest:
– Wolf *(Canis lupus),* living in the Susa Valley in three stable packs (listed in Annex II of the EU Habitats Directive, but also protected by the Bern Convention, CITES, and the EU regulation of trade of fauna and flora);
– Alpine ibex *(Capra ibex),* present in the Upper Susa Valley on rocky slopes with southern exposure (listed in Annex V of the EU Habitats Directive, but also protected by the Bern Convention);
– Bearded vulture *(Gypaetus barbatus),* present in the Gran Bosco di Salbertrand Natural Park (listed in the EU Birds Directive, the Bern Convention, CITES, and the EU regulation of trade of fauna and flora).

The CFAVS does not do and is not responsible for wildlife management. The conservation of the protected species is, however, an integral part of the applied forest management system.

Applied management system
The main silvicultural systems applied are:
– Group cutting: in pure mono-layered larch forests (fig. C21.9), mature beechwoods.
– Group and single tree selection cutting: in larch woods, Scots pine forests (fig. C21.10), mixed and multi-layered stands with silver fir and Norway spruce, beech woods, pure silver fir stands, subalpine woods, maintaining large margins within the forest stand.
– Thinning: applied during the juvenile phases of forest stands.

Fig. C21.7. Fall colours in the Gran Bosco di Salbertrand Natural Park (Photo: CFAVS).

– Conversion to high forest: in beechwoods previously managed as coppice woods.
– Controlled evolution: typical of protection forests where there is no active management but a periodic monitoring followed by possible interventions aimed at maintaining and improving the protective role of the forest.

Aims of the enterprise

What are the preconditions? Being a Consortium of Municipalities, the CFAVS must meet the technical needs of the municipalities for territory management. Additionally, the CFAVS must coordinate its activities with other territorial administrations, such as park authorities, the region, the Metropolitan City of Turin, and other associations acting on the territory.

What are the tasks? The main tasks of the CFAVS are the management of the municipal forest–pastoral properties and the maintenance of the territory.

Fig. C21.8. Veteran beech *(Fagus sylvatica)* in Moncenisio, Upper Susa Valley (Photo: CFAVS).

Fig. C21.9. Group cutting and natural regeneration (right) in the Gran Pertiche larch forest (Photos: CFAVS).

Fig. C21.10. Group (left) and single tree (right) selection cutting in Scots pine forests (Photos: CFAVS).

What are objectives and trade-offs? The silvicultural management in itself is not sufficient to ensure the functioning of a structure such as the CFAVS, and is thus subordinate to the management of other more remunerative activities. The forest management, however, remains the objective of the CFAVS, and is also an efficient way to support local supply chains and to contribute to land management in different ways, providing multiple ecosystem services.

Strengths and weaknesses

Management

- The presence of extensive larch forests producing wood assortments is the strong point of the active forest management of the CFAVS;
- The higher revenue is provided not by silviculture but by the ordinary maintenance of the territory (Italian: Autorità d'Ambito Torinese, ATO Funds) and the participation in the Rural Development Programmes (PSR);
- Every activity must safeguard the protection goals of the protected areas in the territory (Parks and Natura 2000 Network);
- In the last 10 years the CFAVS has followed programmes to improve the local hiking network through the creation of hiking trails, the maintenance of trails, the preparation of signs and rest areas, in compliance with PSR calls;
- The forests affected by the natural disturbances in the Upper Susa Valley have shown good resilience, although in some cases climatic and local factors determined a slower forest recovery. In certain conditions (xeric or particularly cold slopes) the forest dynamics are particularly slow. The CFAVS integrates principles of close-to-nature silviculture into management plans, to favour, in the medium- and long-term, the presence of mixed and multi-layered forests that are more resilient to biotic and abiotic disturbances;
- The policy generally intervenes on issues that from a technical and management point of view are known, by providing and standardising rules and methodologies. The scientific information available on many topics, and the rapid evolution of tools and technologies to address problems, require that professionals update their knowledge and skills; this is difficult to guarantee and maintain, even by the administrators.

Policy

The reference legislation for the CFAVS is primarily at the national and European level; specific regional regulations also apply. The region is the legal entity with which to interface to respond to all technical and management needs, sometimes also with proposals and special agreements in support of decision-making.

Science

The CFAVS mainly plays a technical role. However, the staff often contributes to scientific and material support into research projects. The CFAVS collaborates with the University of Turin, the Institute for Wood Plants and the Environment (Italian: Istituto per le Piante da Legno e l'Ambiente, IPLA S.p.A.), the Piedmont region, and sometimes the Polytechnic of Turin and various French Institutions and Associations (e.g. Centre Regional de la Propriété Forestière–CRPF, Office National des Forêts–ONF, Restauration des Terrains de Montagne–RTM) on experiments and studies, also of innovative nature, to develop new technologies and empirical models.

Communication

Communication is a time-consuming task that requires specific skills to be effective. The CFAVS is a structure supporting municipalities that also operates in the management of private properties, supporting citizens through the Forestry Desk (Italian: Sportello Forestale). Through this service, interested citizens can request, free-of-charge, advice and support for the management of their own forests, also for commercial purposes. In particular, the CFAVS promotes the associated management of forests, acting as a mediator between managers, owners (public and private), local users and citizens in order to coordinate time, area, objectives, and results of the active forest management.

Existing and required tools to support the work of the enterprise

The CFAVS has been involved in active forest management for decades, constantly updating its forest management plans and databases. Today there is a need to optimise and standardise the data that are transmitted to different offices following different procedures that comply with current regulations. In this regard, the CFAVS collaborates with other institutions to optimise procedures that link the forest management plans of the CFAVS to the related

documents transmitted to the region (e.g. forest management authorisation documents, data related to cuttings and harvest plans). The update and implementation of internal procedures of the CFAVS serve as a blueprint for the management of such issues at the regional level.

The management of authorisation procedures for interventions on sites within the Natura 2000 Network requires the compilation of environmental assessments of the interventions and of the forest management plans themselves. These do not yet follow a clearly defined structure, and thus, still require to make evaluations and comparisons with the management bodies of the protected areas. In this context, it is still necessary to find strategies and documents able to meet the needs of the different stakeholders in respect of their institutional roles.

Conclusion

The objectives of the CFAVS are achievable with the commitment and cooperation of other administrations. The main challenges derive from the continuous, constant and rapid changes in the areas of work (i.e. regulations, technologies, scientific aspects and climate change) which must be promptly tackled to maintain levels of performance appropriate to the needs.

The CFAVS needs to remain faithful to its territorial management objectives. However, the consortium has a strong need to renew itself and adapt once again to the changing social, economic, technological and natural scenarios, also through the support of new personnel with specific and targeted skills and assignments.

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Langau – Close-to-nature management, reflections based on 20 years of experience

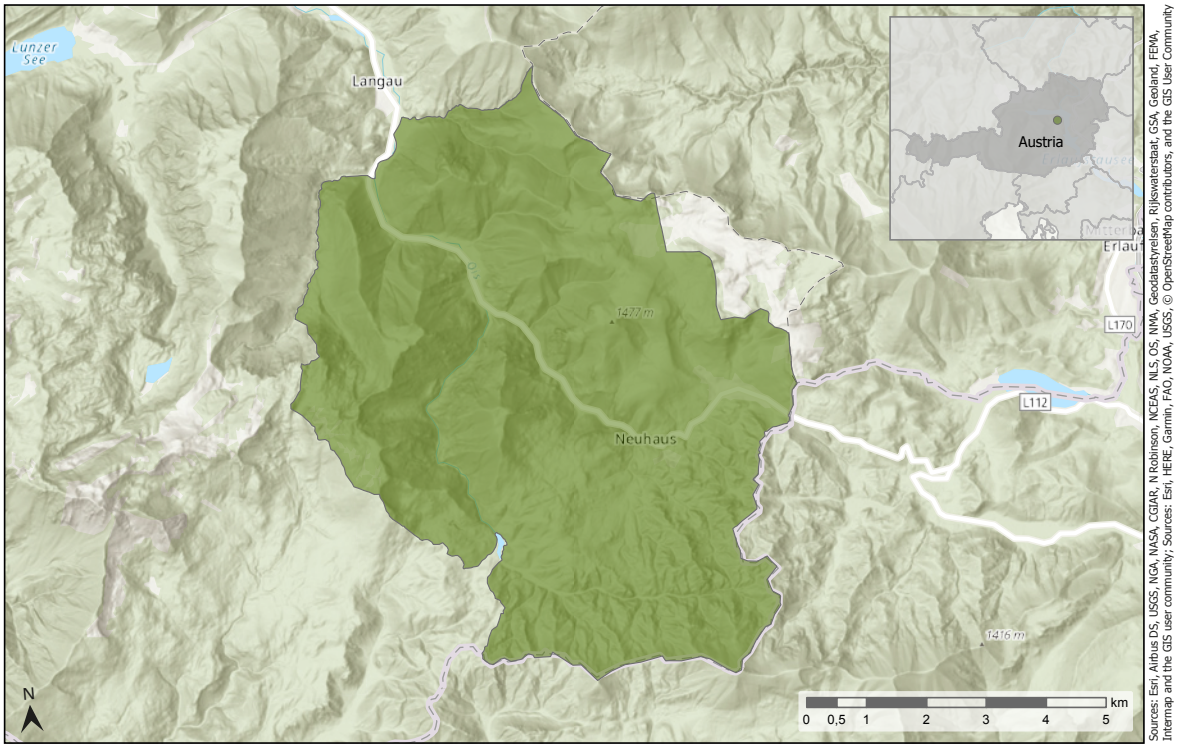
C22

J. Doppler

Forstverwaltung Langau, Gaming, Austria

Context, legal frame, and ownership structure

The private forests of the former 'Rothschild'sche Forstverwaltung Langau' are located in southern Lower Austria on the border to Styria. The complete forest enterprise has very recently changed ownership in 2018/2019. It is now owned by the Prinzhorn Holding. The information presented in this case example refers to the developments taking place under the ownership of the 'Rothschild'sche Forstverwaltung Langau'.



< Fig. C22.1. Mixed mountain forest – the optimal stand (Photo: Johannes Doppler).

Statement

"The key to the success of close-to-nature management is to ensure continuity."

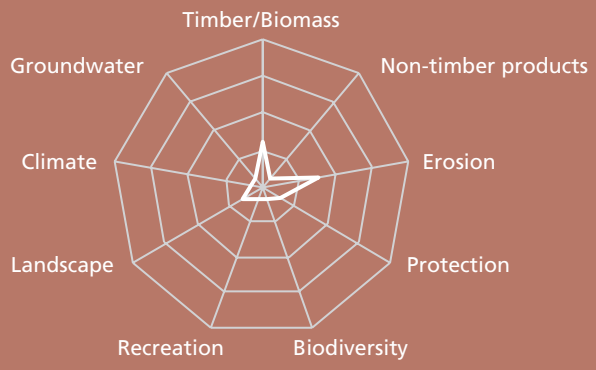


Table C22.1. General information on the Langau forest.

Total forest area	8431 ha
Organisational structure	four forest districts managed by four foresters; one head forest manager
Main management types	No clearcutting since 1994; selective felling at varying intensities
Total standing volume	2600000 m³
Annual growth	5 m³/ha
Annual cut	42000 m³
Deadwood (standing and lying)	50 m³/ha (estimated)
Altitude	1050 m a.s.l.
Ownership	Rothschild'sche Forstverwaltung Langau (owners of the trust were the members of the Rothschild family); since 2018/2019 the forest is owned by Prinzhorn Holding
Climate	Typical climate of the alpine foothills with high precipitation; seasonal extremes in late winter falling mainly as snow; often rainy periods in June/July; low annual average temperature (~5.7 °C)
Soil	Shallow dolomite rendzina soils; limestone brown loam; gravel in floodplain areas
Geology	Northeastern limestone Alps: limestone, dolomite with occasional occurrence of sandstone
Protected areas	1159 ha of wilderness area ('Wildnisgebiet Dürrenstein'); 216 ha of strict forest reserves ('Hinterer Oiswald') 11 ha of old-growth islands/patches
Natural forest community	Submontane and montane Norway spruce–fir–beech forests *(Picea abies–Abies alba–Fagus sylvatica)* with sycamore *(Acer pseudoplatanus),* ash *(Fraxinus excelsior),* mountain elm *(Ulmus glabra);* subalpine Norway spruce forest, beech forests, floodplain forests, ravine forests with sycamore and mountain elm

Because of the supposedly difficult local conditions, forest management in limestone-dominated mountain ranges has traditionally been equated with stand-wise tree removals. This often resulted in ecologically and structurally unstable coniferous forests. Ecological knowledge and experience as well as technical developments, however, have led to a significant improvement of framework conditions. This case study argues that the management of mixed mountain forests that build on the principles of continuous cover forestry is possible despite adverse conditions.

Forest history and cultural heritage

For many centuries, the forests of Langau – owned by the Carthusian Monastery Gaming since the fourteenth century – were not used for the extraction of wood as a raw material. They served as pastures for livestock, primarily for 'clarified butter' production. Only extremely rocky areas were excluded from grazing. In some parts, cattle grazing was practised until the 1960s. It was only in the second half of the eighteenth century, that exploitation of the forest began: primeval forests were cleared on a large scale, with the main aim of supplying firewood ('energy wood') for the cities of Vienna and Bratislava. Beech timber was charred on site as it could not be transported by water because of its weight. Firewood was also used as the main source of energy for the regional iron industry. The first use of timber for construction only started in the second half of the nineteenth century. In retrospect, the introduction of brown and hard coal saved the Langau old-growth forests from being completely exploited.

These plundered natural forests, however, gave rise to the highly valued old Norway spruce–silver fir–beech stands of today. We also know that the historical large clearcutting operations were not 'clearcuts' in a strict sense, as mature beech *(Fagus sylvatica)* and silver fir *(Abies alba),* which were of low value, were not cut and remained as seed trees.

The 'academic' age-class forest with final clearcutting was then introduced from 1870 onwards under the influence of the theory of the highest net revenue. For over a century, 60 % Norway spruce *(Picea abies)* and 40 % European larch *(Larix decidua)* was considered as the ideal growing stock target. The suppression of the vital beech was the consequence of the 'modern' forestry goals, achieved by clearcutting, cattle grazing, and the deterioration of humus layers by burning the cleared areas.

The abandonment of clearcutting did not take place until 1980. A strict and consistent ban on clearcutting was introduced in 1994. Since that time open, unstocked areas originated only after calamities such as windthrow, bark beetle infestations, or avalanches.

Close-to-nature management in the forests of Langau

Soil protection

Ultimately, the soil is at the centre of management considerations. All interventions are measured to determine their influence on soil development; under no circumstances should fertility be impaired. On degraded soils, be it through historical secondary uses or through inappropriate stocking (e.g. pure conifer stands), a reversal of the trend is sought through various measures. These include building up the humus layer through the ban on clearcutting, and minimising the loss of biomass through wood harvesting as far as possible. Branch material remains in the stand and no energy wood assortments such as wood chips are removed. The removal of the whole tree in the course of cable logging is not applied. Further emphasis is put on converting raw humus into mould or mull (i.e. well decomposed leaf organic matter) humus with the exception of subalpine Norway spruce forests. Under the given circumstances this is achieved by promoting broadleaved tree species and silver fir. Increasing the diversity of herbaceous plants can make a considerable contribution to the recovery of the topsoil. This can be supported by irregular thinning of dense forest stands.

Multi-functionality

Silvicultural practices in Langau can be characterised as integrative and sustainable. There is no maximisation of timber production in disregard of the demands of nature conservation, forest aesthetics, wildlife habitats, recreational space, and protective function (fig. C22.2). Despite the consideration of diverse objectives, forestry continues to remain subject to the principle of economic efficiency. This means that the growing stock should be maintained or increased as a minimum requirement. Surpluses for the owners must be generated in the medium term. Reinvestment in the forest (e.g. for the construction of roads, stand maintenance, thinning operations) need to be financed in any case. This has been achieved in Langau forest during the last 20 years, despite low average roundwood prices, by minimising administrative costs, improving operating procedures, and exploring opportunities for additional income through diversification.

Fig. C22.2. Combining ecological and economic aims on the same forest area (Photo: Johannes Doppler).

Fig. C22.3. High-quality timber production in Langau forest (Photo: Johannes Doppler).

Economic considerations

Ecologically oriented forest management does not imply losing sight of economic aims; actually, the contrary is true. In the long term, ecologically oriented silviculture may prove to be more economically attractive than age-class forest management. However, this requires sound knowledge of yield-related inter-relationships between individual trees and stand dynamics. The economic aim in the forest enterprise is to produce large-dimension, high-quality timber (fig. C22.3) for the following reasons:

- 'Wood only grows on wood', an annual diameter increment increase of 5 mm for trees with a diameter of 40 cm yields about twice the area of wood growth as compared to that of a tree with a diameter of 20 cm.
- The proportion of valuable wood assortments increases with larger tree diameters.
- The costs of harvesting wood decreases with increasing tree diameter. This is particularly true in mountain regions, as options for mechanisation are comparatively limited and the proportion of manual work is substantial.
- In close-to-nature forestry, it is primarily the individual tree that is assessed and not the stand. The growth and value development potential of the tree, its quality, health status, and its relationship to neighbouring trees are of main concern.
- There is no need to determine the rotation period as the individual maturity of the tree is considered.
  Example: a Norway spruce of good quality with a diameter of 500 mm at breast height is not removed as its economic value may continue to increase. A tree with a smaller diameter, trunk damage (wood rot) and/or poor quality could very well be removed in view of roundwood production. The question of 'letting a tree mature' is an essential principle of close-to-nature forestry – the actual age of a tree is actually of minor importance.

The responsiveness of individual trees of different species to different silvicultural measures is taken into account. The increase in diameter can be stimulated by providing more space to individual trees. This 'thinning effect' was underestimated in the past, especially for older trees, ultimately leading to rotation periods of 100–120 years for the main

tree species in Langau. Experience shows that even 200-year-old trees still react with additional growth to the removal of 'competitors', for example by increasing the surface area of the tree crown and thus the active assimilation area. At the stand level, this means that even when the number of trees is reduced, the overall stand growth does not necessarily decrease. This correlation is particularly striking in the case of beech. The stocking rate can be reduced to 60 % without loss of total production – growth is 'concentrated' on a small number of trees.

Key silvicultural measures in Langau forest

Favouring natural regeneration

The opening of dense canopies has the positive side effect that more sunlight reaches the forest floor, thus enabling the development of vascular plants that require such conditions. In addition to a diversification of the herbaceous layer the probability of natural regeneration of a forest stand considerably improves. Natural regeneration is the first important step in ecological forest management – provided that the parent stand is adapted to the location and consists, at least partially, of tree species of the potential natural forest community (fig. C22.4).

Natural regeneration has a number of advantages as compared to artificial regeneration (sowing or planting). It is thus at the heart of forest management in Langau forest. It eliminates afforestation costs which are estimated at a minimum of 3000 €/ha. If the enterprise would implement stand-wise clearcutting, this would result in an annual afforestation area of approximately 30 ha. The financial impact would amount to a minimum of € 90 000, whereby such an investment will only produce a return after many decades.

In the case of a stand which is well adapted to a particular site, natural regeneration will ensure propagation of a large variability of genetic material for the next generation stand. In close-to-nature forestry, regeneration of stands is a continuous process and not limited to a single 'mast' or exceptional seed year of the main tree species. The aim is to extend the regeneration period as much as possible and to use several seed years of particular tree species. The seed production of Norway spruce and beech, for example, fluctuates greatly from year to year, but these species have numerous seed years per decade of varying intensity. The seed production of silver fir, sycamore *(Acer pseudoplatanus),* and ash *(Fraxinus excelsior)* does not fluctuate as much. In contrast, the genetic variability of plants used in artificial reforestation is much narrower as they often originate from a few selected individual trees (with obviously good growth or timber characteristics). Natural regeneration takes advantage of nature producing an extensive surplus of new seedlings, and allows natural selection to determine which genotypes survive, and therefore the genetic variability of the populations of particular tree species. Increased focus is given by the enterprise also to activating latent genetic characteristics of trees with regards to changing environmental conditions (epigenetics). This is supported by allowing the establishment of seedlings from different seed years which further broadens the genetic basis of forest stands and adaptation potentials.

The roots of naturally regenerated seedlings can develop freely, adapted to the specific soil conditions. Depending on the planting method used in artificial regeneration, the roots of the plants are often injured and deformed and are usually subject to plant shock, and only recover after a number of years. Under the climatic conditions that prevail in Langau forest, artificial regeneration in spring is always a risk, especially owing to the timing of snowmelt. Seedlings which have already started to sprout are very susceptible to breakage or if that is to be avoided they may have to be preserved in cold storage until conditions for planting are suitable. 'Föhn' weather phases following planting have repeatedly led to high losses of seedlings and expensive replanting measures. Tree species susceptible to browsing such as silver fir and sycamore cannot be artificially regenerated at reasonable economic cost. They need to be available in sufficient numbers, as is the case in natural regeneration. Only then can it be ensured that they will form part of the next generation of silver fir trees.

Thinning with deliberation

The further development of young trees is accompanied by a minimum of intervention. Mature stands provide young trees with canopy shelter and stability allowing management costs to be kept to a minimum. Other positive effects are the creation

Fig. C22.4. Natural regeneration indicates forest site potential (Photo: Johannes Doppler).

of ecological niches through uneven shading or radiation. Shade-bearing tree species can develop under dense canopies while light-demanding ones find suitable conditions in gaps or along stand edges. Marking trees for removal also allows control of the light conditions (fig. C22.5). Cautious interventions will tend to promote 'development. is used again few lines down again shade tolerant tree species, which is called 'pre-regeneration'. This is particularly important for silver fir, for which slow growth in early development stages is typical. Depending on local conditions, opening the canopy too strongly may lead to development of dense grass cover, which then hinders the regeneration of tree species with shallow seedling roots, such as Norway spruce. As a simple rule, in Langau forest no more than 10 % of the mature trees are removed during the first intervention, so that stability of the stand is only slightly affected and that for a short time. Natural disturbance events such as lightning, bark beetle infestations, storms, or snow break also initiate stand renewal. If such disturbances occur in the form of small gaps they can be incorporated as management measures with a view towards enterprise goals.

The next interventions aim at counteracting homogenisation by promoting tree species and structural diversity (vertical and horizontal structure) every 5–20 years, depending on site conditions. Initial successes have been achieved on better forest sites, especially where all tree species in the old stand were still represented. In the absence of beech and silver fir, repopulation tends to take longer. However, the dispersal potential of seeds from old beech and old silver fir in close vicinity to a thinned Norway spruce stand is surprisingly good and will ensure that these species will become part of the next stand. On less fertile soils, the effects of such interventions only showed after several decades.

Fig. C22.5. Tree marking as a vital silvicultural tool for developing forest stands (Photo: Johannes Doppler).

Game management is imperative

Besides the silvicultural treatment, it is necessary to control the game population to ensure successful regeneration (fig. C22.6). If the aim is to manage forests more ecologically, a change of common hunting practices and culture is unavoidable. The 'carrying capacity' of game populations very much depends on actual site conditions; in comparison to nutrient-rich sites, those poor in nutrients can only support smaller ungulate populations. This is a problem particularly on poor dolomite rendzina sites, common in Langau forest. Close-to-nature forest management on the other hand also leads to a significant improvement of game habitat offering ungulates a species-rich diet across the entire forest area.

The Rothschild Forest Administration thus identified 'site condition' as most important when it comes to impact of game, mainly roe deer *(Capreolus capreolus),* red deer *(Cervus elaphus),* and chamois *(Rupicapra rupicapra),* on the forests and regeneration. Also keeping ungulate populations high for hunting purposes by feeding, was practiced and resulted in considerable browsing damages. Thus the formerly renowned hunting area Langau, required an adaptation of its hunting approach best serving the close-to-nature forest management concept. Besides an adequate hunting reform, a major challenge for the forest enterprise was to convince forest owners and employees alike that hunting (which had played a very important role for more than 100 years) should be subordinate to the objectives of forest management.

Essential changes made to Langau's hunting approach:

– Recognition that in mountain forests no economic profits can be made by hunting – hence there is no lease of hunting grounds (which actually results in a loss of sovereignty on the part of the landowner). Therefore, the enterprise no longer collects any income from hunting.

Fig. C22.6. Hunting as a central instrument of forest conversion (Photo: Johannes Doppler).

– The feeding of roe deer and chamois has been stopped: starting in 1980 the counterproductive feeding of chamois, and since 1991 the winter feeding of roe deer, was abandoned. The number of red deer feedings has also gradually been reduced.
– Intensification of hunting in order to reduce excessive game densities with focus on females to reduce the reproduction rate.
– Build on scientific knowledge for setting guidelines as compared to traditional hunting customs and habits.
– The responsibility for the hunting areas was given to the forest managers.

Allowing for self-regulation

Further stand development should incorporate self-regulation as much as possible, thus avoiding labour-intensive intervention. The reduction of stem density will only take place in exceptional cases. Any following intervention is regarded as a so-called 'structural thinning'. Such thinnings aim at counteracting homogenisation in young stands. The thinnings help maintain or improve stand structure and ensure the presence of the targeted tree species as well as the desired distribution of diameter classes and tree heights. If trees of the new generation ultimately grow into the canopy of the previous stand, only mature trees should be considered for removal thus allowing the younger trees to fully develop.

The sequence of interventions is also linked to the ability of a stand to react and follows the forester's experience of intervening 'early, moderately, and regularly'. Such an approach helps avoid destabilisation and lowers the vulnerability of stands to storms and snow break. Once a stand has reached its target volume (e.g. 400–500 m³), the next intervention will remove no more than the increment which accumulated since the last harvest. In the Langau forest under average conditions and an annual increment of around 10 m³/ha, this would mean that approximately 50 m³ can be

removed every seven years. The growing stock (in mature stands between 500 and 600 m³) will therefore only fluctuate slightly more than 10 %. From an economic perspective, this approach allows periodic generation of surpluses, unlike in even-aged forests. In even-aged forests, the high surpluses are only generated at the end of the rotation period (which used to be about 120 years in Langau forest). Selection cutting as performed in close-to-nature forest management thus represents an attractive alternative, especially for small forest holdings.

Well-trained staff and good forest access are essential

Felling is carried out carefully requiring good organisation and appropriate skills to avoid unnecessary damage to the remaining trees. Therefore, the enterprise ensures professional training of its forest workers. This can take place either by visiting other forest enterprises which have extensive experience in close-to-nature forest management or under the guidance of one of the experienced forest workers. A further prerequisite for careful tree felling operations is the availability of a well-designed network of forest roads and skidding trails to avoid irreversible soil compaction by heavy machinery as far as possible. Small cable cranes are used in terrain with slopes of 60 % or more; such slopes are not uncommon in Langau forest. Cable logging has been shown to be economically viable even for small timber quantities, and to keep damage to soil and the stand to a minimum.

Nature conservation – an integral part of forest management

In addition to officially prescribed nature conservation measures, the Rothschild family saw nature conservation as a fundamental obligation as the former owner of Langau forest. We have to thank Albert Rothschild (born 1844; died 1911) for the last area of Norway spruce–silver fir–beech virgin forest in Central Europe. He was the one who, out of his own conviction, protected this area from any forest use already in 1875. This philosophy accompanied the enterprise's operations until its sale in 2019 being particularly evident in the development of forest management towards the greatest possible closeness to nature.

Next to the wilderness area 'Dürrenstein' with its 1159 ha (which includes the primeval forest 'Rothwald' as a core area), there is also the strict forest reserve 'Hinterer Oiswald' (216 ha) as well as six so-called 'old –growth islands' with a total area of 11 ha. About 400 veteran and cavity trees were designated by taking advantage of forest conservation support programmes. The entire forest enterprise is part of the landscape protection area 'Ötscher Dürrenstein' which has also been designated as a Natura 2000 area. Species under Annex II of the Habitat Directive in Ötscher-Dürrenstein are manifold and include: brown bear *(Ursus arctos),* lynx *(Lynx lynx),* greater mouse-eared bat *(Myotis myotis),* Alpine newt *(Ichthyosaura alpestris),* yellow-bellied toad *(Bombina variegata),* Alpine longhorn beetle *(Rosalia alpina),* the scarce large blue

Fig. C22.7. Alpine salamander *(Salamandra atra)* and Alpine longhorn beetle *(Rosalia alpina)* as two typical species of the Langau forest (Photos: Johannes Doppler (left) and Andreas Rigling (right)).

Fig. C22.8. Deadwood as a means for improving species richness in managed forests (Johannes Doppler).

(Phengaris teleius), Jersey tiger moth *(Euplagia quadripunctaria),* and the lady's-slipper orchid *(Cypripedium calceolus).* Bird species under Annex I of the Birds Directive include: black stork *(Ciconia nigra),* golden eagle *(Aquila chrysaetos),* capercaillie *(Tetrao urogallus),* eagle owl *(Bubo bubo),* grey-headed woodpecker *(Picus canus),* black woodpecker *(Dryocopus martius),* red-breasted flycatcher *(Ficedula parva),* and rock ptarmigan *(Lagopus muta).*

Concluding reflections

The concept of close-to-nature forest management in Langau is nowadays applied in different variants, depending on the natural conditions (terrain, climate, soil) and the given stand composition. Stands range from easily accessible mixed forests with good soils to steep southern slopes on dolomite with pure Norway spruce reforestation and extreme stand damage by red deer. Such a diversity of conditions mean that the forest managers of Langau are confronted with a suite of challenges. The path towards the ideal of a 'Plenter' forest-type structure structure in mixed mountain forest stands can therefore be quite different, and in some cases may take considerable effort and a long time. The minimum requirement in Langau forest is to reverse existing site degradation. Such has already been achieved by increasing the amount of broadleaved trees in stands over large areas.

Nature conservation has always been anchored in Langau forest enterprise and is part of our daily work. The enterprise implements various aspects of nature conservation across the entire forest area. Those include besides soil preservation, natural tree species mixtures, and ground vegetation, the preservation of old trees, the designation and protection of special biotopes, and the accumulation of deadwood to a certain extent in all forest districts (fig. C22.8). Recognising the extraordinary functions of forest ecosystems in managed forests should never be underestimated, even if this is associated with supposedly economic compromises.

The key to the successful implementation of a new forest management concept is committed employees. In our forest districts a forest manager

has an annual felling target of approximately 10000 m³ and is responsible for the shooting of around 100 ungulates. All trees to be removed (or retained) need to be consciously and carefully assessed both from a silvicultural and nature conservation perspective. Such work and decision-making requires highly skilled and qualified foresters whose achievements are very much appreciated at the enterprise. With a view to the future both the economic and legal framework of the enterprise will need to support the implementation of forest management in this sense, as 'continuity is essential for successfully carrying on such a concept' in Langau forest.

Box C 13

Ecosponsoring in the City forest of Baden – A specific approach to increase identification of locals with forest management

S. Niedermann

City forest of Baden, Switzerland

Background

"Baden is at home in the forest" is a slogan of the local forest enterprise and describes the relationship between the Swiss City of Baden, its almost 20 000 inhabitants, and the ~800 ha of forest in and around the city. The forest has many different special features and is characterised by a high diversity of environmental sites and a great variety of tree species, the result of a heterogenous and patchy landscape with an altitudinal gradient from 390 to 860 m a.s.l. and the River Limmat flowing through the area. More than 50 % of the land owned by the local citizen municipality of Baden is covered by forest. The forest is a showcase of integrative measures in a managed forest and won a prize for consolidation, solidarity, and innovation in 2005. The prize money has been reinvested in a variety of projects in the forests, in particular for education and nature conservation. Nature reserves have been an integral part of the forest for a long time. A reserve, that protects an old stand of yews *(Taxus baccata)* is well known, and also wind-disturbed areas that were left to develop naturally after the storm Lothar in 1999, are part of the forest. Old-growth islands, light forests (Lichte Wälder), wet and dry sites, forest edges, deadwood, rare species, and individual trees (about 30) that are old, large, or otherwise of special interest, are part of the nature conservation concept.

Education as an integral task

Education is a major pillar of the forest entity and therefore also of the City of Baden. A broad palette of communication measures is provided. Web-based information (see https://wald.baden.ch) complements an extensive network of marked hiking trails and forest paths including thematic descriptions of nature-related processes, but also of necessary forest operations. The adventure paths and thematic pathways are frequently used and highly valued by the people of Baden. Seminars, training courses, guided tours, and participatory work missions are offered for the broad public, school pupils and university students. Taking a 'godparenthood' is another possibility allowing people to experience a closer relation to their local forest. This means that people can sponsor the management of a small piece of forest (up to 100 m²) for a restricted time.

Ecosponsoring as a new way of collaboration

A very innovative and successful tool to develop and create valuable education measures in the forest is to attract sponsors. The city forest has established this tool aiming at generating products out of ecosystem services in forests. This corresponds to a need of society and uses the potential of forest-related goods and services.

The ecosponsoring tool allows nature conservation and recreation projects to be financed and implemented. However, ecosponsoring involves more than just financial issues; it is also a bundle of services that can be marketed. This includes coordination of public relations in collaboration with the sponsor. Thus, parts of society that usually have little contact with forests and nature can be reached. This may enhance the identification of local people with their forests.

The ecosponsoring follows three main steps:

1. Developing an innovative product for an environmental service based on a potential demand of society.
2. Finding a compatible sponsor with a local reference. The donors must also fulfil some ecological standards to stay authentic.
3. Defining the mutual benefits. To generate long-term effects, the project should run for at least five years.

Interest in ecosponsoring has been high. In the past 20 years sustainable and long-term partnerships have developed. Some of these partnerships have lasted for longer than 20 years. An important factor is the exclusive and long-term partnership with selected donors. The limitation of partners is a measure of quality and maintains existing partnerships. This secures the longevity of the partnerships.

Over this period, the projects have generated more than CHF 1.4 million. In 2020, eight projects are active. The income from ecosponsoring accounts

for about 3–6 % of the total turnover of the forest enterprise. The list of achieved project ...is impressive. It includes small-, medium- and larger-scale projects such as: 'Habitat-trees' (safeguarding of trees with a large amount of habitats for species); 'Audioguide' (development of an audioguide that accompanies walks along forest paths with audio-information; the project 'Pioneer species' (safeguarding of pioneer species in managed forests); and 'Supporting oak trees' (promotion of oak trees in the forests). These are just a few examples from a long list of projects.

Fig. 1. Thematic pathways are popular in the City forest of Baden, where private donors support such kind of knowledge transfer. This is an example for hiking trial to learn about the habitat of the rare Pulmonary lichen (Photo: Statdtforstamt Baden).

Tamins – Forest management and the woods of a municipality in Switzerland

C23

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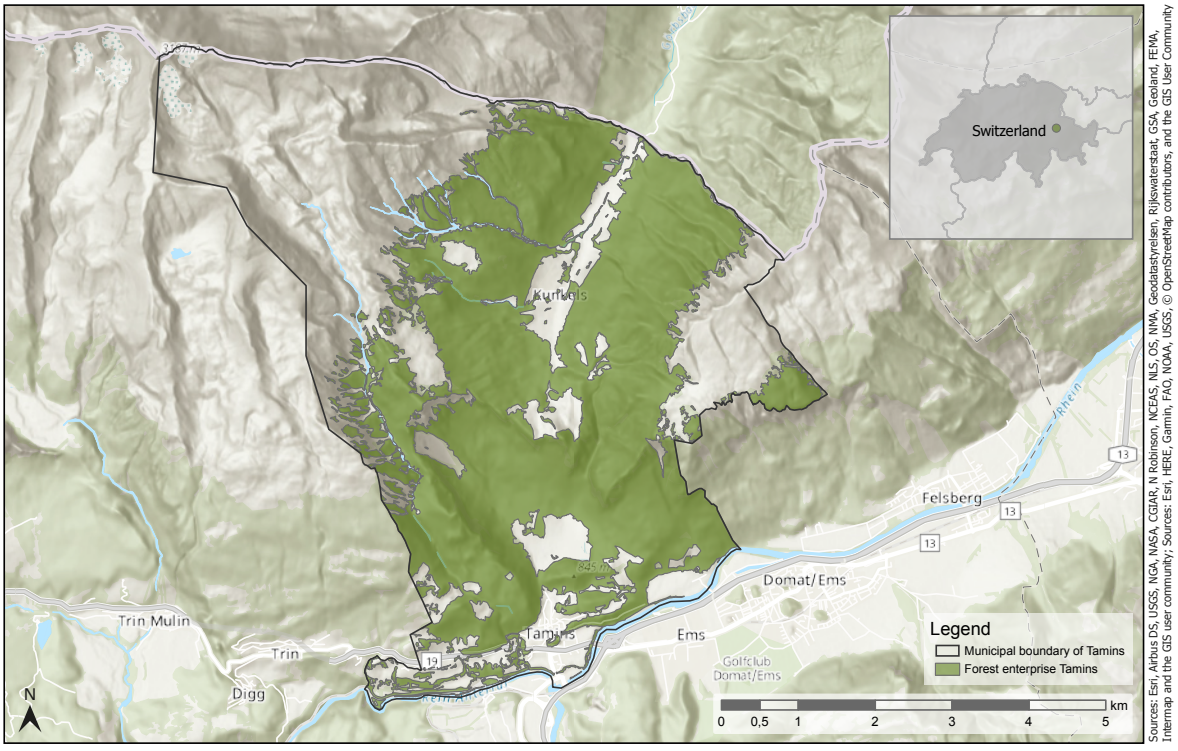
Location and overview

The municipality of Tamins is located in the Chur Rhine Valley in the canton of Grisons, Switzerland. The village of Tamins (662 m a.s.l.) lies between the towns of Chur and Flims at the foot of the Calanda mountain. The Kunkels Pass (1357 m a.s.l.) leads to Vättis in the municipality of Pfäfers in the canton of St. Gallen. The population of Tamins is around 1200. Of the total area of 4084 ha, about 2100 ha is covered by forest. Large areas of the forest area are unproductive, but around 1400 ha is managed. The



< Fig. C23.1. Subalpine forest dominated by Norway spruce and European larch. The steep mountains range up to 3247 m a.s.l. and show a very representative mountain forest in Switzerland with a high topographical diversity and a complex and costly management situation (Photo: Mattiu Cathomen).

Statement

"As many municipalities in alpine regions in Switzerland the forest division of Tamins focuses on forest protection against natural hazards. A second important issue is to improve forests biodiversity by using several sophisticated concepts."

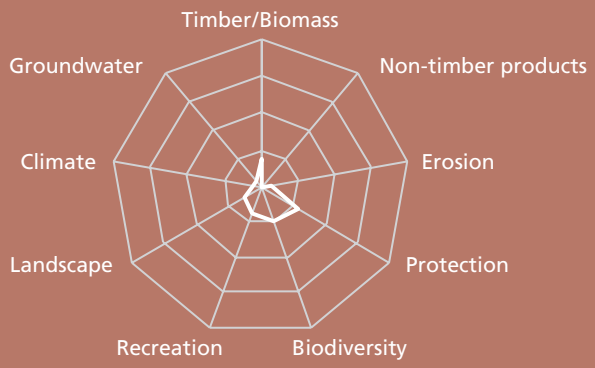


Table C23.1. General information on the forests of Tamins municipality.

Forest community	Wide range from broadleaved dominated to conifer dominated stands
Total forest area	2119 ha
Main management types	Irregular group shelterwood, group and single-tree selection systems
Total volume	305 m³/ha
Annual growth	6000 m³ (on the entire area)
Annual use	4800 m³ (on the entire area)
Deadwood (standing and lying)	Not known
Altitude	566–2100 m
Ownership	Community forest
Geology	Mainly limestone with some crystalline zones
Forest reserves	156 ha
Old-growth islands	13 ha
Habitat trees	0 (so far)
Protective function	Prevent avalanches, rock fall, mudslide and flood

municipality owns 95 % of the forests, and about 50 % of the forests are protection forests. The proportion of coniferous forest is over 80 %. A natural forest reserve (48 ha) and two old-growth and deadwood islands (13 ha) are strictly protected for a time horizon of 50 years. Wood harvesting in general is not allowed in these areas. In 2004, the special forest reserve Eichwald (108 ha) was established, in which the forest is managed to favour biodiversity.

Climate

The climate is regionally strongly dependent on the altitude. The air masses generally come from the west and this determines the climate. This sea air has a cooling influence in summer and a warming influence in winter. The nearest weather station is in Chur. In January 2017, the average temperature was 0.4 °C, and in July 2017 the average temperature was 18.9 °C. Because of the altitude, the Alps form a weather divide between North and South. The valleys in the interior of the Alps are considered particularly dry because they are shielded from precipitation on both sides by the mountains. This means that the conditions are dry; the annual precipitation is around 800 mm, with a third of the precipitation falling in winter as snow. In the northern forests in the north-facing valley, precipitation is significantly higher.

Fig. C23.2. View from the Kunkels Pass where different climatic influences come together (Photo: Mattiu Cathomen).

Local diversity

The forests of Tamins stretch from the lowest point on the banks of the Rhine (566 m a.s.l.) to the highest point (the Ringelspitz peak, 3247 m a.s.l.). The large altitude range is the main reason why Tamins has such diverse forest communities. A further reason for the diversity is the diverse topography with rocky peaks and ridges, scree heaps, hollows and gorges, different expositions. The pass at Kunkels is known as the 'weather kitchen' in the transition between oceanic and continental climate (fig. C23.2). There the geology is characterised by the crystalline of the Aarmassif which appears between the limestone of the infrahelvetic ceilings. The massive Tamins landslide about 9500 years ago strongly influences the topography of today. The forest line on the steep flanks of the Calanda mountain massif rises to a high point of about 2100 m a.s.l.

From one perspective, the varied topography poses a great challenge for the management of the forests; however, it also offers interesting opportunities for year-round management.

The forest

Forest area, stock, and cutting rate

The total forest area of the municipality of Tamins is 2119 ha, and 1621 ha are productive forests; the remainder are mostly shrubby, mainly pine (*Pinus* spp.) trees. However, the managed area is only around 1400 ha. The annual growth on the entire forest area is about 6000 m³. The annual cutting rate was set to 4800 m³ in the operating plan, as the use of the more inaccessible parts of the forest is too costly and time-consuming. The average stock is 305 m³/ha.

Tree species, stages of development, and growth

Norway spruce *(Picea abies)* accounts for around 48.5 % of stocks. Silver fir *(Abies alba)* follows with 17 % and European larch *(Larix decidua)* with 14 %. Other important tree species are beech (*Fagus sylvatica,* 12 %) and Scots pine (*Pinus sylvestris,* 5.5 %). In the regeneration, Norway spruce is again the most strongly represented species with a 49 % share of the regeneration in terms of area. Broadleaved species are more strongly represented, with a share of the regeneration cover of about

38 %. The annual growth of all species is 6.8 m³/ha.

Each forest stand is categorised by the forester's estimation of development stage and its stability. To categorise the stage of development we use five development stages. The stand stability is categorised by the use of three separated fields.

Regeneration and ungulate influence

On about half of the forest area, natural regeneration is not or not sufficiently present. In addition, the tree species composition does not meet the site requirements. Browsing by ungulates – red deer *(Cervus elaphus),* roe deer *(Capreolus capreolus),* and chamois *(Rupicapra rupicapra)* – prevents seedlings of fir, as well as seedlings of the ecologically important mixed tree species such as rowan and sycamore, from developing.

The regeneration of silver fir is occurring slowly again. This is clearly visible at numerous sites. The pressure of the Calanda wolf pack (since 2012) on the ungulate populations is slowly taking effect. Two- and three-year-old seedlings of silver fir are now present. However, these seedlings are still far from 'out of the wood'. This positive development is still at an early stage, and the success of the regeneration can only be conclusively assessed in a few years' time.

Table C 23.2. Tree species in tree stands and regeneration.

Tree species	stock in m³ 2014	% of stock 2014	% of stock 1987	% cover of regeneration 2014
Norway spruce *(Picea abies)*	184 629	48.56 %	49 %	49.04 %
Silver fir *(Abies alba)*	64 663	17.01 %	18 %	2.65 %
European larch *(Larix decidua)*	53 215	14.00 %	9 %	9.68 %
Scots pine *(Pinus sylvestris)*	21 563	5.67 %	6 %	0.84 %
Mountain pine *(Pinus mugo)*	356	0.09 %		
Swiss stone pine *(Pinus cembra)*	82	0.02 %		
European yew *(Taxus baccata)*	48	0.01 %		
Total conifers	**324 557**	**85.36 %**	**82 %**	**62.21 %**
Common beech *(Fagus sylvatica)*	45 688	12.02 %	17 %	27.74 %
Sessile oak *(Quercus petraea)*	5 530	1.45 %	1 %	1.64 %
Sycamore *(Acer pseudoplatanus)*	1 040	0.27 %		0.52 %
Common aspen *(Populus tremula)*	208	0.05 %		0.43 %
Birch (*Betula* spp.)	220	0.06 %		0.64 %
Sweet chestnut *(Castanea sativa)*	97	0.03 %		0.03 %
European ash *(Fraxinus excelsior)*	759	0.20 %		0.58 %
Field maple *(Acer campestre)*	11	0.003 %		0.003 %
Wild cherry *(Prunus avium)*	259	0.07 %		0.60 %
Common whitebeam *(Sorbus aria)*	199	0.05 %		0.19 %
Common walnut *(Juglans regia)*	87	0.02 %		0.28 %
Other broadleaves	1 569	0.42 %		5.13 %
Total broadleaves	**55 667**	**14.64 %**	**18 %**	**37.79 %**
TOTAL	**380 224**	**100.00 %**	100 %	**100.00 %**

Table C 23.3. Stand development stages and characterisation of stand stability.

Stage of development	stable – labile (ha)	Labile – critical (ha)	Critical (ha)	Total (ha)
Regeneration/thicket	7.82	1.95	0.62	10.39
Pole stage	43.24	6.42		49.66
Young timber tree	105.77	16.89	2.17	124.83
Middle-aged timber tree	273.78	44.56	1.82	320.16
Old timber tree	119.02	23.29		142.31
Total	**549.62**	**93.11**	**4.62**	**647.35**

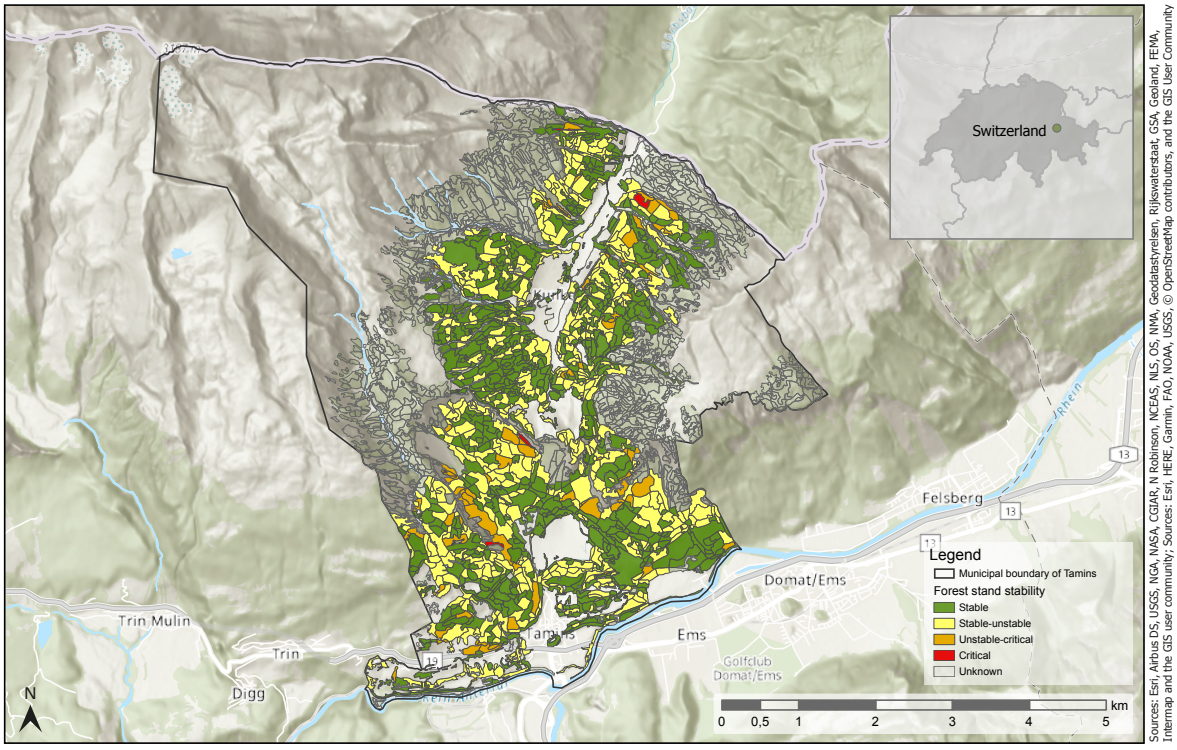


Fig. C23.3. Forest stand stability in Tamins (Source: Office for forest and natural hazards, copyright Swisstopo).

Forest forms

In Tamins there are distinct examples of very special forest forms such as larch, sessile oak *(Quercus petraea)* and beech wood pastures. These forest forms can be traced back to the traditional land uses of forest pasture and the extraction of leaf litter. Among other things, pigs were fattened under oaks and beeches. In addition to food, the animals found shade and protection from rain under the trees. Through the light larch stands and wood pastures much light reaches the ground on which species-rich dry pastures could develop. The rich mosaic of very different habitat types in a small area gives these areas a very high natural value and the diversity of flora and fauna is extraordinarily high. In these areas there are rare tree species in need of light, such as wild apple *(Malus sylvestris)* or wild pear *(Pyrus pyraster).* Such areas must be preserved and promoted. To this end, the special forest reserve Eichwald was established in 2004. The planning and control of measures in the special forest reserve is carried out over a period of four years as part of a separate project. Outside the forest reserve, there are other valuable areas, including: the home pastures on Girsch and Lusbühel, the Alpine pastures of the Hinteralp, and the beech forest below the Kunkels Pass in the 'Liebti' area.

In the lower altitude areas there are also sessile oak forests and oak-dominated stands outside the special forest reserve. Oak forests are very species-rich and should be promoted within the framework of biodiversity. As oak is very fond of warmth and can only compete in drier locations, relatively large openings on south-facing slopes must be created to initiate regeneration of oak. In the case of careless diffuse thinning, hazel *(Corylus avellana)* is unwantedly favoured.

Pure beech forests are found mainly below rocky areas on dry and debris-rich sites. These are poorly growing beech forests of very poor quality (fig. C23.5). From a timber production point-of-view, these dark and single layer beech forests are of only minor importance. In alternation with the open rock locations and the rubble fields, however,

Fig. C23.4. Sessile oak tree in Tamins (Photo: Mattiu Cathomen).

these forests are ecologically valuable. A natural forest reserve has been established in the upper forest and in the Pflida area to protect these forests.

Fir-beech forests and fir–spruce forests are by far the most common forest communities in the forests of Tamins (about 75 % of the area). The vigorous growth and the good quality of spruce and fir timber mean that these forests produce valuable timber. The problem that fir no longer regenerates naturally under the prevailing ungulate pressure is, therefore, particularly serious in Tamins. At 17 % of the total stock in Tamins, the share of fir is still high. However, this share is anything but sustainable, as fir regeneration, and also sapling and pole-stage fir are missing, with a few exceptions. A continuous decline of fir will aggravate the existing problems in the future.

The natural spruce forests are limited to subalpine altitudes. But even at lower altitudes, many spruce-rich stands are faltering. Spruce was promoted by the former management and the high ungulate pressure. Spruce is the most dominant tree species with a share of almost 50 %. Because of its susceptibility to damage, especially to bark beetle infestations, spruce should be prevented from dominating too strongly and mixed forests should be encouraged. However, beech and fir trees are missing in the subalpine altitudinal zone. Larch usually only occurs as a pioneer tree species or as a permanent tree species at the edges where dust avalanches (i.e. avalanches of dry, loose snow) have occurred. The structure of the subalpine spruce forests is open, and regeneration should be present on the whole area. The best places for regeneration are elevated small sites, old standing dead trees, or mouldy wood. The lack of heat has a limiting effect on growth. Therefore, seed germination and growth are dependent on sufficient direct sunlight. The removal of individual trees or narrow openings is sufficient to promote regeneration. It is also advisable to leave some of the cut wood in the forest to protect against avalanches, and to promote the amount of deadwood.

In the uppermost locations on the shady slopes of the Calanda mountain (fig. C23.6), Swiss stone pine *(Pinus cembra)* stands are found. On the northern side of the Central Alps, Swiss stone pine forests are a rarity. The stands have so far not been used or only used to a limited extent. No particular silvicultural measures will be necessary in the future.

Management

Forest functions

About 50 % of the forests are protection forests. Above the village, these forests mainly protect against rockfall. The protection forests in the Kunkels area protect against avalanches and rockfall (fig. C23.7a). Debris flows and landslides are rare. Maintaining a species-rich regeneration is the greatest challenge in the management of protective forests.

Biodiversity has top priority in the management of the species-rich broadleaf forests at lower altitudes. About 100 ha of varied open-grazed oak forests, gnarled beech forests (fig. C23.7b), single trees of specific interest (fig. C23.7c), mixed broadleaved forests, dry pine forests, and other forest types form the special forest reserve Eichwald. Maintaining these forest types and keeping

Fig. C23.5. Beech trees in Tamins (Photo: Mattiu Cathomen).

Fig. C23.6. View of the Calanda mountain (Photo: Mattiu Cathomen).

the dry sites open is very time-consuming and can only be partly achieved by machine. In general, forest stands with a slope around 35% and more are harvested manually due to soil protection issues.

Timber production takes place in the coniferous stands (fig. C23.7d). However, at present this is very difficult and only in rare cases are the costs covered. Although forestry operations are broadly based, logging in commercial forests is heavily dependent on the price of wood.

Accessibility

The current forest road network was largely completed in the second half of the twentieth century. The existing forest roads are not up-to-date for modern forest management standards. There is a lack of basic access by roads that can be used by lorries, which means that the costs and expenses for harvesting and extraction are very high. Extraction is carried out according to the topography and state of the road network. Timber from approxi-

Fig. C23.7a–d. Tough life for trees and especially for regeneration in this rockfall area (a). Gnarled beech tree at 'Müller's Los' (b), European yew *(Taxus baccata)* at 1100 m a.s.l. (c) and a coniferous forest that delivers valuable timber (d) (Photos: Mattiu Cathomen).

mately half of all forests is extracted with cable crane. The woods on the front side of the Kunkels Pass are rather shallow and where the topography tolerates, they are easily accessible with modern machines. Forwarders and harvesters with traction winches are used wherever possible. The use of helicopters for timber harvesting is only considered in extreme cases.

Forestry enterprise

Personnel and infrastructure

The forestry enterprise works very closely with the department of works (joint municipal works yard). Personnel, machines and tools are exchanged. Internal community work is very important for the forestry operation. Three forest wardens and an apprentice are employed in the forestry enterprise in addition to the operating manager. A forestry tractor with back crane, clamping bench and double drum winch, with trailer for wood chip transport and road maintenance is the only larger machine in the enterprise. In the case of fully mechanised woodcutting and cable crane treatments, close cooperation with private well-equipped forestry enterprises from the region is maintained.

Regionality and networking

The forestry enterprise as part of the community is well networked in the region. Alpine, forest, and hiking trails maintained by the enterprise as well as recreational facilities (nature trail, information boards, fireplaces, and benches) are actively used. However, it is sometimes not always clear to the users who actually provides these services. The production and sale of wooden products such as firewood, benches, table groups and well troughs are

	Strengths	Weaknesses
Internal origin (attributes of the organisation)	– ownership (one forest owner) – south-facing slopes (work technique, early snowmelt, dried) – Large share of coniferous timber – Services as utilisation of the forest group (e.g. in bad weather) – Location (access to the railway system and motorway) – Well-trained personnel with very good local knowledge – apprenticeship training – Biodiversity, nature conservation, special forest reserve – Inter-company wood marketing – Well-equipped/supplementary forest entrepreneurs in the region	– Forest development (proportion of truck roads) – Form of operation, competence regulation – Interdependence of business and politics – Unclear separation between forestry enterprise and department of works – Timber market; almost only foreign buyers
	Opportunities	**Threats**
External origin (attributes of the environment)	– Strengthening services in biodiversity, nature conservation – Local recreation, further internal services – Wood products, moon wood (wood that is harvested only during moon phases with the result of higher wood quality) – Internal community services strengthen the reputation and awareness of the enterprise – Cooperation with entrepreneurs	– Political arbitrariness – Financial situation of the municipality – Elimination/reduction of contributions to protection forests and nature conservation – International timber market – Coniferous wood content (susceptible to storms and insect pest outbreaks) – Natural hazards (wind, snow) – Invasive species and stands with strong hazel, forest vine and blackberry components (on south-facing slopes)

good opportunities to get in touch with the local population and is used well in this respect. There is also contact with the cantonal authorities and organisations such as the Mountain Forest Project.

Financial situation

In recent years, the forestry enterprise has regularly posted a deficit. The turnover of the company is 700 000 CHF. The main income of the company on average are federal and cantonal subsidies based on realised forestry enterprise services to protection forests and forest damage (130 000 CHF), to biodiversity (40 000 CHF) and to long-distance cable crane (30 000 CHF). Other incomes are generated by internal settlements (150 000 CHF), wood sales (200 000 CHF), and services for third parties (40 000 CHF).

Outlook

The capital of a forestry enterprise is the wood in the forest. There is a large stock of good and medium quality wood in the Tamins forest. Currently this wood has to be sold below its value and so the growth is not exhausted. However, it is not possible to wait for higher prices of wood in the case of outdated stands. The well-kept and continuously maintained protection forest is an investment in the future, but it is also capital. The care of the protection forest costs only a fraction of what protective structures would cost. The internal services for the community and for biodiversity are an important pillar of the business and are especially important in terms of acceptance of the business in the community. The population greatly appreciates these services.

In recent years the main drivers for forest development are based by climate change, regeneration and society needs on forests. These days the effects on forest stands by irregular and more frequent extreme events like drought are influencing forests vitality and protection forests as well. In addition to this, regeneration is widely limited trough the influence of ungulates. At least the functions of recovery and biodiversity caused by structural changes have become more and more important.

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Vestland – How can we take care of biodiversity in forest areas of complex owner structure and limited tradition of forestry?

C24

G. Kampp Hansen

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Background

Vestland County is a new administrative region in western Norway. The county governor represent the government at the regional level. The county governor's forest advisors are responsible for managing subsidies, implementing new legislation, and providing advice on forest management.

Vestland County is located on the west coast of Norway. The area is characterised by its long fjords and steep mountains, rising from the sea to the mountain plateau of central Norway. The productive

< Fig. C24.1. Impression of a temporary dangerous situation for the houses below the forest, cable-logging site in a typical landscape along the fjords of Vestland (Photo: Simon Rudolf Wolff).

Statement

"Timber production without compromising biodiversity."

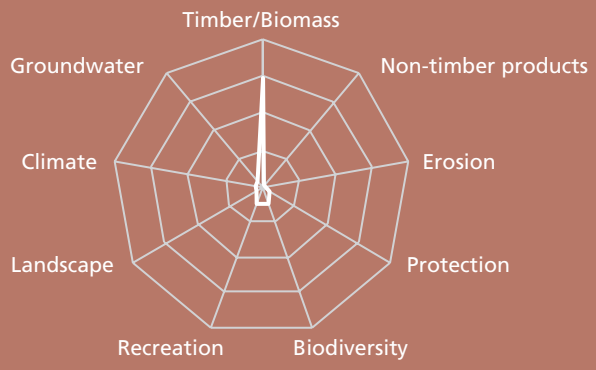

Table C24.1. General information on Vestland County forests.

Total forest area	553000 ha productive forest
Main management types	Clearcut (>90 %) and seed tree harvest
Total volume	150 m³/ha
Annual growth	3 m³/ha
Annual cutting rate	1.2 m³/ha
Deadwood	14 m³/ha
Ownership	Private (approximately 85 %) and public
Climate	8 °C mean annual temperature, 1000–4000 mm mean annual precipitation – depending on location and landscape
Protected area	6 % of the Norwegian forest area

forest area covers 16 % of the land mass (fig. C24.1). The main species are downy birch *(Betula pubescens),* Scots pine *(Pinus sylvestris)* and Norway spruce *(Picea abies)* (fig. C24.2). Broadleaf forest covers 50 % of the forest area and spruce plantations around 15 % (Tomter and Dalen 2018). The nature in Vestland is very diverse because of the varied landscape. Many species have their most northern distribution here. About 60 % of species in Norway are associated with forest, from which it is estimated that only 73 % of species are known (Elven and Sørli 2016).

Vestland has an oceanic climate with mild winters and mild summers. The average yearly precipitation of western Norway is 3000–4000 mm. The rain provides good growing conditions for spruce. Norway spruce has an annual growth of around 17 m³/ha and thus a growth many times higher than that of the natural species of birch and Scots pine.

Scots pine, Norway spruce and Sitka spruce *(Picea sitchensis)* are the primary commercially exploited species, and spruce harvest makes up almost 95 % of the timber that is harvested in this region. The annual cut is around 400000 m³ (Norwegian Agriculture Agency statistics). The main type of harvesting technique is clear-cut harvest followed by planting. Only about 50 % of the harvested area is planted – the rest regenerate naturally with mainly broadleaved species which has little timber quality.

The forest is owned by approximately 16500 private forest owners. The government, the council and different other organisations also own forest, but most of this forest is managed much like the privately owned forests. The average size of a forest property is 10–25 ha (Statistics Norway 2020).

The property structure is complex. A property is often made up of many smaller patches of land. Around 20 % of forest owners do not live on their property and very few have a significant income from the forest. The majority have little knowledge of forestry and have very seldomly decided on goals for the management of their forests.

Fig. C24.2. Typical forest landscape with a mix of monoculture stands of spruce, pine, and birch. In the middle to the left is a key-habitat with old aspen in yellow autumn colours (Photo: Gro Kampp Hansen).

The history of the Vestland forests – deforestation and afforestation

The forest resources of western Norway have been heavily exploited to an absolute low point about 200 years ago. Better forest legislation, great changes in land use, and a massive afforestation effort has helped re-establish the forests.

Farming based on grazing animals is believed to have removed the forest along the coast already from 2500 years ago. Growing populations have harvested timber for buildings, fencing, firewood, and boat and ship building. Grazing animals (mainly sheep and goats, but also cattle and horses) in the mountains have, over a period of many hundreds of years, slowly pushed the treeline downwards. In the period 1500–1800 the market for pine lumber export led to deforestation at a scale that eventually put an end to the export and resulted in the closure of many sawmills. Rising populations around the industrial revolution led to an even greater pressure on the forest resources, and by the end of the nineteenth century even firewood was scarce in some areas (Øyen and Nygård 2007).

Inspired by afforestation programmes in northern Europe, the Norwegian government initiated an afforestation programme. After World War II this was implemented on a large scale, and 390 000 ha of Norway spruce and Sitka spruce *(Picea sitchensis)* forest was planted in Norway (Tomter and Dalen 2018). About 25 % of the afforestation effort was planting forest where there was no forest before (fig. C24.3) – and the remaining 75 % has involved change in forest species, from natural species with low production to highly productive Norway spruce, Sitka spruce, or larch (*Larix* spp.). At the same time there have been major changes in society and in farming technology. Large areas that were formerly used for grazing or firewood have regenerated with natural broadleaf species or pine forest. Together with changes in the climate, this has led to the treeline moving up. It is not known how low a percentage of the west coast that was covered with forest at the lowest point 200 years ago – but from the 1950s and until today we know that the forested area has doubled, and the standing volume has almost quadrupled in our region.

Fig. C24.3. Afforestation with Sitka spruce and larch in an agricultural landscape along the coastline. In this picture there are four different properties (Photo: Gro Kampp Hansen).

In many ways the afforestation project has been a success. The people who initiated it would most likely consider it to be so. However, as the area of spruce forest started to rise, many people criticised the plantations for being too dense and for ruining the landscape. Later, the growing knowledge of the ecosystem we live in and how we affect it, has led people to question the whole afforestation project. Many environmental organisations promote the removal of foreign species from Norwegian forestry. Despite its name, Norway spruce is not naturally distributed along most of the western coast of Norway. It forms natural forest stands on a very few locations. It is expected that it will establish itself as a natural forest type here over time – but has not yet reached this stage after the last ice age and is therefore considered an introduced species in most locations on the west coast of Norway.

The recent history of afforestation is one of the main reasons that forest owners have little knowledge of forestry. There has not been time to establish a tradition for forestry in the region.

The main management strategies and the economy of the forests

The majority of the forests of Vestland County are not managed according to a particular management scheme and only few forest owners have specified goals or aims for their management. The main goal behind most of the activity is timber production. Some forests are harvested by the forest owner themselves, but most (80–90 %) harvests are organised by timber buyers and the harvesting is carried out by professional entrepreneurs.

High levels of salary, challenging terrain, and high petrol prices mean that harvesting costs are high. High stock per hectare compensates for some of the cost. High rainfall means that extra work with a digger is often required to repair terrain damage after harvest. About 30 % of the forest area is classified as cable-logging terrain. Harvesting on another 20 % of the forested area is expected to be 'uneconomic' because the terrain is too challenging with the current costs and technology (Granhus *et al.* 2011). Transportation from harvest sites and to the customer is also more costly than the rest of the country because of the poor condition of the road network.

The average stock in a harvest-mature spruce stand is normally around 500 m³/ha, and the timber is generally of good quality. The average price paid to the forest owner is 300–400 kr/m³ (25–35 €). The average harvesting cost lies between 150–250 kr/m³ (14–23 €) but varies a lot. The average harvest is 400 m³ per forest owner. In 2019 there were 1400 forest owners who reported revenues from forestry, this accounted for 4 % of their total income. The income from forestry amounted to only 0.4 % of the income of all forest owners in the region (Statistics Norway 2020).

Other important services and values from the forests

The forest of Vestland provides the local society with many different services, but very little is valued and consciously managed for these services.

There is a large and growing population of deer *(Cervus elaphus)* in the forests. Damage to forests from deer has been identified but the cost has not yet influenced the management of the deer populations significantly.

Outdoor recreation is very popular in Norway. Forest roads provide access to recreational areas and are also much used for hiking, biking, and horse riding. According to the Outdoor Recreation Act the public must be allowed access to privately owned forests.

The combination of the geology and the climate result in many areas with risk of avalanches, rockfalls, and mudslides. These natural hazards cause damage on infrastructure every year and sometime also cost lives. The forest has a known role in limiting the risk of natural disasters, but this has not yet been incorporated into the active management of the Vestland forests.

Biodiversity in the forests and how to identify and protect it

Just as forest owners have little knowledge and tradition of forestry, the same is true for ecosystem thinking and knowledge of how to manage the forest for biodiversity. When the forests were planted there was little consideration given to how to extract the timber. Therefore, timber harvest often includes forest road building and logging roads through natural forest. Harvesting of pine forest or establishing logging roads can have a negative impact on the biodiversity at a local level.

Because of a growing concern of the negative impact from forestry on biodiversity in the 1980s and 1990s almost the entire Norwegian forest sector became certified through PEFC (Programme for the Endorsement of Forest Certification). To protect the biodiversity of the forest, the PEFC standard demands habitat protection on different scales. On a small scale, forest owners must leave deadwood and trees for old growth in the forest after a harvest and they are not allowed to make clear-cuts along bogs, lakes, or rivers. Areas that cannot be clear-cut covers 7 % of the productive forest area in Norway (Tomter and Dalen 2018). On a larger scale, natural reserves are used to protect small and large areas of high conservation value. Between the two scales is habitat protection:

Many of the locally threatened species are fungi and lichen that can only be identified by a few specialists. 12 types of habitats have been identified to be of great importance to the biodiversity in the Norwegian forests. These habitats are likely to contain the threatened species (Baumann *et al.* 2002). Examples of the 12 habitats are: high concentrations of standing or lying deadwood, groups of old trees, a ravine, several trees with 'lung lichen' *(Lobaria pulmonaria)* (fig. C 24.4) or a forest-fire site (fig. C 24.5).

The habitats are identified in the forest using a method called Miljøregistreringer i Skog (MiS; Environmental Inventories in Forests). The MiS-method use indicators that are easy to learn to identify and the method can be applied relatively easily. The environmental inventories are carried out in connection with forest inventories on a county level. The mapping is subsidised by the state. After the inventory the most valuable habitats are selected as key-habitats and a management plan for the habitat is described. In most of the key-habitats, human activity must be kept to a minimum; however, in some cases grazing and some types of harvesting is allowed, if those activities are considered to improve the habitat conditions, or if the activities do not significantly affect the habitat.

In order to sell timber as PEFC-certified (which is required by >90 % of timber buyers), all certified forest owners must take care of the key-habitats in their forest. The MiS-inventories and the selection of key-habitats is dynamic and should be revised every 15 years. If a forest-fire site has become covered with forest – then it is no longer a key-habitat. If a storm cause windfall and many new habitats of lying deadwood, then only the most valuable ones should be selected as key-habitats. If a selected habitat is in conflict with, for example, the building of a road, it is possible for the forest owner to set aside another area of equal value and then get permission to build a road anyway. This flexibility of the system means that most forest owners accept the habitat registration and protection more easily than if the area was proposed as a natural reserve.

All registered habitats are collected in a national and public database. When a harvest is

Fig. C24.4. Tree lungwort or lung lichen is an easily identifiable indicator of an important habitat as the lung lichen most often grow on old broadleaf trees and are sensitive to pollution and disturbance (Photo: Gro Kampp Hansen).

being planned, the forest owner or planner will consult the database beforehand. Logging roads and harvesting of forest near a key-habitat must be planned in a way, so that the harvest activity does not affect the habitat conditions. In Vestland there are many areas that have not yet been mapped. When a timber buyer organises a harvest in a natural forest, the key-habitats must have been mapped beforehand. When logging roads for spruce stands pass through natural forest, the planner must first check if the area contains some of the easily identified habitat elements using the MiS-method.

Environmental organisations accept the method to a certain degree, but are critical to the level of training and method of the staff that does the inventories. They also question if the protection work in practice as clear-cuts in key-habitats have been discovered. In Vestland the discovered clear-cuts were due to non-forestry activities such as expansion of farming land and public road building.

The MiS-system has turned out to be a simple and effective way of registering forest with high biodiversity. The system is now incorporated in both the PEFC standard and the national forest legislation.

The future of forestry in Vestland County

The forestry in Vestland is currently focused on harvesting the first-generation forest that was planted during the 'afforestation' period. During the next 10–40 years, most of the spruce stands (85 % Norway spruce and 15 % Sitka spruce) will reach maturity and harvest of these stands will probably dominate harvesting and increase the forest activity in this region.

Large areas of pine forest will also reach biological maturity. The current market for roundwood of pine is not very good. A change in the market could lead to growing activity in these forests of natural species.

The habitat protection system within the PEFC standard is dynamic and a rise in harvesting should not change the level of protection of biodiversity – as long as the habitats are mapped properly. Growing activity should lead to an increase in environmental inventories.

Fig. C24.5. Forest fire site left for natural succession (Photo: Gro Kampp Hansen).

Conclusion

The habitat protection on different scales through the Norwegian PEFC-certification standard has been easy to implement in Vestland. It serves as a good example of how to secure the biodiversity in forests that are managed primarily for timber production. It is also a good example of how one can achieve multifunctional management through a set of general guidelines in areas with complex owner structure and limited tradition of forestry.

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Links

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Geonorge. Map data produced by Norwegian Mapping Authority, Mapping and Cadastre. Data downloaded 26.06.2020: https://www.geonorge.no/en

Norwegian PEFC standard: https://www.pefc.no/in-english/our-standards

Vestland County Governor website: https://www.fylkesmannen.no/en/Agriculture-and-food/Forestry

Girona – Fire Flocks, grazing systems to reduce wildfire severity

C25

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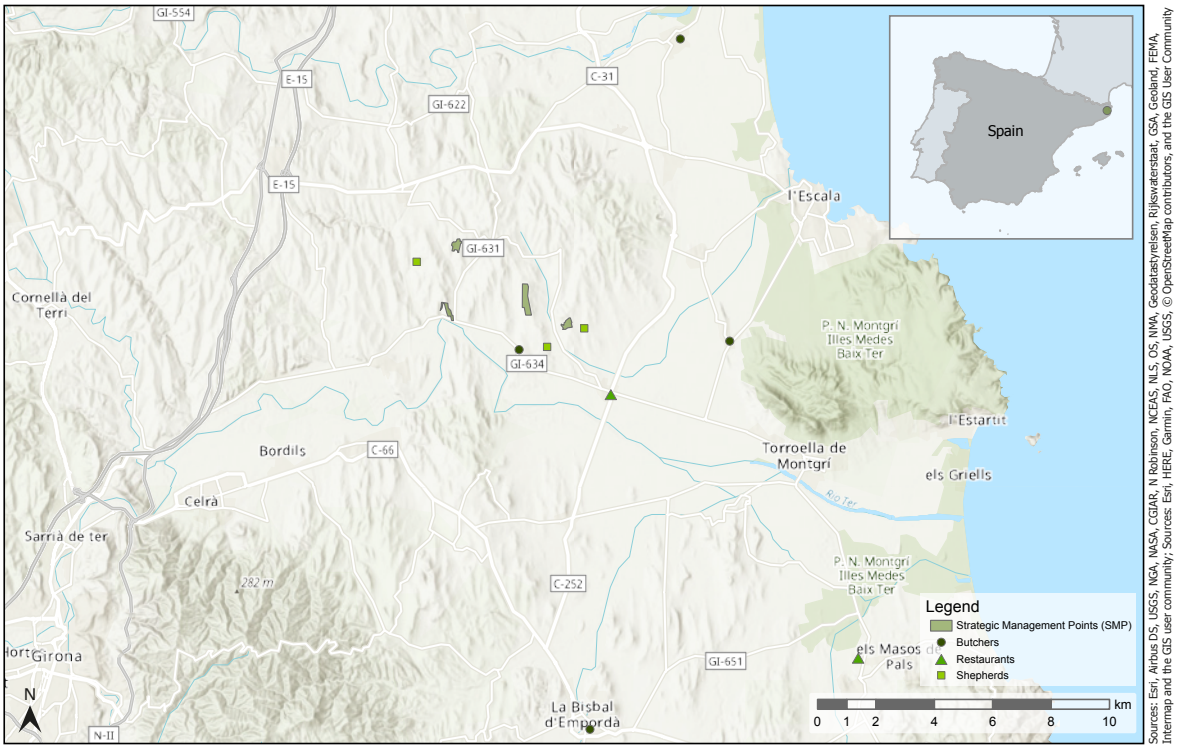
Context, legal frame and ownership structure

Forest history, land uses and cultural heritage

The landscape in the majority of the Catalan region (northeastern Spain) is the result of rural abandonment during the last century (fig. C25.2). The reduction of traditional uses, mainly extensive livestock and multipurpose forestry (timber, woodfuel, charcoal or resins) has allowed regeneration of secondary vegetation characterised by proliferation of shrubby and bushy species. Moreover, the landscape has suffered a process of homogenisation with thousands of continuous hectares of highly fire-prone forests.

These unmanaged forests are under an increasing vulnerability to wildfires because of climate change. A small number of wildfires are responsi-



< Fig. C25.1. The proud shepherd Eugeni (Verges, Baix Emproda), who sells sheep to the restaurant Mas Pi (Photo: Diego Espada).

Statement

"Our mission is to reduce the risk of wildfires while creating a livelihood for rural areas through grazing. The extinction of a wildfire is the answer, but not the solution. The solution depends on a sustainable management of forests and landscapes promoting bioeconomy that allow and include rural development."

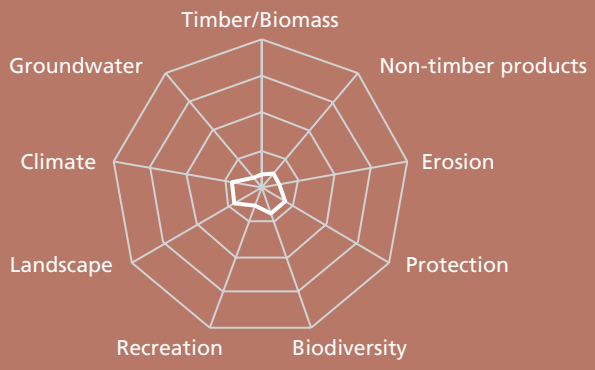


Table C25.1. General information on the forests included in the Fire Flocks project.

Forest community	*Pinus halepensis* forests (42.4 ha), *Quercus ilex* forests (1.5 ha), crops (2.8 ha), shrublands (0.9 ha), grasslands (0.2 ha)
Total forest area	48.11 ha
Main management types	Grazing
Total volume	131 m3/ha (before treatment)
Annual growth	Unknown
Annual Use	Unknown
Deadwood (standing and lying)	Unknown
Altitude	29 to 101 m
Ownership	100 % private
Geology	Limestone
Protected area (total)	0 ha
Nature protection area (Natura 2000)	0 ha
Protective function	10 ha

ble for most of the burnt area (only 11 fires were accountable for 88 % of the surface burnt by 4800 fires last 8 years). These large forest fires represent a growing risk for society, as firefighting services are unable to face them, despite the high budgets and investments allocated.

Of all type of forest fires, crown fires pose the greatest threat to fire control, and burn with greater intensity than surface or torching fires[1]. Traditional direct control of crown fires is impossible because the fire behaviour characteristics are extreme, i.e. high heat intensity, long spotting distances, large flame lengths, and rates of spread (Scott and Reinhardt 2001). In a continuous landscape under extreme weather crown fires evolve fast to megafires.

Fuel reduction treatments such as thinning, prescribed burning or grazing can be used as tools to reduce fire risk and severity. Fuel treatments modify species composition, structure, availability, distribution, fuel moisture, and surface-wind behaviour (Graham *et al.* 1999). The aim of these treatments is generally to reduce the fuel load so that, if a wildfire takes place, it will spread more slowly and with less intensity, and be less severe and easier to control (Piqué and Domènech 2018). To achieve this aim while ensuring that forests are resilient against wildfires, fuel treatments should consider one or more of the following four basic principles (Agee and Skinner 2005): reduce surface fuel, increase the height to the live crown, decrease crown density, and keep large trees of resistant species.

[1] Normal fires burn under 5000 kw/m. Crown fires can burn above 10000 kw/m. If they become plume dominated, then they become megafires achieving more than 30000 kw/m, with major impacts in all ecosystems.

Fig. C25.2. Typical landscape with many different structures in the Val Ager (Photo: Xavier Puig).

However, the effectiveness of a fuel treatment depends on its location in the landscape. Landscape planning allows the establishment of 'firesmart' landscapes with forest structures and spatial distribution patterns that contribute to difficult the spread of crown fires and facilitate the extinction of forest fires (Fernandes 2013). Strategic Management Points (SMP) are bands of low fuel or auxiliary bands anchored to paths that allow the extinguishing system to concentrate resources more safely and efficiently (Costa *et al.* 2011).

Silvopastoralism can be a useful tool for the sustainable management of Mediterranean forests from a biological, social and economic perspective; in fact, the future of Mediterranean agroforestry is built on the recognition of its multifunctional role (Casals *et al.* 2009). Silvopastoralism is a common practice with high benefits for society (landscape conservation, fire risk management, and the production of high-quality meat and dairy) and reduces and controls the amount and continuity of the vegetation mainly from the surface layer. However, the presence of shepherds and their sheep and goats have become more and more rare, leading to an increase in fuel loads in forests, and the expansion of fire-prone forests. Thus, the presence of livestock in woodlands has become a shared interest for land owners, farmers, firefighters, environment rangers, and businesses wanting to sell food products with an added value. All of these factors motivated the project 'Fire Flocks' (Ramats de Foc, Rebaños de Fuego, https://www.ramatsdefoc.org/en, funding Agency: Fundación Daniel y Nina Carasso).

In the stands that have been abandoned for several years, with high amounts of fuel (fig. C25.3), a first intervention using mechanical treatments is usually required, in order to prepare the area and allow the entrance of the livestock Subsequent to the initial mechanical intervention, grazing is a useful, and economically profitable, way of reducing the fuel loads.

The project area is in the province of Girona, northeastern Spain (42.061179 N, 3.046056 E) (see map). It is mainly composed of Aleppo pine with an understory of mastic and kermes oak, and the stands are dense, young and structurally similar. Before the forest was adapted to traditional pastoral regimes that included low intensity fires and the land cover was tolerant to natural fires caused by lightning.

Fig. C25.3. Typical forest stand that has been abandoned for years and contains high loads of burnable material and how the forest may look after grazing (Photos: Jesus Arades).

Aims of the Fire Flocks project
The overarching objective of the project is to create fire resistant landscapes through the continuity of extensive livestock farming. Thus, the specific objectives are to graze the undergrowth forests and shrublands, as a means of reducing the amount of fuel (vegetation) within the forests and create open spaces between forested areas. The project also aims to promote the bioeconomy in rural areas, valorizing the shepherd profession, the livestock, and the products from the livestock. The project also aims to create a certification for products produced from the herds that are kept with the aim of contributing to the control of fire.

Economics
The project is still in a pilot phase, but there has already been some assessment of the economic impact. The available data correspond to the period between January and June in 2017 and 2018. There has been an increase of 12 % in sales of meat from butchers, and an increase of 40 % in the number of restaurants participating in the pilot phase of the campaign.

Moreover, grazing also reduces the costs of fire management for society. Although, as mentioned, stands maintained with grazing need an initial mechanical treatment; thereafter, grazed stands become economically profitable, as they reduce the costs needed to maintain forests with low fuel loads. Thus, the maintenance of the fire flocks SMP would cost around 1200 €/ha over a 5-year period if done with mechanical means (57 600 € for the 48 ha treated).

Ownership structure
The land ownership is all private (48 ha, 100 %). A shepherd can use their own land, or other land if they sign a lease agreement with the holders of the long-term forest tenure rights (typically 5 years).

The land was abandoned about 15 years ago. Historically forests in the area were used to collect wood for individual purposes (at the farm or house level), and land was and still is made up of micro-private properties, with an average area of less than 1 ha.

Legal frame
According to the Spanish forest code there is a right of free public access to forests (private and publicly owned) but the use of non-wood product forests, which include grazing is not included as part of the code. Grazing is regulated by regional forest management plans that fix the livestock capacity of a certain area.

Management
There is a lack of information and guides about grazing in Mediterranean sites as a measure to reduce fuel loads. For each type of pastoral forest in Catalonia, Taüll and Bages (2016) analysed the cover of herbaceous and shrub layer, the palatability of the different species, and the pastoral potential. However, the guide considers that *Pinus halepensis* stands with an undergrowth of *Pistacia lentiscus* and *Quercus coccifera* have no pastoral potential because of their low palatability for the animals (sheep and goats).

The Fire Flocks programme seeks to reduce fuel loads and to break continuity of the vertical and horizontal vegetation layers. The predefined understory vegetation control targets are the following: (1) to graze 90 % of the annual biomass growth of the herbaceous layer, and (2) to graze 60 % of the annual biomass growth of the shrub layer. Thus, the aim is to create discontinuities (both vertical and horizontal) in the fuel loads. For each shepherd, Fire Flocks designs a 5-year pastoral plan in which the number of animals and the number of grazing days per year are defined. The needs for feed supplements are also considered.

Services

Fire Flocks brings together public and private agents interested in the continuity of silvopastoralism, by aligning their various needs, and articulating a production and consumption chain of food products from herds. The chain adds value by decreasing the fuel load, and therefore the fire risk in woodlands (as determined by the Catalan Fire Service or the Agriculture Department).

With Fire Flocks, shepherds release their livestock in forests with predefined understory vegetation control targets (fig. C25.4). However, in comparison to grazing in open pasture, grazing in forests often carries additional effort and a reduction in herd productivity. As reported by Taüll and Bages (2016), the pastoral potential for this type of forests is low or very low.

Fig. C25.4. Goats and sheep grazing in the forest. The animals provide different services and deliver different products (Photos: Diego Espada).

The Artisan Butchers Guild of Girona counties works on adding value to the products of the participating farmers, through a label that certifies the herds' fire risk management tasks. Customers will thereby know that eating Fire Flocks products delivers social benefits, i.e. contributing to the ongoing viability of local extensive (rather than intensive) livestock farms, preserving forests, and reducing fire risk.

Agents involved

The Fire Flocks project aims at generating fire resistant woodlands and increasing the continuity and viability of extensive livestock farming (given its double task in food production and landscape conservation). Therefore, it is important to strengthen the links between wildfire management services, farmers, local butchers, and restaurants.

Wildfire management services identify woodlands that are strategic in fire propagation dynamics (SMP), and describe what results are expected though silvopastoralism, for an effective change in fire behaviour in the area.

Extensive livestock farms graze the SMP with their animals (sheep, goats or cows), following a grazing plan that will allow the aims of the plan to be achieved.

Butchers and restaurants sell meat and dairy products from flocks under the Fire Flocks label, and explain the added value behind them to their customers.

Final customers become part of the fight against wildfires through the regular consumption of Fire Flocks products, and support the continuity of extensive livestock farming in our forests.

Products with the Fire Flocks label

Fire Flocks is the marketing label displaying the added value of products from flocks. Consumption of local meat and dairy contribute to reduction of fire risk, and therefore to conservation of forests (fig. C25.5). A growing network of butchers from the Artisan Butchers Guild of Girona counties, and restaurants offer Fire Flocks products. The final product consumers are the end of this value chain. The consumption of Fire Flocks products can be the flame that maintains the viability of the grazing livestock in Mediterranean forests.

Our shepherds and pastures:

The extensive livestock farms involved in the Fire Flocks project are located close to SMPs, and also to the final consumer (see map).

At the moment, Fire Flocks is a pilot test project involving three shepherds:

– Judit is a young female shepherd who produces goats for meat. She has 150 animals of a local goat breed (Cabra Blanca de Rasquera) highly adapted to Mediterranean forest and producing distinctive and highly appreciated meat. Judit's flock graze in two strategic areas close to her farm. To graze in Fire Flocks plots, Judit is using fences which allow animals to eat forest available feed and slowly reach the objectives of the grazing plan previously defined. Her commercialisation strategy before Fire Flocks was direct selling to the public, but now thanks to the Fire Flocks project, Judit has new clients (butchers) interested in her products. Pau is a young male shepherd with two types of flocks: goats for milk and

Fig. C25.5. Products from the Fire Flocks Project. Goat meat processed by local butchers and marketed in local restaurants, and Yogurt and cheese sold in local shops (Photos: Diego Espada).

sheep for meat. He runs the business together with his father. From the goat milk they produce fresh yoghurts and different types of fresh cheese such as 'mató' and 'recuit'. Their sheep meat is highly appreciated, and they sell to restaurants and butchers. He mainly uses sheep, together with part of the goat flock, to graze the area. Around 400 animals graze different fenced plots of 3 ha over several days and at different times of the year, basically when there is food available. With this strategy the high number of animals have a major impact on the forest ground vegetation, and the grazing plan objectives are easily achieved. As part of the Fire Flocks project, Pau now is selling to new butchers, and sales, especially of goat milk products, have increased since his products have had the Fire Flocks label.

– Eugeni is the oldest shepherd of the Fire Flocks pilot test. He is a traditional shepherd, who grazes his flock of 700 animals (sheep and goats) every day around the farm, combining fields and forest. He produces sheep meat for a family restaurant and for butchers. The strategic area coincides with the grazing area used by Eugeni, and thus no fences have been needed. He maintains his traditional practices and has integrated some of the recommendations from the Fire Flocks projects to reach the grazing plan objectives. In the family restaurant, customers can choose Fire Flocks lamb from the menu and a local butcher is selling his lamb, and the contribution the sheep make to fire risk control is explained to customers. The restaurant, especially, has noticed an increase in sales thanks to being part of the Fire Flocks project.

With the start of the project, five new 'shepherd–butcher' partnerships have been created. These partnerships are of vital importance to convey the message and the social and environmental commitment behind the project and allow the butchers themselves to have tools and knowledge to explain to clients (society) the importance of preventing fires through responsible consumption and proximity.

Conclusion

The project is now evaluating the pilot test phase, and planning to consolidate in the pilot area and expanding to the entire region of Girona, and later to other areas in Catalonia.

On one hand, Fire Flocks is detailing the validation method which will certify performance of the grazing plan and allow shepherds to become part of Fire Flocks. The validation method must include field visits to certify the operations and assess factors according to observations and measures which will help the final decision on the grazing impact on the forest vegetation and, therefore, fire risk control.

On the other hand, around 30 shepherds in Girona have expressed interest in being part of the Fire Flocks project. At the moment the project is working with them to: (a) select the grazing strategic areas, (b) define the grazing plan, and (c) list the butchers and restaurants where the products can be sold with Fire Flocks labels. Shepherds have expressed three main motivations to join Fire Flocks: (a) access to land, (b) added commercialisation value, and (c) recognition of its work in relation to silvopastoralism and the management of the risk of fires. Together with the Artisan Butchers Guild of Girona counties, Fire Flocks is describing the regulations for the Fire Flocks label use. That will be the base of the agreement between shepherds and butchers in relation of the use of Fire Flocks label.

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Box C 14

Sustainable management of Hyrcanian forests

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The northern forests of Iran (Hyrcanian forests) are classified as temperate deciduous broadleaved forests. These forests are located on the northern slopes of the Alborz Mountains and extend from near the shores of the Caspian Sea at –26 m a.s.l. to 2500 m a.s.l. According to the statistics of the Iranian Forests, Range and Watershed Management Organization, the Hyrcanian forests cover an area about 1.9 million ha. About 1 million ha have a forest management plan (Marvi Mohadjer 2013).

The tree composition of these forests is similar to broadleaved European forests, and includes species such as oriental beech *(Fagus orientalis),* hornbeam *(Carpinus betulus),* oak *(Quercus castaneifolia),* linden *(Tilia begonifolia),* alder *(Alnus glutinosa, Alnus subcordata),* and maple *(Acer velutinum, Acer orientalis)* (fig. 2). The species diversity of these forests is very high, with about 50 species of trees, 80 species of shrubs, and more than 100 species of herbaceous plants. Although, the tree species composition is similar, there are of course differences, and there are many endemic species including: ironwood *(Parrotia persica),* Caspian poplar *(Populus caspica),* chestnut-leaved oak *(Quercus castaneifolia),* Hyrcanian box tree *(Buxus hyrcana).*

Fig. 1. Hyrcanian Forests (Google Earth Image).

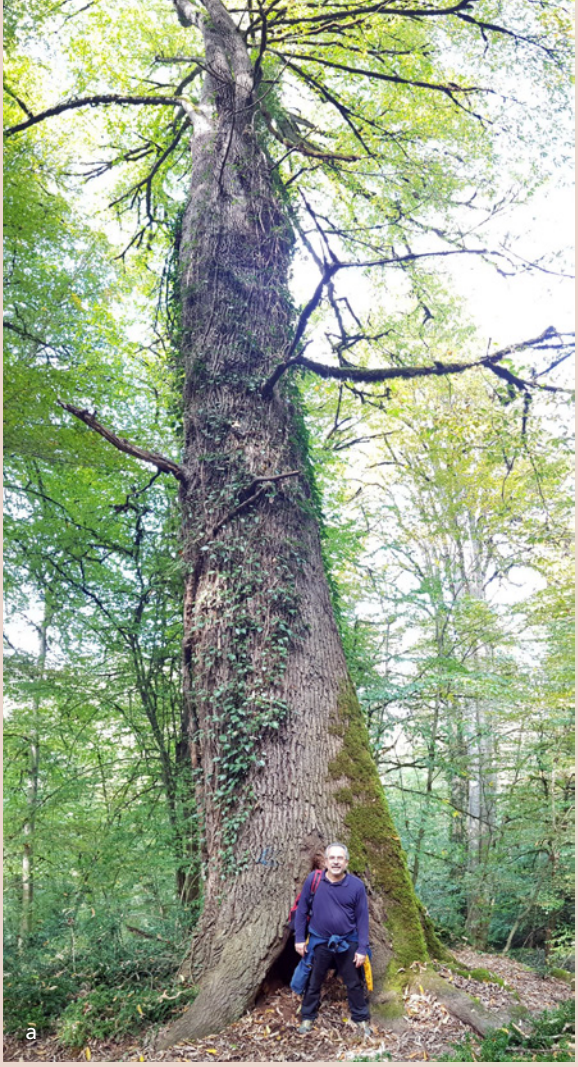
The Hyrcanian forests were formed during the Tertiary period, and owing to their geographical location below 40 °N degrees (36–38 °N), the glacial periods of the late Tertiary and early Quaternary did not damage these forests; the glaciers were above 3000 m a.s.l. in the northern Alborz. Therefore, the Hyrcanian forests can be considered as ancient forests that have high genetic value and biodiversity.

In short, the Hyrcanian forests are valuable as ancient natural forests with an uneven-aged structure, and high diversity. So far the genetic diversity of the forests has been relatively unexplored, and they can be said to be among the rare forests of the Northern Hemisphere.

The industrial exploitation of these forests dates back about 100 years. This period can be divided into wood harvesting without a forest management plan (1900–1950) and wood harvesting with a forest management plan (1950–2010). In the harvesting period without a plan, mostly Hyrcanian box tree, Persian walnut *(Juglans regia),* and oak species were exploited, and their timber was exported to European countries. During the period with a plan, the silvicultural method used was the shelterwood system. In about 1990, Iranian forest experts concluded that the shelterwood system was not suitable for Hyrcanian natural and uneven-aged forests, and the decision to use a system in which cutting and regeneration are not confined to particular areas but are distributed throughout a stand; the cuttings consist of the removal of single trees or small groups of trees; the practice leads to the development of uneven-aged stands with a more varied species composition (selection system) was taken for all parts of the Hyrcanian forests that had a forest management plan.

The implementation of close-to-nature silviculture took about 20 years. In 2016, owing to the increasing environmental importance of these forests because of their ancient nature, high biodiversity, naturalness, and because there was a problem with overgrazing by livestock in these forests, the Iranian Parliament implemented a 10-year ban on wood harvesting in the Hyrcanian forests.

The purpose of the ban is to protect the valuable parts of these forests with the help of international institutions such as the United Nations Educational, Scientific and Cultural Organization (UNESCO). In 2019, the Hyrcanian forests were designated as a UNESCO World Heritage Site (UNESCO



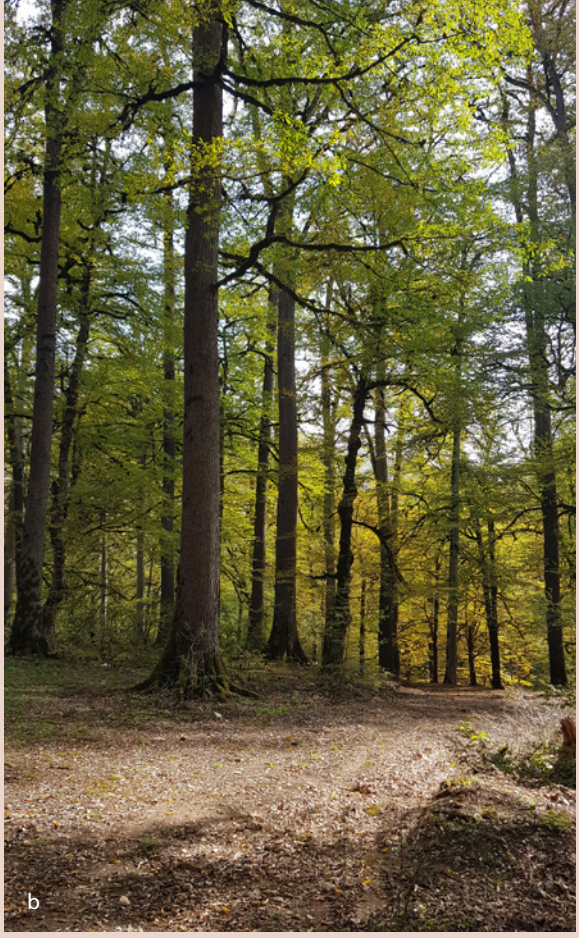


Fig. 2. (a) Chestnut-leaved oak *(Quercus castaneifolia)* with a diameter at breast height of over 1.5 m. (Photo: Georg von Graefe). (b) Chestnut-leaved oak *(Quercus castaneifolia)* stand. (Photo: Jahangir Feghhi). (c) Oriental beech *(Fagus orientalis)* stand. (Photo: Jahangir Feghhi). (d) Oriental beech *(Fagus orientalis)* with a diameter at breast height of over 1 m. (Photo: Vahid Etemad). (e) Oriental beech *(Fagus orientalis)* stand. Photo: Vahid Etemad).

2019). For the areas were harvesting is allowed, integrated management of the protection and exploitation of various functions of these forests, such as water and soil conservation, landscaping, ecotourism, water production, use of medicinal plants, and biodiversity conservation will be implemented by the Iranian Forests, Range and Watershed Management Organization.

The most important actions to be taken in this 10-year period are summarised as follows:

1. Creating the management work units based on catchment areas;
2. Solving the problem of grazing in the forest;
3. Protecting valuable parts of these forests, especially in terms of biodiversity;
4. The independence of the country's wood industry from the wood production of these forests by the wood import;
5. Preparation of suitable ecotourism plans;
6. Emphasis on the use of non-wood products and services of these forests (e.g. production of fresh water, medicinal plants);
7. Development of agroforestry on suitable non-forest land;
8. Development of wood production on suitable non-forest land;

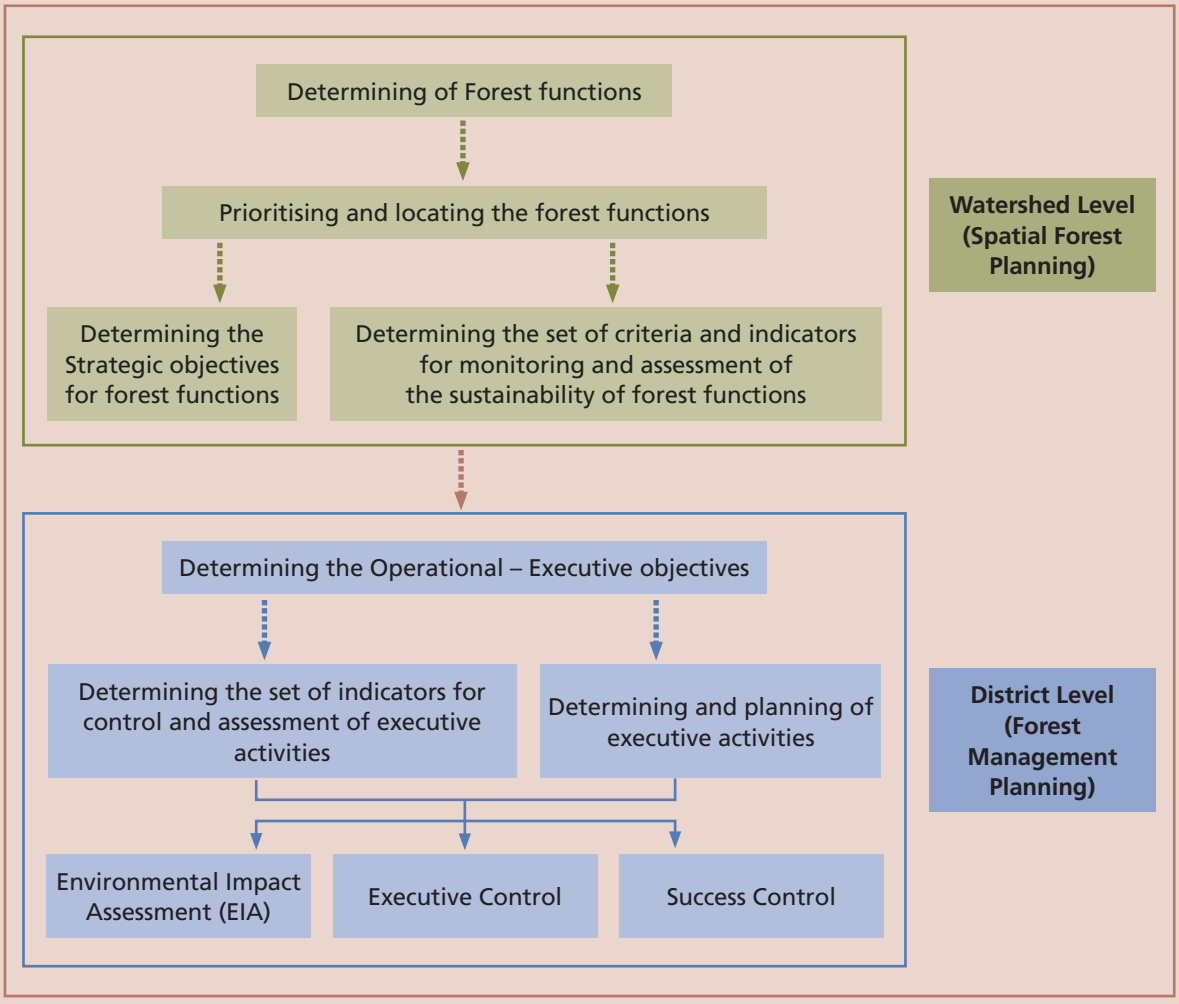


Fig. 3. Conceptual model of Sustainable Hyrcanian Forest Management (SHFM).

9. Preparation of sustainable forest management plans based on forest ecological capability with participation of all stakeholders and at the watershed level (fig. 3);
10. Sustainability control of forest functions using appropriate criteria and indicators (fig. 3).

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Cairngorms Forests – A rich heritage of native timber production

C26

W. Boyd-Wallis, D. Hetherington

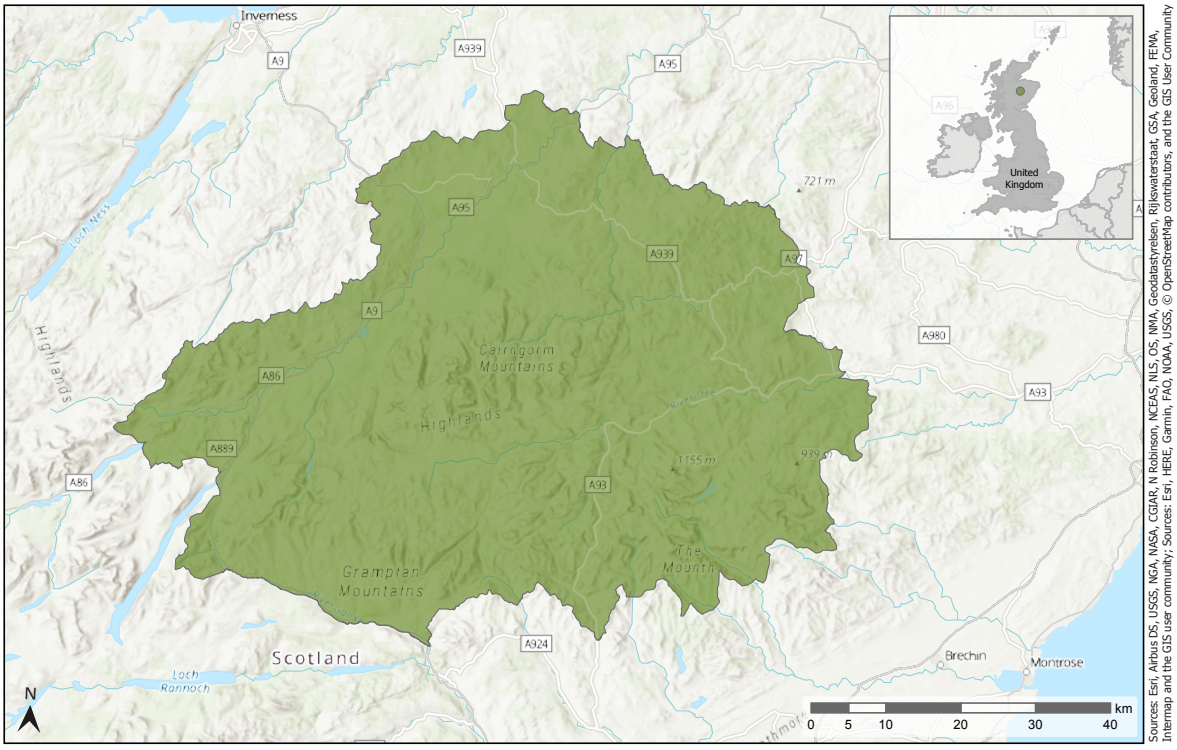
Cairngorms National Park Authority

Portrait Statement

Our vision is for the Park's forests to flourish and expand, providing us and future generations with healthier and better connected forest habitats, more diverse landscapes, greater capacity to store carbon, high quality timber, outstanding recreation experiences and greater opportunities for local business development.

Context, legal framework, and ownership structure

At 4528 km², the Cairngorms National Park is one of Europe's largest national parks. Despite its woodland cover being dwarfed by the expanse of open moorland and mountain, it represents some of the finest, most extensive and best connected native woodlands in Scotland, which are home to a



< Fig. C26.1. Wooded landscape, showing both commercial and remnant native woodland (Photo: Damian Shields, VisitScotland/CNPA).

Statement

"The need for sustainable, locally-sourced resources, including timber, has never been greater than now and is only going to increase in the future."

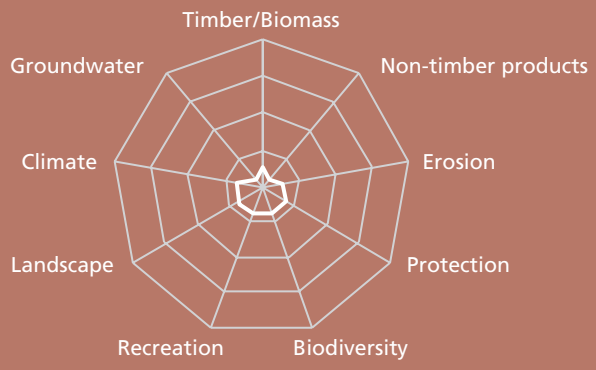


Table C26.1. General information on the Cairngorms National Park.

Total forest area	62300 ha based on 2015 survey, but currently expanding by approximately 1000 ha annually
Main management types	Clear felling/restocking, Low Impact Silvicultural Systems, Continuous Cover Forestry, nature reserve
Total volume	12126000 m³ in 2015
Annual growth	No data
Annual cutting rate	No data
Deadwood	Unknown, but some woodlands are being managed to produce more for biodiversity objectives
Ownership	A complex mix of mainly private land, with some owned by the state and conservation NGOs
Climate	Varies with altitude and distance from the Atlantic, but average 6.5 °C mean annual temperature, 900 mm mean annual precipitation at lower altitudes.
Geology	Mainly Dalradian sedimentary rock and post-tectonic granitoid intrusions.
Soils	Podzols are the most representative soil group in the national park (around 50 %), and consist of iron and humus-iron podzols at lower elevations. Peaty podzols and peaty gleyed podzols occur further upslope (and typically have an iron pan). Other groups include montane soils, peats, rankers and gleys. Brown earth soils cover only 4 % of the park.
Protected area	National Park (IUCN category V). Includes 54,399 ha of National Nature Reserve, covering significant areas of Scots pine and birch forest, as well as mountain willow scrub.
Natura2000 area	In the national park there is a total of 106 300 ha of SAC. Designated woodland habitat types include: Caledonian Forest; Bog Woodland; Western Acidic Oak Woodland; Alder Woodland on Floodplains; Mountain Willow Scrub; and Juniper scrub; There is also 201 300 ha of SPA, with woodland-related qualifying species of capercaillie, Scottish crossbill, osprey and golden eagle.

wide range of biodiversity rarely found elsewhere in the UK. There is a long heritage of forest management across the National Park and it continues to be the perfect test-bed for combining commercial forestry with good environmental management (fig. C26.1).

The UK as a whole is simultaneously one of the least wooded countries in Europe (just 13 % cover) and one of the largest importers of timber products in the world. At 19 % cover, Scotland is the most wooded part of the UK and aims to be greenhouse gas Net Zero by 2045, five years earlier than the UK as a whole. Woodland creation is therefore seen by the Scottish Government, not only as a way of reducing dependence on timber imports, but as an important way of helping meet climate change tar-

Fig. C26.2. Berdalen in southwestern Norway, where climate and geology are similar to the Cairngorms, showing a higher tree line consisting of Scots pine giving way to downy birch at around 900 m (Photo: David Hetherington).

gets through carbon sequestration. Annual woodland creation targets for Scotland have recently risen from 10000 ha to 12000 ha and will rise to 18000 ha by 2025. Covering as it does 6 % of Scotland, the Cairngorms National Park therefore has an important role to play, not only in conserving and enhancing biodiversity, but also in providing forest products and nature-based solutions to the climate emergency.

A long history of exploitation for timber and heavy grazing pressure, mainly by livestock but in more recent decades by high populations of deer, has meant that much of the national park has been deforested, its altitudinal treeline truncated to 650 m, while the remnant woodlands are often scattered and fragmented. Most of the deforested land is today upland dry and wet heath. However, the soils of the Cairngorms are capable of growing a wide range of tree species, not least Scots pine *(Pinus sylvestris)* and Downy Birch *(Betula pubescens).*

These two species grow at significantly higher elevations in south west Norway where latitude, climate and soils are very similar to the Scottish Highlands, but where grazing pressures have historically been lower (fig. C26.2). Indeed, in areas of the Cairngorms where grazing pressure has been reduced in recent years, we are seeing young pines and birches starting to grow much higher than the supposed 'natural' treeline.

This means we have enormous potential for creating more pine and birch woodlands across the National Park, in a way that reverses fragmentation and strengthens a forest habitat network across the park. This is important for aiding landscape-scale species movement, both for species that need better dispersal and population mixing to improve their genetic integrity, or those that need to migrate in order to adapt to climate change.

Forest management and biodiversity

One focus is currently on creating strips of riparian woodland in otherwise treeless landscapes, such as grouse moors that are typically managed with sheep grazing and heather burning. Not only does the pattern of planted riparian woodlands mean they can serve as long (albeit thin), woodland corridors and stepping stones, but in time they will play

Fig. C26.3. Aspen in the Cairngorms. It is home to specialist biodiversity, including moss, lichen, hoverfly and moth species (Photo: David Hetherington).

a crucial role in shading watercourses and thus helping to keep mountain streams cool. Recently recorded water temperatures in these streams of 27.5˚C are injurious to both Atlantic salmon *(Salmo salar)* and freshwater pearl mussel *(Margaritifera margaritifera),* two of the qualifying species of several of the river systems in the Cairngorms protected with Natura designation.

These new woodlands could be enriched with a wide range of other tree species, including the Aspen, a species which supports a range of specialist flora and fauna (fig. C26.3). The swathes of trees that already cloak the lower slopes of our mountains are an inspiring reminder of the potential for more forest across the whole of Scotland.

Over the last two decades a number of estates in the Park have significantly reduced deer pressure resulting in some spectacular woodland regeneration without any need for fencing. This has saved some of our most celebrated pinewoods from serious decline (fig. C26.4). Alongside this, many grouse-moor managers have removed deer, limited sheep grazing and controlled mountain hares to further their own objectives, and this has resulted in woodland regeneration arising in unexpected places on the edge of the moors (fig. C26.5).

Stocking levels of natural regeneration can be very high (>5000 trees/ha); in some locations if thinned appropriately this creates potential for the production of a unique, high quality timber resource. A number of forest managers across the Park are making good use of regeneration and continuous cover in existing forests as a means of combining good environmental management with commercial timber production.

Development strategy

Last year the Cairngorms National Park Authority (CNPA) launched a new Forest Strategy for the National Park. A key objective of the strategy is to promote the creation of new woodlands whilst demonstrating the potential for integration of different land uses across the Park. The strategy seeks in its 100 year vision to see a 'forest culture' develop

Fig. C26.4. naturally regenerating pines at the expanding edge of Abernethy Forest, a National Nature Reserve (Photo: David Hetherington).

Fig. C26.5. The margins of a grouse moor returning to young pine, birch and willow woodland (Photo: David Hetherington).

throughout the Park's communities. We want to see more people employed in forestry and benefiting from all the environmental, social and economic opportunities that more healthy and extensive forests provide.

The Forest Strategy stresses the need to create 5000 ha of new forest over the next five years and provides guidance on how and where this could be done. The emphasis of the strategy is on native species because as a National Park we always want to produce the best quality habitat for wildlife alongside other forest management objectives.

The proportion of Scotland's woodland made up of native species is just 22.5 %. Indeed, the North American Sitka spruce *(Picea sitchensis)* is the most common tree species in Scotland, having been favoured by the forestry sector over the last few decades because it can grow quickly in wet and acidic conditions found across much of Scotland. However, the Cairngorms National Park is the only municipality or national park in Scotland where native trees constitute the majority (>70 %) of woodland. This is partly because relatively large remnants of native woodland have persisted to the present day, and because traditionally the commercial conifer of choice has been the native Scots pine, which grows very well in the soils and climate of the Cairngorms (fig. C26.6). Non-native species are by no means ruled out for carefully planned productive forestry but we believe we can demonstrate the untapped commercial potential for more native timber use.

The biggest challenge in delivering woodland expansion in the predominantly cultural landscapes of a Category V national park, where most of the land is privately-owned, is persuading land managers to change the use or nature of the land. At present most unwooded land in the park is used for either hunting (e.g. red deer stalking and red grouse shooting) and/or agriculture (i.e. sheep grazing). Furthermore, some of the open habitats are protected by nature designations, including Natura2000, which don't allow, for example, species-rich heath or grassland to revert to woodland, even by natural regeneration of native tree species. One of the roles of the national park authority is to

Fig. C26.6. Planted Scots pinewood (Photo: David Hetherington).

Fig. C26.7. Young, planted Scots pine and birch woodland on a former grouse moor (Photo: David Hetherington).

make landowners aware of the benefits of woodland creation and explore with them how to deliver change and reconcile it with their other land management objectives (fig. C26.7).

Social and societal aspects

The reasons for more woodland creation in the Park are many, but the Scottish Government's declaration of a climate emergency has increased our resolve to ensure the land is put to best use for future generations. We cannot go on forever importing so much timber when we have the potential to produce much more of our own. We cannot go on increasing the height of flood defences when our hillsides could support a much more diverse and water-absorbent wooded landscape. Locally produced, sustainable resources are now needed more than ever.

With this urgency in mind there are now added incentives for landowners to create woodland in the National Park. Scottish Forestry Grant Scheme applications within target areas of the park may receive an additional 12.5 % payment on top of the standard woodland grant payment rates. Furthermore, the Cairngorms National Park Authority (with partners Scottish Forestry, Woodland Trust Scotland and NatureScot) have launched a 'Woodland Challenge Fund' to help with the costs of putting together grant applications, such as surveys and forestry agents' fees. These incentives are predominantly aimed at increasing native forests which we believe, if managed well, will become increasingly marketable in the future, as well as sequestering carbon and creating valuable wildlife habitat for a wide range of threatened species such as the capercaillie and wildcat.

Box C 15

The Green Guarantee

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Limited green space in the Netherlands

The Netherlands is one of the most densely populated countries in the world. When divided equally amongst its 16,9 million inhabitants, each Dutch citizen has 295 m² of forest and nature at their disposal. Together with 1323 m² of agricultural land, this amounts to a total of 1618 m² of green space per person in 2015 (CBS 2018). The government of the Netherlands has made considerable effort in the previous decades to increase the amount of forest and nature area and has to some degree succeeded in doing so. However, the change has come largely at the cost of agricultural land. At the same time, land use for industry, infrastructure, and domestic purposes has continued to rise (CBS 2016). So, in fact, the totality of green space in the Netherlands is not increasing, nor is it equally distributed over the country or its people. Especially in heavily urbanised Randstad area (the combined cities of Amsterdam, Den Haag, Rotterdam, and Utrecht), very little green space remains. However, Dutch people are renowned for their trading abilities and have thus found a way to make green space availability a tradable commodity.

Green Guarantee

Since the early 2000s, the Dutch have come to realise that an additional instrument was needed to supplement the major policy-driven land-use changes for the availability of green space on a local scale. To this end, several organisations started the development of the so-called 'Green Guarantee' (Marijnissen 2013). The object of these guarantees can be anything within the green realm. Notable examples deal with the view from one's house, growing certain agricultural crops, or the planting and maintenance of single trees, orchards, hedgerows, and small forest areas.

Drawing up the agreement

A 'Green Guarantee' is an agreement, commonly under private law between two, or in some cases several, parties, with an interest in a certain local green space. The first party to the agreement typically represents the landowner or manager that can thus directly influence the future of the green space under consideration. They may grow certain crops or graze certain animals. They can offer to plant certain trees or for an area to remain open. The second party represents a stakeholder in the green space, commonly the owner or tenant of a dwelling in or near the green space. If these parties find common ground regarding the future of the green space, they may enter into negotiation about the terms of a 'Green Guarantee'. The following elements would be part of such an agreement:

1. Identification of parties subject to the 'Green Guarantee';
2. Definition of the physical properties of the green space and its management by all parties under the stewardship of the first party (i.e. the owner/manager);
3. The contribution (money, goods, services) of the second party (stakeholder) for the provision as agreed under element 2;
4. The duration of the 'Green Guarantee'.

The negotiation process does not necessarily entail a formal process in which lawyers draw up an agreement. Depending on the complexity of the agreement – e.g. regarding the duration, number of parties, financial contributions – parties may choose to come to an oral or a written agreement. Both are recognised by Dutch law.

Hypothetical examples

A Owners of a private estate have decided to build a new cottage in place of a dilapidated farmhouse. A tenant farmer manages the arable land surrounding the newly built cottage. The farmer commonly uses the land to grow maize as a high-protein food for his dairy cows. When the new tenants move into the cottage, they do not wish to have their garden enclosed by a 2-meter high wall of maize every summer. They would rather have the farmer growing another grain, such as wheat or barley. The new tenants of the cottage approach the estate owners. The owners inform the tenants of the cottage that there are no restrictions in the agreement with the farmer that put limitations on the type of crops the farmer may grow. The estate owners then refer the cottage tenants to the farmer. After a short

negotiation, the farmer and the cottage tenants agree that during the next summer, the farmer will grow wheat instead of maize. The difference in value between the two crops is then paid by the tenants after each growing season. No agreement on paper had to be drawn up and all parties are happy with the easy and flexible agreement, the terms of which are renewed every year.

B A medium-sized city is planning a new housing location on former agricultural land. When selling the building lots, the potential homeowners express the importance of an open view on the adjacent agricultural lands. On behalf of the potential homeowners, the municipality approaches the farmer owning the land next to the building project. The farmer agrees to plant and maintain a low hedgerow, obscuring the current barbed wire fence from view of the houses. Furthermore, the farmer agrees to graze livestock on the land, thus maintaining its current open landscape. The farmer agrees to do this for the next 50 years, or as long as he manages the land. This 'Green Guarantee' is more complex than the previous example. The agreement has to be drawn up between the farmer and many homeowners. There also remains uncertainty as to what to do when one of the parties sells their property. Lawyers are asked to formulate the details of such an agreement. The homeowners organise themselves in a simple legal entity called an association. The association compensates the farmer on an annual basis for the maintenance of the hedgerow and for the limitations placed on the use of the land. In addition, the farmer is paid a lump-sum for the lost income of the land on which the hedgerow was planted as well as all the establishment expenses. All parties conclude that the agreement will be binding for the homeowners' association and the farmer, even after transfer of ownership. As this can potentially lower the price of the farmland and increase the price of the houses, when sold, an additional yearly fee is paid to the farmer covering this risk.

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Fig. 1. What is the value of an umbrella species and its cavity? The `carpenter` Black Woodpecker is of special interest as the builder of habitats that are used by many different species. The introduced approach may allow people to pay also for such services (Photo: Andreas Rigling).

Bois Landry – management of a multifunctional forest: a collaborative experience

C27

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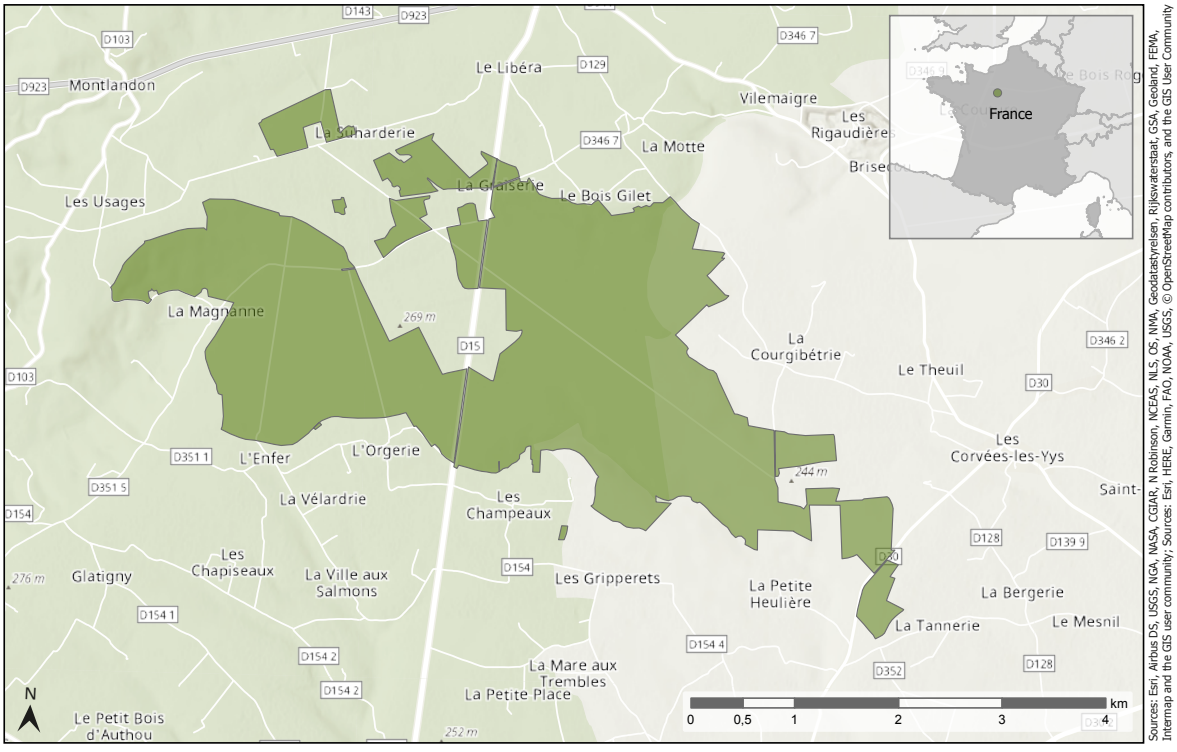
Context, legal framework, and ownership structure

The Domaine du Bois Landry is a private forest estate (1206 ha) located in central France in the department of Eure-et-Loir. Since 1 January 2000, the forest has belonged to the landowner-group Eugène Daubeck. This forest is part of the 'Percheron forest' which spans an area of about 48 000 ha in the Perche Regional Natural Park. This park serves as an ecological corridor of supra-regional interest and part of the 'Green and Blue



< Fig. C27.1. Roe deer as a main influencing factor of forest development. One of the main goals of the forest owner is to maintain a vital stock of game animals. The domaine offers training courses (in cooperation with the Institut pour le Développement Forestier) to educate visitors about forest ecosystems and game management (Photo: Michel Sineau).

Statement

"Frequent contact and regular communication between agents of the forest service and representatives of public forest owners is important in the perspective of maintaining a good level of knowledge about the forest situation and its evolution."

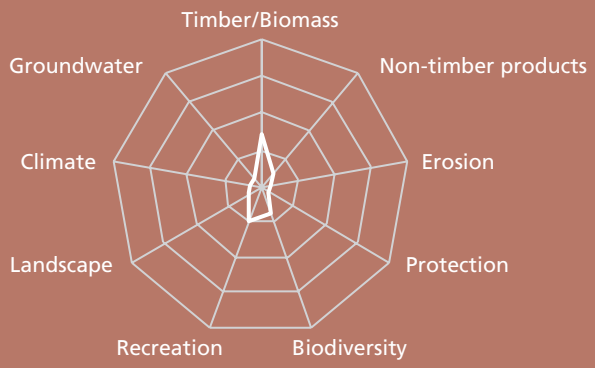


Table C27.1. General information on the Bois Landry.

Total forest area	1206 ha
Main management types	Conversion from coppice with and without standards to irregular forest management / continuous cover forestry
Total standing volume	186 m³/ha – 170 trees/ha
Annual growth	3.97 m³/ha
Annual cut	2 m³/ha
Deadwood (standing and lying)	1.6 m³/ha
Altitude	200–270 m a.s.l.
Ownership	Private landowner group Eugène Daubeck
Climate	Oceanic with temperate summers, average annual rainfall reaching 590 mm, and average minimum and maximum temperatures of 1 °C and 8 °C in February (coldest month), and 13 °C and 25 °C in August (hottest month).
Soil	The soils have generally good potential on the plateau, with a reserve for temporary hydromorphic zones; quite poor on the Perche sand and on slopes. They are of a brown earth type leached throughout the massif with a silty-clay texture and are quite deep on flint clays (1 to 2 m deep) and are shallow to superficial on slopes and outcrops of Perche sands.
Geology	the geological layer is made up of Upper Cretaceous formations represented, over most of the territory, by sedimentary flint clays (eastern part) and Perche sands that outcrop on the slopes to the west and north of the massif.
Protected areas	Natura 2000 – Forêts et Etangs du Perche – Birds Directive – Type A (ZPS) – Code: FR2512004 – Arrêté du 27/04/2006 – 47 681 ha
Special administrative status	Territoire pilote pour la gestion et de la préservation des écosystèmes forestiers et de la biodiversité Label Stratégie Nationale pour la Biodiversité [Pilot territory for the management and conservation of forests and biodiversity – National Strategy for Biodiversity label]. Territoire Wildlife Estate 'Territoire de Faune Sauvage' [Wildlife Area]

Infrastructure' – a national initiative to promote connectivity of species. The forest has been certified by the Programme for the Endorsement of Forest Certification (PEFC) since January 2000 and in April 2006 an area was designated as a Natura 2000 Special Protection Area 'Forests and Ponds' (SPA FR 2512004). Further, in 2014 it was awarded with the National Biodiversity Strategy Label (Maintenance and Preservation of Biodiversity), and in 2015 it received the Wildlife Estates 'Wildlife Area' Label and the Belleuropa Prize. With regard to the management of deer hunting, the estate obtained the status of experimental territory in 2007 and of a pilot territory since February 2017.

The forest has traditionally been managed as coppice with and without standards, and is now

being transformed into a high forest with irregular structure in the main forest area. There are still some coppice areas left and in production. The dominant tree in the upper stratum is sessile oak *(Quercus petraea),* which grows mixed with pedunculate oak *(Q. robur),* ash *(Fraxinus excelsior),* wild cherry *(Prunus avium),* and chestnut *(Castanea sativa).* The most common trees in the coppice are hornbeam *(Carpinus betulus),* as well as birch *(Betula pendula),* hazel *(Corylus avellana),* wild service tree *(Sorbus torminalis),* and aspen *(Populus tremula).*

The Groupement Foncier Rural Eugène Daubeck was established in the early 2000s as a collaborative association (which manages the hunting on the estate) and a commercial company (which develops various activities to enhance the value of forest products, including green tourism, R&D, carpentry, honey production, local shop). The Domaine du Bois Landry addresses the needs of a variety of groups, and especially city dwellers in need of nature and preserved spaces.

Prior to 2000, this forest was managed quite extensively. The locals called it 'a minimalist' management approach, also known as 'good father' management. The hunting regime was ineffective and this had resulted in a very high population density of roe deer *(Capreolus capreolus).* Consequently, natural regeneration was non-existent, biodiversity was harmed, and the roe deer population was in very poor condition.

Cooperation with research

In 2005, as a consequence of the poor status of regeneration and also the increasing loss of biodiversity as a result of the overbrowsing, the Groupement Foncier Rural Eugène Daubeck began a collaboration with researchers from the CEFS (Comportement et Ecologie de la Faune Sauvage) laboratory of l'Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE) in Toulouse. The two objectives of this collaboration were: (i) to ensure deer population management compatible with silvicultural objectives; and (ii) to contribute to the development of a management method, using a set of indicators (indicators of ecological change, IEC) to monitor the relationship between deer populations and their habitat. The principle of the collaboration based on the provision of reliable field data by the Domaine du Bois Landry so that INRAE can analyse the data and propose management alternatives for the forest owner.

There was no attempt made to estimate the size of the roe deer population. Annual hunting removals increased from 2001–2002 (104 deer) to 2006–2007 (173 deer) and remained at a high level in 2007–2008 and 2008–2009 (167 and 198 deer, respectively). At the same time, several IECs were monitored on deer abundance, body condition, and impact on understorey vegetation. The presence and degree of browsing of hornbeam *(Carpinus betulus)* (the main coppice species) and brambles (*Rubus* spp.; the predominant undergrowth and of major food importance for deer in Western European forests) were also monitored. An overall browsing index (the proportion of plots where at least one of the species considered was browsed) was also calculated considering all woody species. The browsing index was not calculated for ivy *(Hedera helix)* and honeysuckle *(Lonicera periclymenum);* these species are regularly consumed by deer, but the presence of browsing is difficult to estimate.

The frequency of adult females producing two or more corpora lutea (temporary endocrine structures in the ovaries of female mammals that develop immediately after ovulation; they reflect the number of ova released and the potential litter size) increased sharply between 2006–2007 and 2007–2008, showing a significant variation over the entire period. The body mass of young deer decreased between 2001–2002 and 2006–2007. After a large increase between 2006–2007 and 2007–2008, and a more moderate increase between 2010–2011 and 2011–2012, body mass stabilised, with a mean (±SE) of 11.79 (±0.15) kg for males and 11.34 (±0.16) kg for females (estimated on 20 December each year). Similarly, jaw length was at a minimum in 2006–2007, increased sharply from 2006–2007 to 2007–2008, then continued to vary before stabilising at a high level from 2011–2012 to 2014–2015. Body mass of juveniles and jaw length were highly correlated, and these characteristics were also correlated, although less strongly, with the ovulation rate of adult females (fig. C27.2).

The kilometric abundance index (the mean number of deer observed per kilometre walked on standardised transects) (fig. C27.3) declined from March 2006 to March 2009, suggesting a sharp decrease in population density; after 2009 the

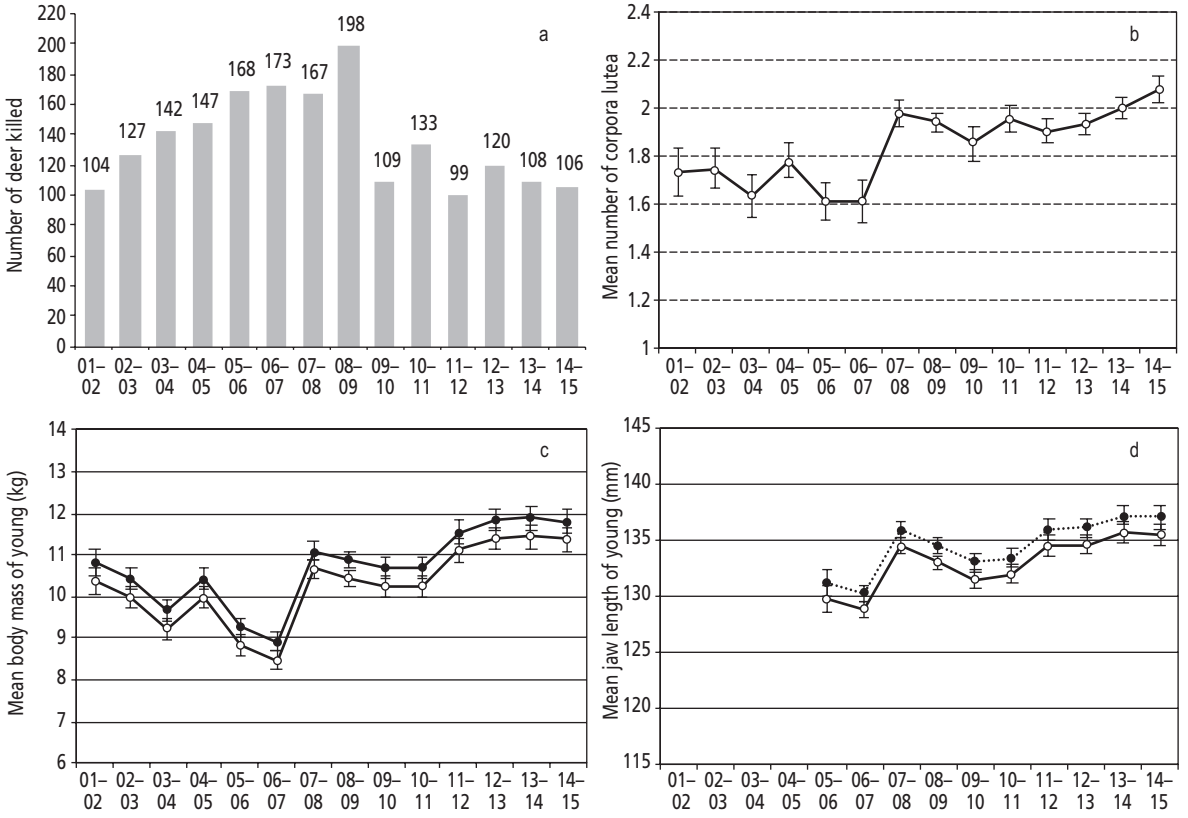


Fig. C27.2. Hunting pressure and body condition indicators between the 2001–2002 and 2014–2015 hunting seasons: (a) annual number of roe deer culled; (b) ovulation rate ± SE in adult females; (c) mean body mass ± SE; and (d) mean jaw length ± SE of young, as estimated on 20 December (males: black, females: white symbols).

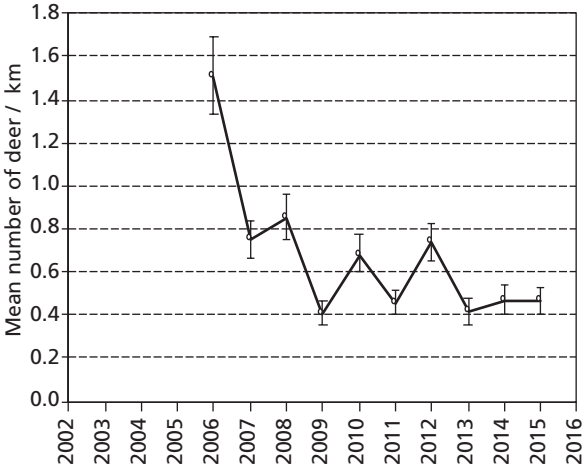


Fig. C27.3. Kilometric index (± SE), as estimated using a linear model in which the observer's identity is set as a random-effect factor.

index showed significant oscillations until 2013, and finally stabilised between 2013 and 2015.

The overall index of browsing (fig. C27.4) decreased between 2007 and 2013 and tended to increase between 2013 and 2015. The proportion of plots with oak tree stands decreased sharply between 2007 and 2010 and then more slowly from 2010 to 2015. During the same period, the proportion of plots with woody species available for deer increased between 2007 and 2013 and decreased thereafter. This variation is mainly due to oak seedlings, whose availability depends on the irregular production of acorns. However, the proportion of plots with brambles increased between 2007 and 2015.

As shown by the variations in the different IECs, the sharp increase in hunting pressure has reduced population density, improving the body condition

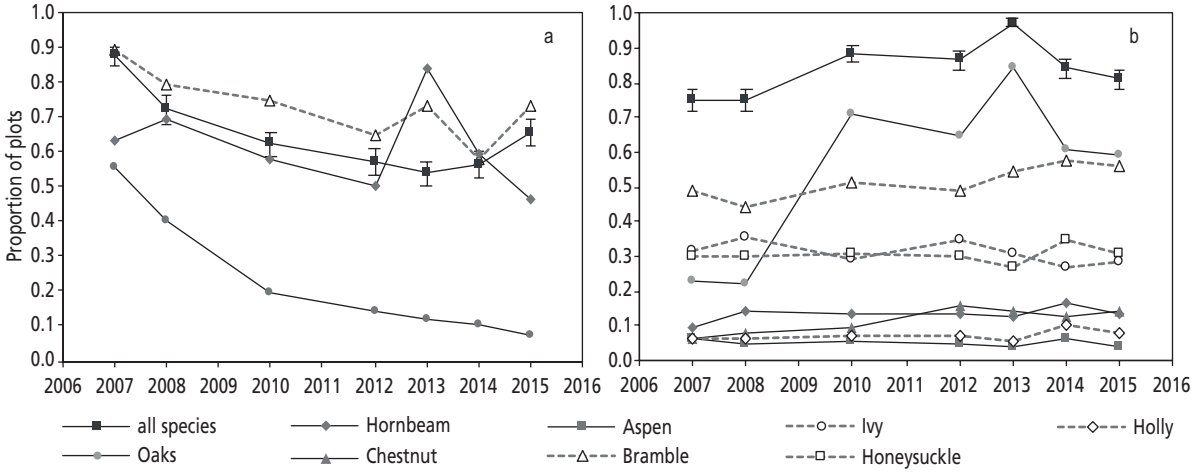


Fig. C27.4. (a) Global browsing index (±SE), and proportion of plots (without SE) where brambles, hornbeams, and oaks had been browsed by roe deer. (b) Proportion of plots with woody species available for roe deer (SE only shown for all species combined).

of the animals and the regeneration capacity of the forest. This shows how the use of a coherent set of IECs can provide information on the game population–habitat system and can help the manager to modulate hunting quotas to meet specific management objectives. In this case, hunting quotas increased until the indicators showed an improvement in the body condition of the deer and a sharp decrease in population density. Subsequently, quotas were lowered and maintained at a level designed to ensure sufficient hunting opportunities, good deer body condition, and forest sustainability. Because beautiful big deer are indicators of a 'beautiful' growing forest.

Economy

The owners of Bois Landry have a remarkable attitude to analyse and evaluate their economic situation. In their sort of model approach the forest is seen as a house providing different goods and services. An ecosystem that is used with respect and necessary 'conservation' of nature, though naturally exposed to risks. The model, which is based on practical philosophy, combines ecology (knowledge of the home), economy (management and administration of the home), and social aspects (needs and demands of its inhabitants). This practical model imposes a multifactorial, multidimensional, and global vision that is also often synthesised by the classic ecological, economic, and social triptych; the idea is, therefore, also to motivate collaborative action, in order to share the development project with partners, often with other points of view, or with other skills.

The economic result of this multifunctional management speaks for itself when comparing the figures for the last two decades; we thus take a closer look at the average figures for the periods 2000–2009 and 2010–2019. The first period was very much impacted by roe deer and this was perceived as a silvicultural constraint. In the second period, the roe deer became a part of a functioning ecosystem. Thus, two very different phases can be distinguished in the relationship between the forest and the large fauna, and with the deer species in particular. The primary condition for the effectiveness of the Bois Landry multifunctional management model is the capacity to restore and maintain, the forest–game balance, depending on human activities (fig. C27.5). If this is not in balance, forest managers simply cannot carry out the tasks needed to regenerate stands and rationally harvest mature trees.

This difference can be read in terms of the various economic management indicators at our disposal: volume harvested, timber selling price, basal area, and consumption value.

Fig. C27.5. Hunting infrastructure as a measure of human activities in order to keep the forest–game balance. This is important for Bois Landry to maintain multiple goods and services, but especially so for biodiversity (Photo: Carol Descordes).

Fig. C27.6. Timber production forests dominated by broadleaved species. This type of forests remain on large parts of the property; small islands of old-growth elements are retained (Photo: Carol Descordes).

- The annual harvested volumes during period 1 rarely exceeded 1000 m³ (average of 576 m³–0.5 m³/ha). To compensate for years with low harvests the exploitation of firewood was increased. From 2010 onwards, the average annual harvest volume has increased by four times and is greater than 2500 m³ on average (2 m³/ha).
- The average prices for sold timber has increased from the first period (69 €/m³) to the second period (136 €/m³). This increase is due to the evolution of the market, but also and above all to the improvement in the quality and amount of the timber harvested and sold. The average volume of trees sold has thus increased from an average of 0.8 m³/ha to 1.4 m³/ha within only 10 years of time. Also, the proportion of B quality timber has increased in that time span, as a measure of quality timber that was not well represented before.
- The increase in volumes was not to the detriment of the basal area, which increased between 2011 (17 m²/ha) and 2019 (20.5 m²/ha), nor of the consumption value, which remained high (€ 17320 in 2019).

Forest management and biodiversity

The research cooperation started in 2005 with the aim to develop a strategy to reach a forest–game balance was extended in 2011 and integrated a more global dimension of biodiversity protection, in order to further improve the sustainability of forest management and the conservation of ordinary biodiversity; new collaborations have been necessary for its implementation. Three new partners have thus been associated with this project since 2011: the 'Île-de-France Centre-Val de Loire' Regional Centre for Forest Owners, and the associations Eure et Loir Nature and Athena (for technical issues); and since 2018, the François Sommer Foundation (for financial issues).

A new 'Simple Management Plan' called 'Biodiversity', dividing the forest into two parts, has been approved: the western part of the forest remains under traditional management with homogeneous stands on large plots, in which islands of old-growth and conservation will be preserved (fig. C27.6); the eastern part of the forest is subject to more continuous management on smaller plots with more

Fig. C27.7. New elements according to the management plan 'Biodiversity' in the eastern part of Bois Landry with openings (Photo: Carol Descordes).

openings, in order to diversify the vertical structure of the habitats (fig. C27.7).

The divergence of the two parts of the forest according to management activities is followed by measures of forest structure. As forest management can influence the abundance and distribution of deer (roe deer and red deer *[Cervus elaphus]*) populations, which are known to have an indirect impact on biodiversity, these populations and their impact on vegetation are monitored using IECs. The effects of forest management on biodiversity are monitored using several indicators: indirect (the Potential Biodiversity Indicator or PBI) and direct indicators, taking into account the abundance and diversity of targeted taxonomic groups: birds, reptiles, and bats.

Social and societal aspects

In 2013 producers of logs and timber processing in Eure-et-Loir, the Domaine du Bois Landry have developed a platform for processing firewood from eco-certified forests. This diversification of processed products allows the estate to offer high-quality firewood of lengths between 25 and 50 cm and wood pellets for sale to professionals (retailers in the Grand Ouest) and individuals (Eure-et-Loir) (fig. C27.8).

To further develop multifunctional project of Bois Landry, the Domaine has set up different structures to diversify its production. Thus, another association and a company, both with the name Forestis, were founded. The aim of the Forestis association is to support and offer opportunities for recreation (sport, education, and culture) in nature.

The company SARL Forestis manages all the commercial activities of the Domaine. Located 1.5 h drive from Paris, the Domaine has built tree houses to welcome the people of Ile-de-France in an exclusive area of 50 ha; the cabins provide unique opportunities to stay overnight in the heart of the forest (fig. C27.9). Wooden huts, accessible by ladders, stairs, footbridges or zip lines, have been built in century-old oaks (between 5 and 13 m high), with another one on a pond within the forest (fig. C27.1). These huts offer an unusual natural space for sleeping, recharging batteries, resting, and walking.

Fig. C27.8. The processing of firewood has been developed (Photo: Carol Descordes).

Educational and orientation courses are provided in the forest, to learn how to orientate in nature, to discover the local fauna and flora, and to share a moment of nature. Local staff explain what forest operations are carried and explain why these operations are necessary.

The Domaine du Bois Landry also offers training courses about the natural environment, for professional groups and seminar participants. Internships in integrated forest land management with the Belval school, and a training course in the use of the practical guide to forest–game balance are offered in cooperation with the Institut pour le Développement Forestier (IDF). Finally, a store selling Percheron local products made by the estate under its own brand (terrines and honey from Bois Landry) was opened in 2010 in the reception area near the cabins. All these commercial activities allow Bois Landry to employ seven full-time employees.

While the multifunctional management model requires vision and willingness to develop its dynamic strategy, it also requires people with the skills to guide its practical implementation. Multifunctionality is a concept that can only flourish through the transmission and sharing of silvicultural know-how.

Conclusion – Multifunctionality and ecological resilience for a practical implementation of the multiple functions of the forest

Multifunctionality is a 'beautiful' concept – a quasi-philosophical concept that visionary American conservationist and forester Aldo Leopold (1887–1948) could have used in his time. For 20 years, the Domaine du Bois Landry has sought to implement this concept, and Leopold's ideas and principles. Implementing this vision has not been easy and there has been a need to fight for the principles and against different ingrained and established ideas such as 'managing' without population counts (in the case of the roe deer). In the same way, managing a natural forest area with an ecological vision seems to run counter to many of the current principles of forest management, that are

Fig. C27.9. Holiday cabin in the Bois Landry. The construction material is from the local forest, and the marketing and management of the holiday infrastructure is also done by the Domaine du Bois Landry (Photo: Carole Descordes).

still applied across European countries! It has been visionary years ago, when the owners of Bois Landry have started to think in a different direction. The adventure has been all the more exciting because of the need to fight for this vision! This encouraged approach seems to be paying off now.

Sonian Forest – A case from Brussels

C28

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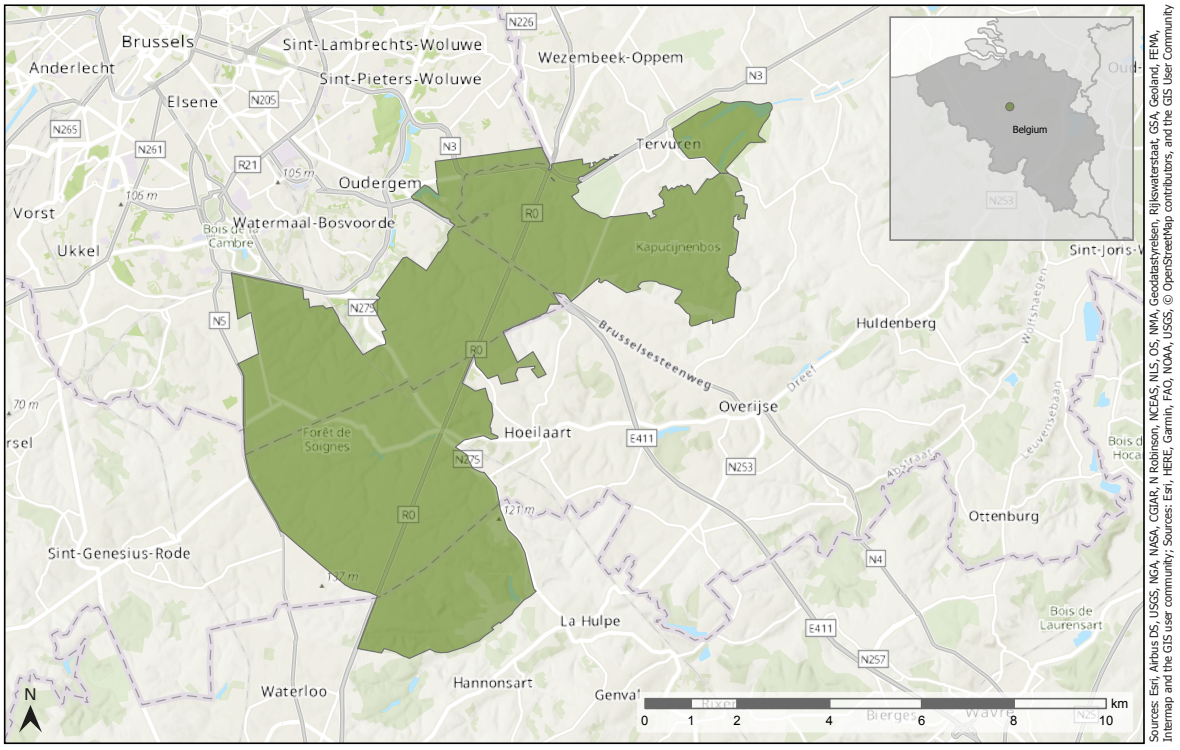
Portrait of the enterprise – Important figures

Located at the southern edge of Brussels, the main management aims in the Sonian forests are recreation and biodiversity conservation. Of course there are also other factors at play, such as wood production, soil protection and landscape aesthetics.

The Sonian Forest (Dutch: Zoniënwoud; French: Forêt de Soignes) is located on the southern border of Brussels. The forest complex covers more than 5000 ha and stretches over the three regions that



< Fig. C28.1. Scenic views and old growth elements are of priority importance in the Sonian forest. Big diameter standing deadwood is a scarce element in forests (Photo: Kris Vandekerkhove).

Statement

"In a heavily frequented urban forest, with extraordinary high natural values and a comparable cultural heritage, integrated forest management is the only way to ensure that the various functions of the forest can be maintained while remaining flexible enough to adjust to changing environmental conditions and a variety of societal expectations."

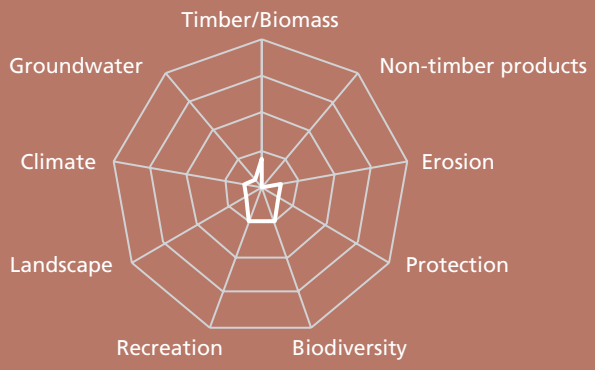


Table C28.1. General information on the Sonian Forest.

Predominant forest community	9120 – Atlantic acidophilous beech forests with holly *(Ilex aquifolium)* and sometimes also yew *(Taxus baccata)* in the shrub layer (*Quercion robori-petraeae* or *Ilici-Fagenion*) 9160 – Sub-Atlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli* 91E0 – Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)*
Main tree species	*Fagus sylvatica* (65 %), *Quercus* spp. (15 %), *Pinus* spp. (4 %), *Acer* spp. (4 %)
Altitude	50–150 m
Soil type	Mainly dry loamy Luvisols (Tertiary calcium-rich sandstone substrate, covered with a 0.5–4 m thick layer of Quaternary niveo-aeolic loess deposits of the Weichselian glaciation)
Total forest area	5000 ha
Main management types	Selective thinnings with the aim of producing high-quality wood. Clearcuts in certain stands or to create clearings
Volume	400 m^3/ha
Basal area	28 m^2/ha
Annual increment	5–15 m^3/ha (total 30 000–50 000 m^3)
Annual harvest	3–4 m^3/ha (total 15 000–20 000 m^3)

constitute Belgium, and that are responsible for the management of the larger part of it: Brussels (1700 ha), Flanders (2700 ha), and Wallonia (600 ha). Smaller parts of the complex are managed by other public authorities or private owners.

It is the largest ancient woodland site of lowland Belgium, with a very high natural value. Almost the entire forest falls within the Natura 2000 network. Its central location in one of Europe's most urbanised areas, with over 2 million visitors per year, means that the cultural ecosystem services (tourism, recreation) are very important, and are therefore a predominant focus for the management. Nonetheless, wood production is still an important goal, with the production of high-quality timber (mainly beech). The forest is known for its majestic beech *(Fagus sylvatica)* stands, where even-aged trees reach up to the sky in a competition for light, creating a closed forest of pillar-like trunks, often described as 'cathedral forest' (fig. C28.2).

Ownership and cooperation

The larger part of the Sonian Forest complex is publicly owned by the three aforementioned regions. Since the 1980s, forest management and policy in Belgium have been the responsibility of the regions, with no national legislation remaining. This means

Fig. C28.2. Typical beech cathedral of the Sonian Forest in winter (Photo: Patrick Huvenne).

that every region developed its own management plan and regulations for its part of the Sonian Forest, making forest management and policy very complex and difficult. This used to lead to potential complications for visitors, who had to comply with different regulations in the respective regions, the borders between which are not visible in the forest.

Because the pressures and challenges on the forest in the three regions are the same – urbanisation, transport, tourism – the three management units responsible for the forest came together to develop a long-term strategic plan for the total forest complex (the so-called 'Structural Vision for the Sonian Forest'). It involved an intensive participation of stakeholders (communities, owners of adjacent domains, wood harvesters, and sports, youth, and nature associations, etc.) and other relevant authorities (administrations for transport infrastructure, for heritage protection, etc.).

Fig. C28.3. Recognisable visual identity and typeface of the Sonian Forest, used in the three regions in different languages.

The Structural Vision is, however, not just a policy document. The scheme led to the creation of a recognisable 'corporate identity' used in maps and information panels (fig. C28.3.). The Vision is now used as a framework for the planning of specific interventions in the management plans of each region. It contains a framework on concept and management of the forest, dealing with the most important ecosystem services and challenges of the forest complex, such as nature conservation and recreational pressures. Forest recreation, for instance, is now organised with 'entrance gates' and zonation over the three regions. Furthermore, the scheme was the basis for several operational projects:

a) The extension of the existing network of strict forest reserves to a total area of over 350 ha spread over the forest complex, complemented with smaller set-aside areas to serve as 'stepping stones' for spontaneous development of the forest ecosystem.

b) A Life+ project called 'OZON' (Dutch: Ontsnippering ZONiënwoud; Defragmentation of the Sonian Forest – www.sonianforest.be/lifeozon) that led to the construction of a 'green bridge' over the ring road around Brussels (fig. C28.6), three tunnels under it, specific tunnels for amphibians and the refurbishment of old tunnels to make them safe wildlife connections. Railways and highways were fenced during the project to avoid further 'roadkill'.
c) Close collaboration between the forest and nature administrations and the heritage protection agencies in each region (in total six agencies) led to the successful inclusion of the beech forest reserves of the Sonian Forest as a component of the UNESCO World Heritage Site 'Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe'.
d) The development of the 'entrance gates' close to villages at the edge of the forest, each of them equipped with parking, information panels, and facilities.
e) Projects like the HORIZONplus, financed by the administration for urban planning, organisation of 'green and blue infrastructure' (i.e. to ensure the connectivity of green spaces and the surface hydrographic network, respectively) between the Sonian Forest, the neighbouring village centres, and the surrounding natural areas.

History

Being located in a prosperous area with fertile soils, at a cross-roads of cultures that in the Middle Ages was one of the most urbanised regions in the world, history has strongly defined the management and current look of the Sonian Forest.

The first written source on the forest is the 'Donatio Angelae', a bull dating back to the year 819. In this document the forest is explicitly mentioned for the first time *(est ibi silva… que vocatur Sonia).* The Frankish kings subdivided it in a *'silva communis'* and a *'silva domini'* that was attributed to the local lord *('que singularis est').* It was, however, allowed for locals to enter and take out all the wood they needed, except for oak and beech *(preter quercum et fagum),* as they belonged to the lord.

From the twelfth century onwards, the Dukes of Brabant were the sovereigns of the forest, and declared it as their exclusive hunting ground, and added further restrictions on public use. This led to the creation of the 'Cuerboeck van Soniën' (first version: 1371), which can be considered as one of the oldest known forest legislations, and surely the oldest complete law book on forest use. Forest grazing was an important activity at the time, also after the House of Burgundy acquired the Duchy of Brabant. This family developed a sophisticated management system, later known as 'tire et aire'. It can be compared with a modern-day shelterwood system with final cuts of 3–10 ha and an 80–100 year rotation, in which the seed trees of oak and beech remain for a second or third rotation. This system has defined the forest management until the beginning of the twentieth century. The family also installed 200 ha of hunting reserves, in which no trees were to be cut, to provide an impressive scenery for hunting events.

Under the Habsburg Emperor Charles V, who ruled over the Low Countries between 1506 and 1555, the management was further rationalised, with the cuttings evenly distributed in time and space over the forest, and further restrictions on forest grazing and wood gathering. During the sixteenth and seventeenth centuries, increasing religious tensions, wars, and instability in what was then known as the 'Spanish' or 'Southern Netherlands' led to a severe overexploitation and degradation of the forest.

When the ownership of the Southern Netherlands (more-or-less corresponding to present-day Belgium) was passed on to the Austrian branch of the Habsburg family in 1714, a period of relative stability started. They constructed new roads and started extensive reforestation on degraded parts of the Sonian Forest, mainly with beech.

The French conquest of the Southern Netherlands in 1794 started a short period of chaos and rebellion. The French needed large quantities of wood for their fleet, and the Sonian Forest became a hide-out for rebels during the Peasants' War (1798). Under Napoleonic rule, however, the French forest administration was well-organised, as forests were of great strategic importance, for shipbuilding, among other reasons. They replanted areas of overexploited forest, mainly with oak, that are still recognisable today. After Napoleon's defeat at Waterloo (1815), the Northern and Southern Netherlands were unified. The Sonian Forest became

royal property once more under William I of Orange-Nassau, who handed it over to a private holding, that used it as capital buffer for their financial operations.

After the independence of Belgium in 1830, large parts of the forest however were sold by the holding and deforested, quickly reducing the forest surface from 12 000 ha to about 4500 ha. Some parts became private parks, but most was brought under agriculture or settlements. Under public pressure, the Belgian state bought the remainder of the forest in 1848.

Art has played a major role in the preservation of the forest. Artists became an important influence in the forest management, being among the first people to protest against clearcuts. In 1909, a Brussels painter, Rene Stevens, founded the Friends of the Sonian Forest, Belgium's first nature conservation organisation. By the end of the nineteenth century, the forest also became a popular destination for weekend trips by the Brussels upper-class. Together with the influential artists, they opposed the conventional forest management with its relatively large-scale and intensive harvests, and to the deforestations that still took place, e.g. for the building of horse racing tracks in Bosvoorde and Groenendaal. This resulted in the abolishment of the tire-et-aire management. For almost a full century, there were no final fellings, only selective thinnings. This resulted in a remarkably high number and share of over-mature trees and stands.

Nowadays, a predominant small-scale, close-to-nature forest management system is implemented, mainly with selective thinnings and small group final fellings (in German Femelschlag) with natural regeneration of beech *(Fagus sylvatica)* and sycamore *(Acer pseudoplatanus)* or artificial regeneration with different species (e.g. oak, *Quercus* spp.; lime, *Tilia cordata;* hornbeam, *Carpinus betulus*). In the northern part of the forest, also a larger stand conversion experiment was performed with final fellings over larger areas and clustered retention trees, and larger-scale planting of light-demanding tree species. In other beech stands, continuous cover forestry has been introduced. A network of strict forest reserves and set-aside areas protect a large share of the over-mature trees and stands.

Specific aspects of the management/ Strengths and weaknesses

Economic aspects

Wood production remains a goal of the forest managers, despite changing public expectations. A total of about 15 000–20 000 m³ of wood is harvested in the total forest complex each year.

The wood quality in Sonian Forest is particularly good. Already in the eighteenth century, the timber from the straight and tall beech trees had become internationally renowned. The high-quality wood is mainly used for veneer and carpentry. Until recently, several specialised processors of this high-quality wood were present in the areas surrounding the forest. Most of these companies are gone, and most of the wood is now exported to be processed abroad. For the low-quality wood (crown wood), there is still a local market for firewood. Also, this market is declining as firewood is only used as secondary heating in Belgium, and regulations on security or taxation are increasing.

Harvesting in the forest is strictly regulated by the authorities, especially with respect to health and safety regulation and biodiversity protection. Public opinion and the acceptance of forest management are factors that influences the decision making. Most wood is sold standing, while the forest rangers have the responsibility to supervise the logging operations.

Therefore, forest contractors need to be certified on training and security regulations. The trees are marked by the authorities, and the logging operations are designed by the forest rangers, including the indication of skidding tracks. A challenge is to avoid these tracks being used as biking or walking trails. The logging operations are completely halted in spring (i.e. from April 15th to June 15th) to protect flora and fauna. In case the preceding winter has been too wet to allow important logging operations, exceptions can be made to the spring logging ban. Several more regulations are in place, trying to balance the logging operations with ecological and social constraints.

The forest management and planning is certified by the Forest Stewardship Council (FSC) in Brussels and the Flemish region, and the Programme for the Endorsement of Forest Certification (PEFC) in the Walloon region.

Ecological aspects

The site ranks amongst the most species-rich beech forests of Western Europe, boasting a diverse groundcover vegetation, an extremely rich mycological diversity with more than 1000 species of fungi, and a high variety of animals. In total, 418 species of vascular plants have been recorded in the Sonian Forest, 71 of which are considered ancient woodland indicators, many of them typical for beech forests. Although large predators are missing, the forest is home to a rich and diverse fauna. It has a stable population of roe deer *(Capreolus capreolus),* and wild boar *(Sus scrofa)* have recently recolonised the area. Also, pine marten *(Martes martes)* and typical bat species (Bechstein's bat, *Myotis bechsteinii;* Greater mouse-eared bat, *Myotis myotis;* Leisler's bat, *Nyctalus leisleri*) occur. Bird species include Goshawk *(Accipiter gentilis),* Black woodpecker *(Dryocopus martius)* and Middle spotted woodpecker *(Dendrocoptes medius).* The site has a remarkably diverse number of forest-related hoverflies (Syrphidae), carabid beetles and saproxylic beetles (like *Gnorimus nobilis* and *Platycerus caraboides*). Over 600 species of beetles have been registered including 250 saproxylic species. Of the carabid beetle *Carabus auronitens,* the form *putzeysii* is endemic to the forest.

Nonetheless the Natura 2000 fitness check shows possibilities for further improvement, especially regarding the amount of deadwood outside the reserves, and (semi-)open habitats (fig. C28.4). Therefore, the management plans focus particularly on enhancing the natural value by installing a nature-oriented management in the permanent open areas (e.g. former horse racing tracks), and diversifying the forest by creating open patches and gradients, increasing tree species variety, and retaining deadwood.

Social aspects

The social function is hugely important for the Sonian Forest, as it is the main green recreation area for hundreds of thousands of people. Every year, at least 2 million forest visits are counted (fig. C28.5.).

This obviously has consequences for the management. The main challenge is to make sure that the stream of visitors does not conflict with the for-

Fig. C28.4. Creating open spaces boosts regeneration and species diversity (Photo: Patrick Huvenne).

est management and conservation goals of the forest. The Structural Vision of the whole massif, therefore, contains a well-planned zoning strategy, including a number of access points in the periphery of the forest, around which most of the recreational pressure and facilities (e.g. parking, and marked walking, horse-riding and cycling trails) are concentrated. In this way, recreational pressure in the centre of the forest is reduced. Some of the more remote forest areas are strict forest reserves, in which no management is practiced and public access is limited.

A lot of effort also goes into increasing public awareness and acceptance of management operations. The mainly urban visitors have little understanding of wood harvesting, and the number of protests against cuts is likely to increase in the future. Reducing the harvesting period and organising the wood harvest in specific zones helps to limit negative reactions to logging operations from people using the area for recreation. Extensive grazing of the open areas with Scottish Highland cattle creates a sense of wilderness which is also appreciated by the public.

Communication with the public is a crucial factor. Much of it is done by volunteers that are interested and educated in nature conservation. They serve as nature guides, working together in associations. The forest management invests in an active participation for those that feel affiliated to the forest complex. There is a participation platform that unites forest managers, sport associations and youth movements, communities, and nature enthusiasts. This enables a broad network to be informed about the plans and developments in the forest.

While on the one hand, intensive recreational use is a source of potential conflict, it also creates the opportunity to gain public and political support for the extension and enhancement of the forest complex. To this end, a regional masterplan was developed with the aim of physically connecting the Sonian Forest to other forest remnants and natural areas in the wider surroundings.

Cultural aspects

Given its rich cultural history and proximity to the capital, the heritage value of the Sonian Forest is also of utmost importance. The Sonian Forest and the Park of Tervuren, are designated as protected landscape. Several ancient remnants, buildings, and other constructions are protected monuments.

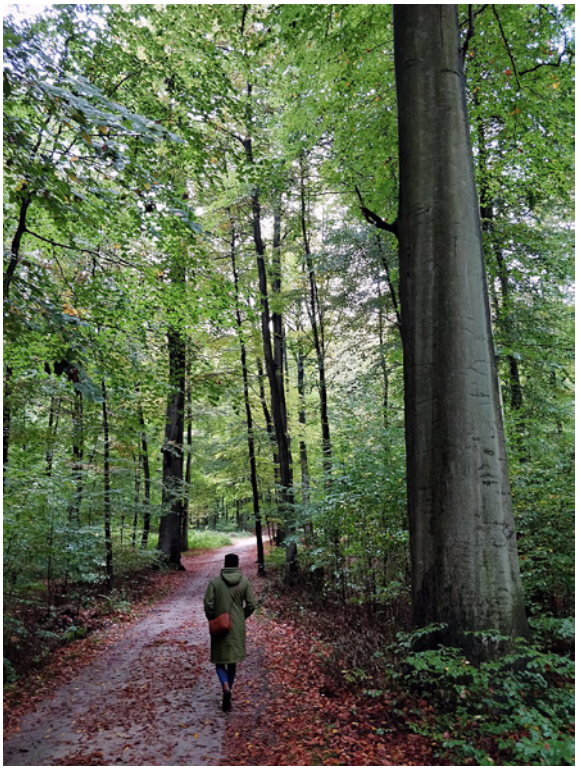


Fig. C28.5. The majestic beech trees attract many visitors (Photo: Jakob Derks).

Large parts of the forest are mapped as archaeological relict zones. The most valuable and non-managed forest reserves in all three regions are part of the UNESCO Serial world natural heritage site 'Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe'.

The forest includes one of the oldest arboreta in the world: the Geographic Arboretum Tervuren. The arboretum was a prototype for collections elsewhere, and it includes more than 700 tree and shrub species, organised in 40 groups representing forest types of the temperate climate in the Northern Hemisphere. The publication of a detailed book and website on the arboretum (2020) is an example of the efforts to educate the visitors and to promote the establishment of a community of forest supporters.

The protection as a landscape also influences forest management and imposes restrictions on certain operational choices, such as road building. Although the management plan foresees diversification of the forest in terms of structure and spe-

cies composition, to better fulfil current needs and climatic developments, attention is also given to preservation of the characteristic 'look' of even-aged open 'cathedral' forest stands that have characterised the forest for many centuries in some small parts of the complex.

Resilience

The landscape that made the Sonian Forest famous is also a risk. The beech-dominated stands may look spectacular but are vulnerable to changing climatic conditions. Beech trees, especially on forest edges and in open canopy conditions, are sensitive to long summer droughts. Furthermore, the long, lean stems on the rather shallow root systems are vulnerable to windthrow. More severe droughts and storms are predicted to occur more often in the near future as a consequence of climate change.

By broadening the species composition of the tree layer, by enhancing the diversity of the structure through the development of a multi-layer forest, and by encouraging natural processes, the managers have tried to establish a 'nature-based solution' to address a wide range of risks.

Improving the ecological connectivity, linking plant and animal populations that are separated by the multitude of roads, highways, and railways that cut up the forest complex, is another priority with regards to ecological processes and also forest resilience.

Conclusion

The Sonian Forest combines a unique natural value with the use and character of an urban forest. While its biodiversity is of international importance, most of the forest has been used for wood production since time immemorial, and its current landscape is the result of this logging and planting. The recreational use is intense, puts pressure on the forest complex, but is at the same time the strongest argument for strengthening or even the enlarging the forest complex. Even more than in many other forests, the forest management needs to combine several, often contradictory, demands and

Fig. C28.6. The Groenendaal ecoduct ecologically reconnects the forest, cut in two by the busy ring road around Brussels (Photo: SVD Absoluut).

approaches. This always has to be done in close collaboration between the responsible administrations, scientists, and stakeholders. Based on a scientifically sound common vision and strategy, the forest management has evolved quickly in the last decade, resulting in a stronger, more resilient forest ecosystem, serving nature and society.

Links and contacts

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Box C 16

'Bluebell-mania' in Hallerbos

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Brief description of the context

The forest named 'Hallerbos' (Forest of Halle) is only a (long) stone's throw away from the Sonian Forest (see B 12 and C 28 in this book). Hallerbos is located 15 km south-west of the Sonian Forest, and covers approximately 500 ha. It is located on productive, fertile loamy soils (with some sandy outcrops); the annual increment of the oak *(Quercus robur, Q. petraea)* and beech *(Fagus sylvatica)* stands reaches 10–12 m³/ha. It is managed by the same management unit as the Flemish part of the Sonian Forest.

Unlike the Sonian Forest, Hallerbos used to be a private forest, owned by clergy and nobility, including the famous House of Arenberg. They were renowned for their sophisticated and fine-tuned 'coppice with standards' management, producing high quality timber (mainly oak) and large amounts of valuable firewood, a management that was in place for at least 500 years. This dramatically changed during and shortly after World War I.

During WW-I (1914–1918) the forest was confiscated by the German army, and completely stripped of its valuable timber. The Germans installed two mobile sawmills and a narrow-gauge railway track to process and transport timber out of the forest. At the end of the war, only small-sized trees and trees with poor form remained. After the war, the forest was seized by the Belgian state, as its owners were accused of collaboration with the enemy.

In the period 1930–1950, massive replanting of the forest took place. In the beginning, labour and seedling plants were provided by Germany as a form of war reparation. The forest was transformed

Fig. 1. Mystic scene in the Hallerbos forest (Photo: Pierre Kestemont)

to high forest, with even-aged stands of oak and mainly beech on the rich soils, and Scots pine *(Pinus sylvestris)* on sandy outcrops. This has led to the very peculiar situation of a 500 ha even-aged forest with an age-span of merely 20 years.

A lower biodiversity level is associated with such forests: the stands are commonly dense with little structural diversity, and the forest floor is dark. Still, the forest is quite rich in species as it is an ancient woodland (it has never been deforested) and covers a wide range of soil conditions ranging from wet calcareous alluvium to dry acid sandy soils. One particular species performs very well in these conditions, especially in the dense even-aged beech stands on loamy soils: the bluebell.

A particular forest history leading to a particular natural spectacle

Bluebell (*Hyacinthoides non-scripta,* formerly *Endymion non-scriptus* or *Scilla non-scripta*) is a bulbous perennial plant (fig. 1, 2). It is a typical Atlantic species, occurring in Ireland, the UK, western Belgium and France up to northwestern Spain and Portugal. It grows in quite a broad range of soil conditions; however, it does not tolerate poor sandy soils and wet soils. Unlike most other species, bluebells are able to cope with deep shadow conditions. They grow and flower in spring, right before the trees flush. Especially in very dense and summer-dark broadleaved forest stands, this species can outcompete most other ground vegetation species, and form dense patches, with attractive and impressive flowering. In most forests, such light conditions are often patchy and small, and so are the patches of bluebells. In Hallerbos, however, these conditions are present on a large scale, and bluebells are plentiful over vast areas. During the short flowering period that lasts only two weeks (end of April), this leads to spectacular displays. Iconic pictures of the bluebell flowering of Hallerbos have been published far and wide, and have led to a massive peak of visitors and touristic activity during the flowering period. Visitors come from close-by and far away, even from the Far-East, to see this natural spectacle. For the managers of the forest, this phenomenon generates two important challenges: how to orderly organise this peak of visitors, and how to make sure that forest management supports and does not jeopardise the dominance of bluebells.

Fig. 2. Wilde hyacinth *(Hyacinthoides non-scripta)* also called Bluebell in the Sonian Forest (Photo: Kris Vandekerkhove).

Specific aims and measures in forest management and 'crowd control'

Although spectacular and beautiful, it is clear that the current large-scale dominance of bluebell in Hallerbos is not a fully natural situation, but the result of its peculiar management history. In natural Atlantic forests, and in the traditional coppice with standards, Bluebell will always be present, and dominant in the patches with deep shadow: under dense regeneration phases, but never on large areas. It is the peculiar age structure of the Hallerbos that offers the conditions for this massive development. This also means that as the forest stands grow older and gradually open up, competition between bluebell and other ground vegetation will increase, generating a more natural patchy distribution of bluebell. If this is allowed to happen, the forest will lose its specific attraction.

Fig. 3. Bluebell mania in Hallerbos. Photographers compete for the best spots (Photo: Pierre Kestemont).

Therefore, the challenge for the forest managers is to create a more balanced age structure to ensure a long-term continuity and larger-scale stability of the forest, and at the same time produce valuable timber, without losing the bluebells. A strategy was chosen to diversify stands and management, selecting management types that avoid long-time opening of the canopy cover. About 20 % of the forest is set aside as strict reserves. Most of the other broadleaved stands receive a low-intensity selective thinning, but another 10 % is also selected for premature regeneration. A normal rotation period for beech would be about 120 to 140 years, but some of the 70- to 90-year-old stands are now regenerated through shelterwood cuts of 0.5 to 2 ha. The results of these experimental cuts are being closely monitored by the local forest warden, to evaluate its success, both on tree regeneration and the ground flora, in particular on the performance of the bluebells.

Visitor numbers were always high during the bluebell flowering season, but have boomed over the last decade. This is both a gift and a curse for the forest. It gives an extra (even international) allure to the forest, and forests as a whole. At the same time, uncontrolled access will lead, and in fact have led, to soil and vegetation damage and may generate visitor conflicts and traffic accidents.

In order to control and lead this massive inflow of visitors, a wide range of measures has been put in place. First, public access by car to the forest is forbidden. Several parking lots and the main road that provides access to the central forest parking are temporarily closed to traffic. There are free bus shuttles (paid by the city) from the Halle city centre to the forest. The Forest and Nature Agency also organises a 'bluebell festival' in all its 'bluebell forests' throughout Flanders. Especially in the Hallerbos (the 'main stage') there are guided tours in the forest. There are also activities in the city, bringing both tourism revenues to the city and reducing the visitor pressure on the woodland. A close cooperation between the Agency, the city, police, volunteers, and private initiatives is necessary. A website (https://www.hallerbos.be; in Dutch and English), run by the forest managers gives day-to-day updates on the development of the flowering season, so visitors are well informed about the best

time to come. In the forest, a team of 40 to 50 voluntary stewards make sure that visitors stay on the tracks, and are not tempted to enter the stands for the ultimate picture while trampling the vulnerable vegetation. In the most popular areas, several kilometres of black rope is placed as a symbolic 'fence'. Although it can be easily crossed, the rope works as a psychological barrier, and is respected by the large majority of visitors. At the same time, it is a very flexible system that can be quickly deployed (and removed) and does not spoil the view like a real fence would.

Status of implementation

The alternative management has only been in place for about 10 years, and the crowd management has grown in the last five years. It is, therefore, premature to evaluate whether it will be successful in the long run, but developments are closely monitored by the managers. By diversifying the management, sustainable conservation of important stretches of bluebell-dominated forest can be assured. The measures to control and lead public access during the visitor peak were gradually introduced over the last years, and have already proven to be effective. Although the number of visitors has sharply increased, the damage to the vegetation is decreasing and less access violations have been reported. Visitors appear to accept and support the efforts of the managers to provide them with a unique experience while at the same time protecting the forest.

Serra de Llaberia – A case of local applied management of fire-prone ecosystems from northeastern Spain

C29

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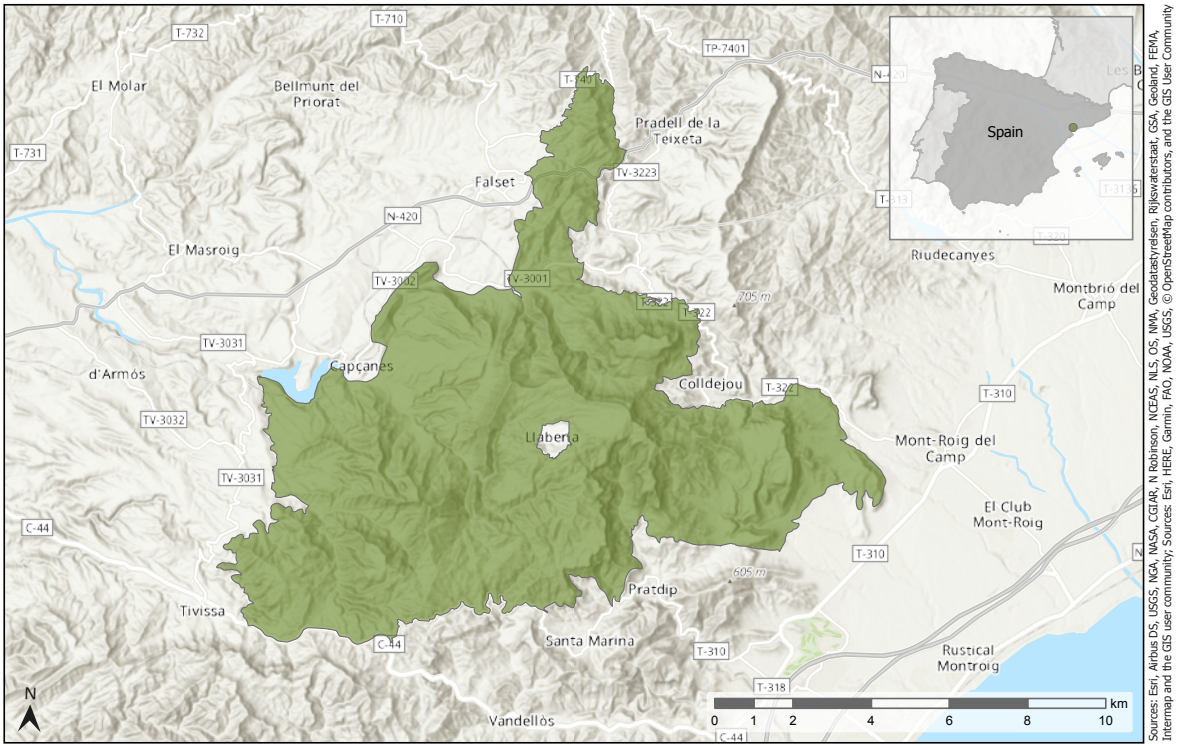
Context, legal frame, and ownership structure

Forest history, land uses, and cultural heritage

The Serra de Llaberia is a mountain range, in the Province of Tarragona, northeastern Spain. The range is named after the village of Llaberia (41.085555 N, 0.841334 E). The area is included in the Natura 2000 site Tivissa-Vandellòs-Llaberia (ES5140009) and occupies 10 350 ha, ranging from 181 m to 915 m altitude. This Mediterranean area has a climatic gradient, between a maritime xero-



< Fig. C29.1. Open structures of *Pinus nigra* stands, maintained by the natural fire regime and the presence of livestock. During Life + PINASSA project in 2017, mechanical treatments were performed to reduce the understory and favour the seedlings of natural regeneration (Photo: Rafel López-Monné/Consorci de la Serra de Llaberia).

Statement

"The rural abandonment and the wildfires have created a forgotten landscape. A reintroduction of the sustainable use of forest is needed for its survival!"

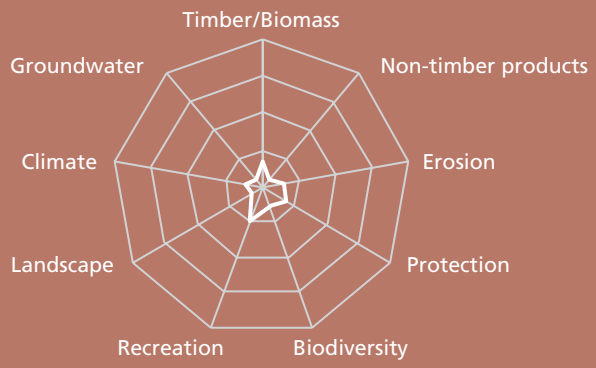


Table C29.1. General information on forests of Serra de Llaberia.

Forest community:	*Pinus halepensis* forests (4731 ha), *Quercus ilex* forests (772 ha), *Pinus nigra* forests (173 ha), *Quercus faginea* forests (120 ha), *Pinus pinea* forests (18 ha), broadleaved species forests (19 ha), shrublands (2548 ha), grasslands (213 ha), abandoned crops (122 ha)
Total forest area:	9451.63 ha
Main Management types	Thinning, prescribed burns, and grazing
Use	Forest and shrublands (9173 ha), agriculture land (846 ha), infrastructure (53 ha), and bare rock (279 ha)
Deadwood (standing and lying)	Between 5–10 % is left after silvicultural treatments
Altitude	From 181 m to 915 m, average 400–480 m
Ownership	Public (1108 ha, 11 %), Private (7674 ha, 74 %),
Private with custody agreements (1567 ha, 15 %)	600–1500 m
Geology	Limestones and clays of Jurassic and Triassic rocks, with poorly developed soils
Protected area (total)	10350 ha
Nature protection area (Natura 2000)	10350 ha

thermic and continental xerothermic climate, with hot summers and mild winters, an annual average temperature of 13 °C and a mean annual precipitation around 650 mm. The parent material is composed of limestones and clays of Jurassic and Triassic rocks, with poorly developed soils.

The main forest formations are represented by stands of young, dense, and homogeneous Aleppo pine *(Pinus halepensis)* and holm oak *(Quercus ilex).* There are also remnants of Pyrenean black pine (*Pinus nigra* subsp. *salzmannii* var. *pyrenaica*) and quejigo oak *(Quercus faginea)* forests from the traditional-pastoral regimes that included low intensity fires with tolerance to natural fires caused by lightning.

The landscape has been strongly modified as a result of land-use changes and sequential abandonment of agricultural land throughout the twentieth century, starting from 4 % forest cover at the beginning of the twentieth century to 89 % nowadays. The abandonment of the terraced sites formerly used for agriculture (principally olive trees, hazelnuts and vines), which protected the soil and preserved the natural vegetation in the recent past, have been progressively removed, causing important land degradation problems. The reduction of other traditional uses, mainly extensive livestock, and multipurpose forestry (for timber, woodfuel, charcoal or resins) has allowed a secondary vegetation regeneration characterised by bush proliferation. Moreover, the landscape has experienced a process of homogenisation with thousands of hectares of continuous highly fire-prone forests.

The area has suffered several large wildfires in the last decades, and it has a fire regime interval of 50 years which is dominated by wind-driven fires

from the west. Fires are natural to the area and still today natural ignitions account for a third of all fires. Historical fire used by shepherds was the main source of low and medium intensity fires until the twentieth century, and created open forest stands of Pyrenean black pine, stone pine *(Pinus pinea)* and quejigo oak. After the mid-1950s, with rural abandonment and depopulation, the fire regime changed to high intensity and stand replacement fires favouring Aleppo pine, as an obligate serotinous cone seeder (it requires fire for the seeds to be released from the cones), and holm oak, as a dominant resprouter, along with maquis species such as kermes oak *(Quercus coccifera),* mastic *(Pistacia lentiscus),* prickly juniper *(Juniperus oxycedrus),* and the strawberry tree *(Arbutus unedo).* Since the late 1970s, the area has suffered large, high intensity fires such as in 1978 and 1981 with around 8000 ha burned each of these years, or in 1991 and 1994 with around 2000 ha fires each of these years. Recent fire activity has slowed down because of the efforts of the fire service and forest management. However, in spite of these efforts fuels continue to accumulate in forests, and consequently there is a continuing risk of large forest fires.

The area is managed by a public consortium (Consorci de la Serra de Llaberia) created in 2004 and composed of eight members, seven of which are townships (Capçanes, Colldejou, Marçà, Pratdip, Tivissa, Torre de Fontaubella, and Serra d'Almos) and the remaining member is the Landscape and Sustainability Catalan Service (Departament de Territori i Sostenibilitat de la Generalitat de Catalunya). The consortium is governed by a plenary council and managed by a government board. It also has an advisory board formed by local volunteers that are asked for their opinion on specific issues.

The consortium has three permanent workers, a forestry engineer, a forestry technician, and an office clerk. In 2009 the consortium created a private forestry enterprise (enterprise of the environmental service of the Serra de Llaberia), consisting of five workers and a foreman. This enterprise executes the main forestry works that the consortium plans and is also used by other public and private entities and companies.

Currently, low public and private investment and low levels of tourist activity result in low economic incomes in the area. Although the forests produce only small volumes of timber, there are

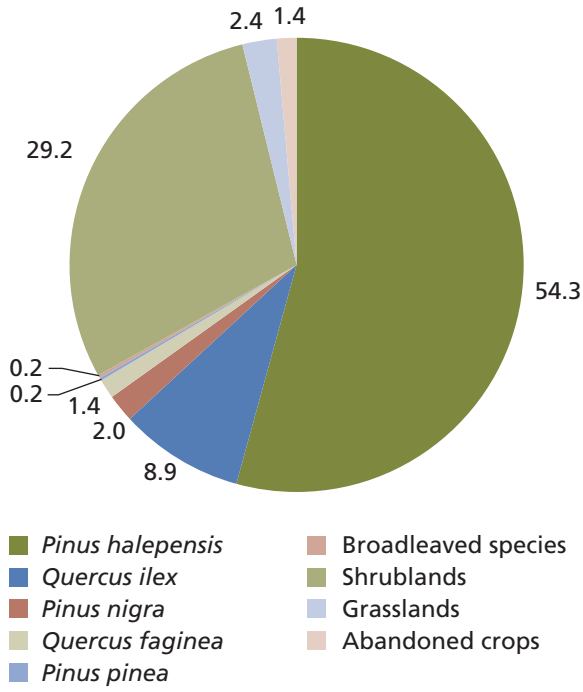


Fig. C29.2 Species composition of the Serra de Llaberia forests.

interesting and feasible economic development options for non-wood forest products (mushrooms and truffles, medicinal and aromatic plants, honey, and biomass).

Management by a consortium is not typical in Catalonia; however, a consortium offers several advantages for management of fire-prone forest with low capacity to generate incomes. The main advantages include: access to expertise (e.g. in the use of sustainable silvicultural techniques); coherent planning across a landscape; possibilities to attract investment through European and regional projects; and options to boost the tourism and generate employment for local people in rural areas.

Aims of the enterprise

The main objectives of the consortium are the preservation, revaluation, and multifunctional management of the Natural Interest Area of Serra de Llaberia. The consortium is focused on: conservation and sustainable management; dissemination, promotion and education of the environmental interest of the area; social and occupational insertion,

employment and training of people at risk of social exclusion; technical support to enable the municipalities (landowners, forest associations, city councils, and other entities) to access EU and national funds for the writing of scientific-technical documentation, and the technical direction of forest works; promotion and execution of actions for wildfire prevention; and providing facilities and information to visitors.

Economy

In 2018, the consortium managed a total investment of 422 370 €, from which 67 % (282 557 €) was used for infrastructures and 33 % (139 813 €) for conservation purposes.

The operating expenses of the Consortium (payroll and maintenance of their own buildings) was 107 331 €, that came from public investment, mainly from the Catalan government but also from the regional and local administrations.

Ownership structure

The land ownership is mainly private (7674 ha, 74 %) and most of them are small properties (less than 10 ha). Public lands represent just 11 % of the land (1108 ha) and are owned by the councils and Catalan government. There are also 1567 ha (15 %) of private land that are currently managed by custody agreements.

Legal frame

The Serra de Llaberia was declared an Area of Special Natural Interest (Catalan: Espai d'Interès Natural (EIN) 1992. Then in 1997 the area was declared a Site of Community Importance (SCI) under the Habitats Directive, and in 2005 it was declared a Special Protection Area of Birds (SPA) under the Birds Directive. With the Habitats Directive, the extension of the protected area was broadened and included in Natura 2000 sites. The area also contains a Geological Interest Site.

Nowadays, the area is under the legal framework of the Habitats Directive transposed by the national government in 2006. The basic regulations in terms of uses and allowed activities are included in the Law-Decree 328/1992. In 2004, a special plan of delimitation of the area was approved.

Management

The management of the area is looking to reduce the vulnerability in front of wildfires and to achieve a better adaptation and resilience to aridity caused

Fig. C29.3. Forest management actions performed to favour mature mixed stands of *Pinus nigra* and *Quercus ilex*. Deadwood is left in site and new stand deadwood is created (Photo: Consorci de la Serra de Llaberia).

by climate change. Forest management is focused on the objective of creating more mature structures, concentrating biomass on the wood of trees and not in fine fuel. This, along with lower degrees of vertical and horizontal continuity of the stands, increases the chances of forest stands surviving fires and allowing them to develop into old-growth stands of open forest that had been typical of the area, and which are critical for the maintenance of diversity in the area. All the treatments are done to allow the final cutting to be delayed. Over the last five years criteria for maintaining deadwood in the forest have also been considered for conservation purposes, before there was no technical criteria to left deadwood on the site or to generate new deadwood for species conservation (fig. C29.3 and C29.4).

The treatments applied in the area follow regional guidelines and silvicultural models for sustainable forest management (ORGEST) (Piqué *et al.* 2014) and provide practical, applicable, and updated information to forest managers at an operational level.

The area has been pioneering in its use of prescribed burning (the planned and precise application of low intensity fires) as a management tool. The Catalan Fire Service started a programme of prescribed fire and fire ecology research in this area and neighbouring area in the 1990s, and Serra de Llaberia is part of its permanent areas of training and natural fire use planning programme. Prescribed burning can be used to limit the scope of large forest fires as part of pre-extinguishing and prevention plans, as well as to emulate natural processes that allow for the maintenance of ecosystem biological capacity (Domènech *et al.* 2018). The execution of the prescribed burns is carried out based on pre-established objectives: to protect the ecosystem from the risk of devastating fires, restore and improve fauna and flora habitats, and management of forests (fig. C29.5).

Services

Ecological and nature conservation

The consortium offers different services to the ecological and natural conservation of the area:

– The participation in European projects to preserve habitats of Special Community Interest under the Habitats Directive. In recent years, the consortium has been a partner in a number of

Fig. C29.4. Actions performed to reduce canopy cover around a fountain to recharge the aquifer and recover and open grassland space that use to be in the area 30 years ago when grazing was a frequent activity. The maintenance is done by goat's flocks (Photo: Consorci de la Serra de Llaberia).

Fig. C29.5. In the foreground, open spaces for fire prevention and habitat improvement, performed by prescribed burns in 2013 and 2014 by the Catalan Fire Service. In the background, dense formations of *Pinus halepensis* stands from post-fire regeneration from 1994 wildfire (Photo: Rafel López-Monné/Consorci de la Serra de Llaberia).

European projects, such as Life Taxus that aimed to improve the understanding and conservation of yew *(Taxus baccata)* forests in Catalonia. It has also been involved in the project Life+Pinassa which aimed to apply sustainable management for the of Pyrenean black pine (*Pinus nigra* subsp. *salzmannii* var. *pyrenaica*) forests in Catalonia. In the Life+Pinassa project area prescribed fire was used as a management technique to preserve mature forests and also to reduce fire vulnerability in Aleppo pine saplings (fig. C29.6.).

– Projects related to the conservation and improvement of the fauna. A project concerning the conservation of the Mediterranean tortoise (*Testudo hermanni* subsp. *hermanni*) has been ongoing for several years. The consortium manages a centre together with the Landscape and Sustainability Catalan Service in Marçà with the objective of improving the reproduction, recovery, and subsequent release in the natural protected area of the Mediterranean tortoise. Work has also been done in the conservation of the European freshwater white-clawed crayfish *(Austropotamobius pallipes)* and control of the American signal crayfish *(Pacifastacus leniusculus)* proliferation. Moreover, the consortium has worked on the conservation, creation, and improvement of natural pools that ensure water availability for fauna.
– Forest management and fire prevention. The consortium has developed forest planning for the whole area which has allowed prioritisation of the actions depending on the fire prevention efficiency. It has also identified the Strategic Management Points (SMPs); SMPs are bands of low fuel or auxiliary bands anchored to paths that allow the resources for extinguishing large fires to be concentrated more safely and efficiently (Costa *et al.* 2011). Another important activity related to both forest management and fire prevention is the production of local biomass for local consumption. Recently a new district heating for public buildings has been planned in Tivissa and the consortium will supply it with locally and sustainably managed biomass from SMPs. With the same objective, the consortium coordinates a network of landowners and local entities to prioritise actions for fire prevention and maintenance of water points for the fire extinction service.
– Extensive local livestock. The consortium has also enhanced the habitat for a local goat breed (Cabra Blanca de Rasquera) maintaining open spaces and other features they need (water pools and tracks). The consortium has also worked with the national fire shepherds' school in order to improve the conditions for the local shepherds and help the new young shepherds. In this sense, the consortium is involved in the projects Open-2preserve and FireShepherds, which both aim to introduce extensive silvopastoralism as a measure to prevent forest fires and to promote production of local forest products (milk and cheese, see also chapter C25 in this book).

Fig. C29.6. Prescribed fire performed by the Catalan Fire Service during the Life+Pinassa project in 2016. Aims where to reduce the surface fuel load and increase the distance between canopies and surface fuel to reduce fuel continuity (Photo: Consorci de la Serra de Llaberia).

Social

The consortium performs valuable social tasks for the local population working with persons at risk of social exclusion. The aim is to provide opportunities to people, who for different reasons (e.g. age, long periods of unemployment, or financial or health issues) have had difficult access to the labour market. The consortium, with the support of a specialised company of training and work, provides participants with help getting a job. The participants must follow a two-year programme and are professionally trained in forestry operations. Later, they can perform tasks, such as the maintenance of the path network, prevention of forest fires, and conservation of habitats in wetlands. They also restore stone structures from the national heritage. They are guided by the technical personnel of the consortium and are always accompanied by a foreman.

Cultural

The consortium works in the conservation of the cultural heritage of the area. It improves and maintains the historical path network and restores and maintains the drystone elements such as the retaining walls for terracing, cobblestoned paths, lime kilns, and other unique elements constructed using this technique.

Conclusion

More needs to be done to change the current fire regime, in which large wildfires have occurred, to one with lower intensity fires. Although there has been some progress in restoring a landscape with more heterogeneous and mature forest stands, more needs to be done to change shrub-dominated landscapes in which large wildfires have occurred in the recent past, to forest-dominated landscapes

Fig. C29.7. Trail improvement and erosion control. A network of local companies to carry out forestry work has been created. The Consorci de la Serra de Llaberia has its own company aimed at professionalise and support people at risk of social exclusion (Photo: Consorci de la Serra de Llaberia).

which typically experience lower intensity fires and which more typical of the area in the more distant past (fig. C29.8.).

The legal protection of the natural area allows for the area to be managed in a way that allows for nature conservation and also management for production of forest products. The framework is not as restrictive as in a national park and allows for more flexible management practices.

The consortium has generated a high economic and social impact in the area. It has successfully created a network between the different entities, councils, and enterprises involved in the management of the natural area that work together for its conservation.

The consortium is a model of an integrated management of a natural site. Management is planned, developed, and executed from the region itself with the active and continuous involvement of the municipalities.

Portrait

"Our mission is local development through sustainable management practices to increase resilience against wildfires in a context of climate change aridity".

Interesting web pages

Consorci de la Serra de Llaberia: http://www.serrallaberia.org/

Open2preserve project: https://open2preserve.eu/

Life Taxus project: http://www.taxus.cat/home/

Life+Pinassa project: http://lifepinassa.eu/?lang=en

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Costa, P.; Castellnou, M.; Larrañaga, A.; Miralles, M.; Kraus, D., 2011: Prevention of large wildfires using the fire types concept. Unitat Tècnica del GRAF, Departament d'Interior, Generalitat de Catalunya, Barcelona.

Domènech, R.; Piqué., M.; Larrañaga, A.; Beltrán, M.; Castellnou, M., 2018: The role of fire in the conservation of the black pine (Pinus nigra Arn.) habitat. Life+PINASSA project (LIFE13 NAT/ES/000724). 64 p.

Piqué, M.; Vericat, P.; Cervera, T.; Baiges, T.; Farriol, R., 2014: Tipologies forestals arbrades. Sèrie: Orientacions de gestió forestal sostenible per a Catalunya (ORGEST) [Forest typologies. Series: Guidelines for sustainable management of forests in Catalonia].. Centre de la Propietat Forestal. Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi Natural. Generalitat de Catalunya, Barcelona. 346 p.

Fig. C29.8. The village of Serra d'Almos, with an agroforestry mosaic, is an example of fire resilient and productive landscape that is working to be recognised as a World Heritage Site by UNESCO (Photo: Rafel López-Monné/Consorci de la Serra de Llaberia).

Box C 17

Forestry and the strategic development of local economies

S. Dilschneider

Managing Director Ecoloc Institute for Local Economic Design, Basel, Switzerland

Forest growing stock and local wood processing are an important resource in the local economy of many rural communities. However, declines in timber prices together with a shift towards cheaper production locations in the global economy and, thus, more competitive timber imports from abroad (e.g., from Eastern Europe) result in reduced, and sometimes insufficient, incomes; this can have devastating effects on local value chains with a desertification of local and regional communities.

When it comes to strategically developing local economies it is important to clearly understand and skilfully coordinate the basic elements of an integrative local and regional development. This requires an analysis of local value chains, the development of synergies between local businesses and the identification of incentives for the consumption of local goods and services.

Because of its abundance in many rural communities and its wide variety of usages, wood is an important basis for the local creation of added value and the endogenous development of communities. Beyond being just energetically processed, wood can better be used in building construction and furniture production since the material use value per cubic metre of solid wood massively exceeds the energy use value. If other local business sectors can be synergetically linked to the material production, or if the processing quality can be increased, then significant added value is created locally. Therefore, the de facto 'design' of local value chains by linking local business to each other – or creating new businesses in the first place – is a critical aspect of local development.

Effective local value chains, however, are just one aspect of development. Strong local economies also depend on import substitution by locally created goods and services. When local supply meets local demand, a strong local economy has a basis to thrive. For example, a locally produced, high-quality wood construction element purchased by a local homeowner can replace externally purchased concrete as construction material and prevent the outflow of capital that can instead multiply locally. This raises the question by which measures to boost or sustain local demand for locally produced goods and services. Awareness of the enormous relevance of consumption patterns for the status of the local economy – and in turn also the social fabric – is very important. Today, this is demonstrated by the thousands of 'buy local' initiatives in communities worldwide.

However, the basic factor of a beneficial local circle remains local liquidity. If residents cannot generate sufficient income, they are forced to purchase cheaper externally-produced goods and services. So, policy is another important aspect of the development that requires consideration. Community councils must understand the relevance of developing integrated perspectives for local development, not only to maintain the 'internal' competitiveness of local goods and services, but also to actually bridge the collective action paradox of 'individually cheaper, but collectively more expensive' externally produced goods and services. Key elements for local policy are education, participation, incentives and 'nudging', synergetic and systemic thinking, as well as the implementation of a diverse set of available social innovations, such as local finance or community capital strategies to effectively 'design' the world we live in. Appreciating and protecting the basic resources in our immediate environment – such as wood and forestry – are, therefore, essential.

The Ecoloc Institute is engaged in project developments in Germany, Switzerland, and Kenya that specifically focus on highly integrated local strategising with the aims of plugging the leaks of capital drain, enhancing the efficiency of the local economy, and fostering a holistic notion – and realisation – of the 'good life'. The focus on sustainability from the vantage point of mainstream economics has failed; this failure can be seen everywhere in terms of staggering social inequality and the squandering of resources through goal-inefficient economic practices.

An approach that demonstrates how households and communities will effectively benefit from an ethically goal-efficient and socially equitable local and regional economy is pivotal. Measuring capital flows and the efficiency of designed local economies are key elements of that approach.

Fig. 1. Tom's sawmill is a small-scale sawmill in southwestern Germany. It serves as a showcase for the importance of a local value chain where locals process valuable products from their own timber (Photo: Frank Krumm).

Amden – Management for species conservation in a special forest reserve

C30

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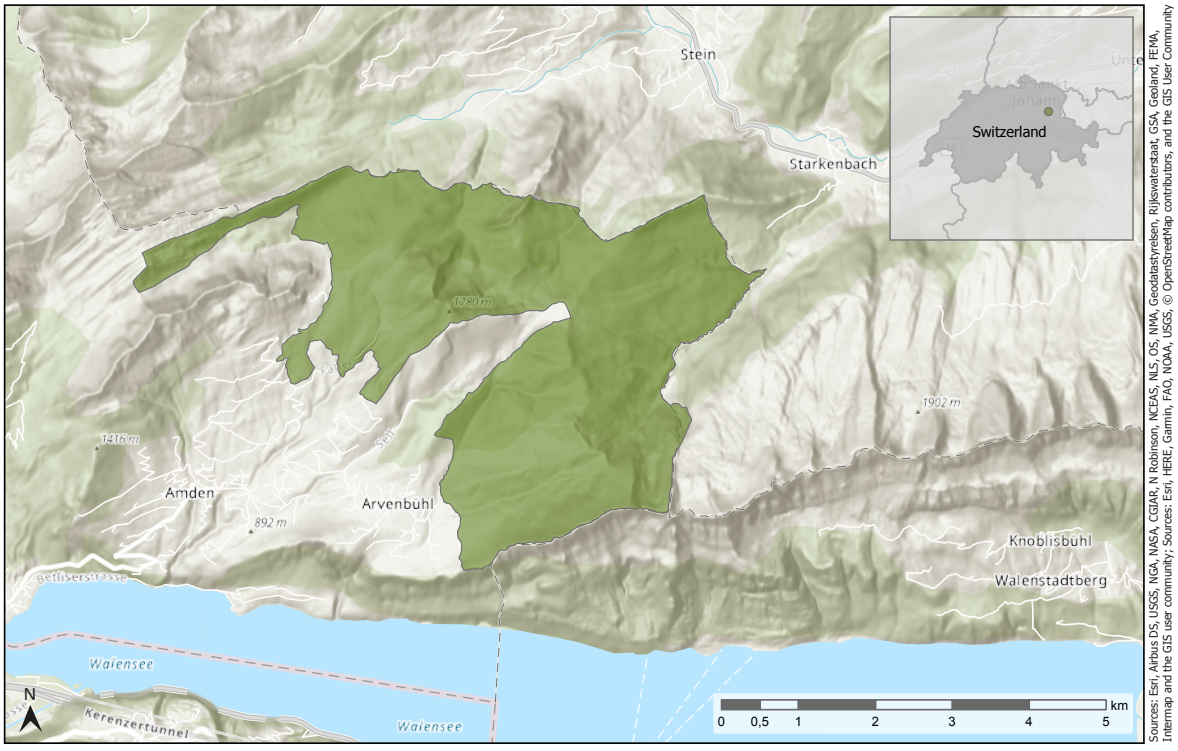
Background

The municipality of Amden (area – 4300 ha; population –1800 inhabitants; altitude 420–2101 m) lies on the edge of the Alps in northeastern Switzerland between the Lake Walen and the Toggenburg Valley. Around 2000 ha or 46 % of the municipal territory is covered by forest whereof 75 % is owned by the local community of Amden, a public corporation without fiscal sovereignty. Private forest covers 13 % of the forest area and is divided into small parcels. The local community of Amden also owns



< Fig. C30.1. Target species – a male capercaillie – in the forest Amden (Photo: René Güttinger, RGBlick).

Statement

"The forest reserve is on the right track, should be further developed according to the defined objectives and evaluated regularly."

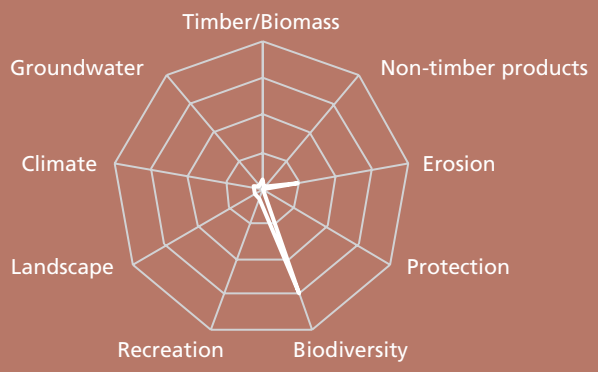


Table C 30.1. Forest characteristics in the special forest reserve Amden.

Forest communities	43 % high-montane fir-spruce forest and 39 % high-montane fir-beech forest, 18 % diverse
Forest area	1045 ha
Management system	'Plentering' (single-tree or group selection system)
Standing volume	328 m^3/ha
Annual increment	ca. 7.0 m^3/ha
Annual timber harvest	2.0 m^3/ha
Deadwood (standing and laying)	Standing 4 snags/ha, laying 5 m^3/ha

1159 ha of Alpine pastures, which they lease to 50 local farmers.

The area has an annual precipitation of 2000 mm and is characterised by a remarkable snow layer in winter (e.g. up to 5 m in winter 1998/99). Therefore, protection against natural hazards – including avalanches, floods, landslides – protective forest maintenance and technical constructions are important objectives of the forest management. The geological bedrock consists of flysch, limestone, molasse, and moraine. From these materials, very different soils have formed; the soils vary from very wet to extremely dry, and from very acidic to alkaline. Raised bogs and mires of national importance, protected dry grasslands and rare forest sites are indirectly indicators of this.

There are two forest reserves in the municipality: Amden and Seerenwald. The special forest reserve of Amden is dedicated to conservation of capercaillie *(Tetrao urogallus).* The special forest reserve of Seerenwald at Lake Walenstadt (about 80 ha) is dedicated to conservation of the lime trees *(Tilia cordata, T. platyphyllos)* as well as floristic and faunistic biodiversity.

Forest history and forestry

In the nineteenth century, the Amden municipality was dominated by agriculture and there was a great demand for timber. As a consequence, the forests were overexploited and the supply of wood had to be restricted by regulations (Ehrbar 2006). From the middle of the twentieth century onwards, the protective function of forests against natural hazards became a priority. In 2006, the different forest functions were specified in a planning process. Since then, 38 % of the forest area has been managed as a protection forest against natural hazards, and 57 % has been managed as a forest reserve, whereby a large part of the reserve area is also a protection forest against natural hazards. Commercial production of timber is a primary objective on only 5 % of the area.

The overall forestry objectives in Amden is to preserve the natural characteristics of the mixed-mountain forest of the region while providing multiple-services to the community. Special emphasis is given to the protection from natural disturbances and biodiversity conservation. The forestry system is integrative with single or multiple

Fig. C30.2. View on the eastern part of the Amden forest reserve. It is dominated by spruce-fir forests. (Photo: Rolf Ehrbar).

tree harvesting and mainly natural regeneration as principle. Because of the often poor productivity of soils and the very difficult topographical conditions with deep valleys/gorges and streams and steep slopes, the development of a forest road and path network is very difficult. The density of access is low with less than 4 m of forest road per hectare. There is no other forest district in the region with such a low value. Timber harvesting with skidders is only possible on 20 % of the forest area. On the remaining area, cable cranes and helicopters are used. About one-fifth of the timber remains in the forest. The cost of forest management is covered by financial support from the Confederation and the canton of St. Gallen as sales of timber does not cover the cost of management. Therefore, poor quality assortments are left in the stand for economic and ecological reasons. The amount of wood to be left in the forest is already specified in the planning. However, if the revenue covers the costs for the wood transport, the logs are transported to the next forest road and sold. The majority of the timber produced is supplied to the market, also because the community has a large wood energy plant installation.

Timber harvesting costs in the narrow sense could be reduced with a better forest road network. It would also support the management of the protective function of the forest. However, the cost–benefit ratio of such a forest road investment would be negative and economically hardly justifiable. Further, such an infrastructure would not be compatible with the primary objectives of habitat and species conservation.

A single district forester is responsible for the forest management. The local community of Amden employs its own forestry group. It is responsible for implementation of all forest management in the reserve, and for all protection forest activities. In addition, orders of the political municipality such as technical protection constructions and work for third parties are also important.

The special forest reserve of Amden

The forest reserve of Amden is located in the northeast of the municipality on either side of the watershed of the River Linth and the River Thur. The coordinates of the centre of the reserve are 9°13’E,

Fig. C30.3. Schematic representation of a typical bilberry-fir-spruce forest in the reserve. The ground vegetation is mainly composed by bilberry and ferns (Illustration: Andrea Klaiber, www.doppel-kopf.ch).

47°10'N. The forest reserve covers a total area of 1772 ha, of which 1045 ha are forest (fig. C30.2). The reserve extends from 1040 to 2101 m above sea level and lies in the vegetation-specific zones from upper-montane to alpine. Table C30.1 presents an overview of the characteristics of the special forest reserve which is owned by the local community of Amden.

Exact figures on tree species composition are not available. The interpretation of the stand map shows mixture proportions of about 68 % spruce *(Picea abies),* 9 % silver fir *(Abies alba),* and 22 % deciduous broadleaved trees with beech *(Fagus sylvatica)* as dominant species. The reserve perimeter is characterised by a considerable amount of bilberry fir-spruce forest (fig. C30.3) and contains 290 ha of mires. Forest and mires are intensively intertwined, which is responsible for the large forest edge ecotone (fig. C30.4).

Objectives and strategy in the special forest reserve of Amden

The main objectives of the special forest reserve of Amden are to conserve and promote the local, nationally important capercaillie population and to increase habitat connectivity with neighbouring populations. The aim is to double the area of habitat used by capercaillie with positive effects on the resident population. With this aim in mind, the local community of Amden together with the canton of St. Gallen have established a special forest reserve in 2006 as conservation tool for optimally implementation the habitat improvement measures. In contrast to a strict forest reserve, measures for a specific objective can be applied in a special forest reserve. Therefore, they are particularly useful for the conservation of threatened forest species that depend on well structured, semi-open forests such as the capercaillie (Bollmann *et al.* 2008). The minimum population size of the capercaillie in

Fig. C30.4. Forest and mires are closely intertwined. This spatial habitat mixture causes a long forest edge ecotone which is preferably used by species that depend on stocked and open habitats, including the capercaillie (Photo: Rolf Ehrbar).

2003 was estimated at 16 individuals using genetic methods (Debrunner *et al.* 2005). A description of the species' biological characteristics, its habitat needs and the significance of the forests reserve for local and regional capercaillie conservation is given in Bollmann (2006) and Bollmann *et al.* (2013). Habitat deterioration by increasing timber growing stock and high canopy closure were identified as the main threats to the resident capercaillie population. Therefore, large-scale habitat improvement by logging measures were defined as the main conservation strategy in the long term. The contract between the canton of St. Gallen and the local community of Amden specifies an operating period of 50 years for the forest reserve. The canton has committed to provide sufficient funds to cover the costs for habitat management, and the local community signed up to implement the measures as planned according to the objectives of the reserve.

Planning and management in the special forest reserve

A management system was established for the planning and management of the forest reserve. It comprises the provision of the basic principles, the planning and implementation of management measures based on various thematic materials that were developed before or at the start period of the reserve.

Habitat suitability map as basis

Habitat modelling revealed that the entire forest reserve is potentially suitable as habitat for the capercaillie (Robin *et al.* 2004). However, the actual habitat quality must be determined for each stand based on structural features and plant composition. For this reason, a habitat suitability map was developed, which shows where the capercaillie's requirements are met and where they are not (fig. C30.5). This was done according to the method of Schroth (1994). This method evaluates essential habitat requirements for the capercaillie with regard to forest structure (canopy closure 40–60 %), cover of ground vegetation (ground vegetation with moderate to high dwarf shrub ratio and shelter elements), and food availability (abundance of *Vaccinium* sp. and ant hills). The method classifies the habitat quality into five categories, from 'unsuitable' (dense homogeneous stands with little ground vegetation) to 'optimally suitable' (semi-

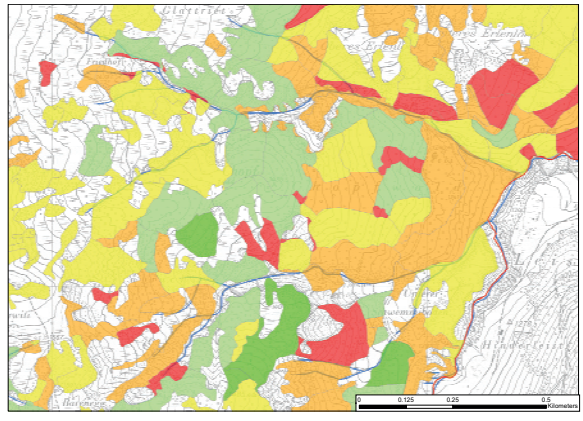


Fig. C30.5. Extract from the habitat suitability map 2017 with suitability classes from unsuitable (red) to optimally suitable (dark green).

Fig. C30.6. Example of unsuitable capercaillie habitat with homogeneous, dense stands characterised by high canopy closure and sparse ground vegetation (Photo: Kurt Bollmann).

open, heterogeneous stands with well developed ground vegetation and Vaccinium abundance). These criteria can accurately predict the probability of capercaillie being present in a particular habitat. At the start of the project, about one-third of the forest area was classified as unsuitable habitat (fig. C30.6), one-third as poorly suitable habitat, and one-third as suitable/good habitat (fig. C30.7).

Identification of the need for habitat improvement measures and prioritisation of measures

When determining the need for habitat measures, three questions arise: Where? When? and How? Therefore, the way in which the interventions are carried out is a matter of spatial and temporal prioritisation. Priority was given to stands with unsuitable habitat quality, since, there is a close relationship between habitat characteristics and the presence of capercaillie. In order to be able to derive the type of intervention, an assessment form was developed and applied for each stand. The comparison of the habitat requirement profile (with its target figures) with the current state of the forest stand reveals the actual habitat deficit. This enabled determination of the required forestry measures to improve the habitat quality. Methodologically, this procedure corresponds to the 'NaiS' planning and controlling system, which was developed for the management of protection forests against natural hazards (Nachhaltigkeit im Schutzwald [Sustainability in Protection Forests]; Frehner *et al.* 2005).

The 'Capercaillie habitat assessment form' was developed as a working tool (fig. C30.8). It is structured in such a way that the actual, stand-specific habitat quality assessed in the forest can be compared with the target state according to the ecological requirement profile of the species (e.g. Bollmann *et al.* 2005) (fig. C30.9). The need for action can be derived from the difference between the target and actual state which relates to the useful and effective measures. The form has been used in the test areas ('Weiserflächen', see below) and for

Fig. C30.7. Example of suitable capercaillie habitat characterised by coniferous trees with moderate canopy cover, a well developed ground vegetation cover, a high proportion of bilberry shrubs and possibilities for hiding below basal-branched trees and behind root plates (Photo: Rolf Ehrbar).

all logging operations in the special forest reserve. This means that all forestry activities are recorded and effects on the capercaillie population can be related to the reference situation and the logging operations later on.

Test areas, project planning and controlling

As an example, the need for logging operations and habitat improvement measures was determined on test areas, so-called 'Weiserflächen'. The test areas are used for both project planning and later for the impact control of forestry measures. In order to fulfil this purpose, the test areas must be representative of the forest area as a whole, the habitat suitability classes, and the forest stands. The diversity of sites and forest stands in the Amden forest reserve required 12 test areas. They were established in 2004 and cover between 1 and 10 ha. They were used to: (i) determine the need for habitat improvement measures; (ii) determine the suitable measures; and (iii) define the milestones which have to be monitored for future impact analyses. Then, the trees for logging were marked in each stand, and the amount of harvest and the remaining standing stock was recorded. From this, the intensity of intervention, an important comparative figure in silviculture, can be calculated. Since the 12 test areas represent the range of conditions in the forest reserve, the amount and intensity of intervention could be extrapolated to the entire forest area.

As mentioned above, the operation impact analysis is also carried out on the test areas. For this purpose, the habitat assessment form was extended and adopted. The current condition of the forest stand is also assessed in the impact analysis according to the criteria of the ecological requirement profile. Herewith, it can be determined whether the logging and habitat measures improved the conditions and have led to the achievement of the desired milestones. Or, what were the reasons for any deviations from the milestones? This makes it possible to define the conservation and silvicultural strategy for the next period and to identify appropriate adaptations. Thanks to

Test area habitat assessment form | **Derivation of need for habitat measures** | Version: 22.02.2019

Community:	Location:	Test area No.:	Date:	Name:
1. Site type(s):		Forest type:	Natural hazard to be considered:	
2. Stand No.:			**Suitability class:**	

3. State, development trend and measures

Stand and tree traits	Minimal profile* see comment!	Actual situation	Actual condition Trend in 10, in 50 years	Effective measures with control values	Reasonability	**6. Milestones with control values** Will be evaluated in years.
WINTER-Habitat • **Tree mixture** (Type and degree)	Dominance of **conifer trees**; If site condition allow: Fir, Pine > 10-20% else Spruce, Larch; Deciduous trees < 30%, Preserve Beech, no pure spruce stands					
• **Basal-branched single trees (i.e. spruce) or "Rotten" (tree collectives)**	Several basal-branched trees or "Rotten" (tree collectives)					
• **Horizontal structure** - Cover, ecotones, eventual gaps, Stem number	Degree of **canopy cover** 30-**40-50-60**-70% Ecotone length > 100m/ha; Several basal-branched tree collectives, single trees; Low stem number					
• **Mature trees** - Crown development - Slenderness ratio - Target diameter	Sitting-/Sleeping-/Lekking-trees with strong, horizontal branches and sight protection from predators through the crown; Minimum 1 flight aisle, downhill, 4 m wide					
SUMMER-Habitat • **Nutrition** - Blueberry	**Berry herb cover** 70-100%; the more berries, the better (in particular blueberry). Substitution of blueberry if possible by other Ericaceae, raspberry, *Eriophorum* sp., and herbs					
• **Cover** - Vegetation in 30-50 cm height	**Extensive**, but **irregular** occurrence of **ground vegetation**, also in pole wood; As much berry herb cover as better					
• **Regeneration** - Seedlings to pole timber	Tree regeneration covers <50% of stand area, ideally as patches ("Rotten"); Closed thickets >10 m diameter have gaps, as of pole timber of 3-4 m					
• **Requisites** (laying dead wood, root plate, sand bath; gastroliths, fens; ant hills)	**Insects**, in particular caterpillars and ants (as hatchling food); Warm, sunny sites with a rich availability of insects and hiding structures; Vegetation-free sites for sandbath and gastroliths					

very bad minimal ideal

in 50 years
in 10 years
actual

4. Action required ☐ yes ☐ no

5. Urgency ☐ small ☐ medium ☐ high

bold = compulsory ressource classes

Timber harvest:
Remove timber (ratio or m^3, timber assortments):
Phytosanitary treatments (z.B. debarking: assortments, m^3):
Special measures:
Timber transport (means and distances):

6. Rotation period:
7. Harvesting type and volume of next treatment:

**** The minimum habitat profile has been derived from capercaillie core areas. It has to be adapted to local conditions in each individual case by experts!***

Fig. C30.8. Capercaillie habitat assessment form for test areas (Weiserflächen).

this feedback process, the management of the special forests reserve can be continuously improved.

Both, the development of the requirement profile and the derivation of the need for action on the test areas were carried out on an interdisciplinary basis with the participation of researchers and practitioners. This integral approach proved to be extremely valuable.

Measures taken

A detailed action plan is drawn up for four to five years at a time. As already mentioned, the measures are prioritised according to the habitat suitability map. In the first 12 years of the forest reserve, 23 000 m^3 of timber were cut on 281 ha. The average utilisation intensity was 80 m^3/ha and the average intervention area was 3 ha. In addition, disturbances (storm damage and beetles) resulted in a removal of around 1400 m^3 of timber. On average, about a quarter of the standing stock on the logged stands was used according to plan, which is a target-oriented intensity of intervention according to our experience. Too intensive logging causes problems with snow pressure for the regeneration and vegetation competition, and too little intervention is ineffective and inefficient. The type of logging is comparable to group 'plentering', a silvicultural system in which trees are removed in groups to create gaps of sufficient size for regeneration of light-demanding species. While the chosen intensity of intervention is appropriate, it would be desirable to significantly increase the number of forest stands treated annually. Actually, this is supported by the responsible cantonal department. For the next five years, significantly more resources will be available for habitat improvement measures for the capercaillie. The outcome of such a logging intervention is shown in Figure C30.10.

In the period mentioned, in addition to the timber revenue of approximately CHF 1.2 million, over CHF 2 million in the form of subsidies and foundation support were invested in the management of the forest reserve. A total of 127 ha of forest stands were classified as not suitable as capercaillie habitat and have been designated as unmanaged. They are, in fact, natural process areas with no priority importance for capercaillie conservation. However, these areas support deadwood related conservation goals in the reserve. Deadwood as a biodiversity resource is considered as a secondary ecological objective in the forest reserve. The aim is to reach at least the habitat threshold value of standing deadwood for the three-toed woodpecker *(Picoides tridactylus).* For this purpose, trees infested and dying from bark beetle infestations are left standing whenever possible (fig. C30.11).

Changes in habitat suitability

In 2017, the habitat suitability map was updated with the aim of determining the impact of the previous logging operations on habitat quality. The suitability value has improved between 2003 and 2017 on 18 % of the forest area (Schmid 2018). On average, habitat suitability increased by 0.6 points (on a scale of 1 [unsuitable] to 5 [optimally suitable]) as a consequence of the logging operations. The proportion of suitable to optimally suitable areas increased by almost 10 % to 46 %. This habitat improvement is the direct consequence of logging operations. It was shown that all three assessment criteria of the habitat suitability map could be influenced by forestry measures, but cover of ground vegetation and forest structure were influenced more than food availability. Habitat quality was affected positively in the fir-spruce forests, and also the fir-beech forests. This positive development in this mixed broadleaved-coniferous forest type was not predicted at the beginning of the project. However, the relatively short observation period with respect to forest succession must be taken into account in the interpretation of the results.

Developments in the test areas

The impact analysis of the forestry measures was carried out on the test areas in 2017. They revealed that the management objectives were broadly achieved. In no cases was the intervention too strong, but in some stands it was too weak and had to be adjusted. There was a tendency to leave too little deadwood. The habitat assessment form proved to be very useful for the impact analysis. The impact analysis was carried out by an interdisciplinary team of foresters and ornithologists.

Fig. C30.9. The habitat assessment form is also used to assess the bilberry vegetation, the abundance of basal-branched tress and the occurrence of anthills (Photo: Rolf Ehrbar).

Fig. C30.10. Harvesting measures improve the light conditions in previously dense stocks and thus initiate natural regeneration and the development of ground vegetation and ant nests (Photo: Kurt Bollmann).

Development of the capercaillie population and the use of summer habitat

The impact monitoring on the test areas showed that the summer habitat is the limiting factor for the capercaillie. Summer habitat is characterised by mature stands with moderate canopy cover and a high proportion of bilberry ground vegetation cover. Since the use of summer habitat by the capercaillie had not been recorded at the beginning of the project, plausible assumptions had to be made (Ehrbar 2019). In summer 2017, the distribution of the capercaillie was determined by means of moulting feathers, faeces, and direct observation of capercaillies (Schmid 2018). This investigation led to the results that the forestry measures have caused an increase of summer habitat and that capercaillie move into and use logged and improved stands soon after they have been restored. Therefore, we concluded that the habitat measures were effective and the silvicultural objectives pursued were appropriate. This is in accordance with the previous statement concerning the overall improvement and the development in the test areas. The capercaillie population has responded to the logging operations and moves into the improved habitats. It prefers fir-spruce forest stands, which is likely related to the high abundance of bilberry plants *(Vaccinium myrtillus)* and the suitable forest structure. Fir-spruce stands is also the preferred winter habitat as long as the canopy cover does not exceed 60–70 %.

The number of capercaillie was determined on the basis of DNA analyses from faeces samples collected on snow in spring 2008 and 2017 (Mollet 2018). No increase in the number of capercaillie was detected between 2008 and 2017. The observations made in the summer of 2017, and the winters of 2008 and 2017, confirmed that capercaillie used suitable habitats more intensively than unsuitable habitats.

Fig. C30.11. Standing deadwood in the Amden forest reserve. Forest management also aims at increasing the deadwood volume in the reserve (Photo: Rolf Ehrbar).

Conclusions

The special forest reserve Amden is a good practice example for an integrative management of a mountain forest that is primarily aimed at improving and conserving the habitat of an emblematic target species of nature conservation and at the same time taking into account the other important services of a mountain forest (e.g. protection, recreation, production of timber and non-timber products). The general management of the special forest reserve has been successful so far. The large area of the reserve, the high percentage of mires, the long resulting forest edge ecotone and the poor accessibility to the area are important quality features of this reserve for capercaillie conservation. From the conservation perspective, the status as special forest reserve is very important as it gives the possibility of active habitat management by forestry measures that would not be possible in a

strict forest reserve. The forestry measures have been effective and have resulted in a higher area ratio of suitable capercaillie habitat. The habitat suitability map accurately reflects the species' requirements for both summer and winter habitat. The test areas enable the evaluation of the logging operations carried out using the habitat assessment form based on the ecological requirement profile of capercaillie. The planning and control system enables the targeted development of the forest reserve, and the interdisciplinary planning process with forest experts and ornithologists ensures a high professional standard, also during success control activities. The impacts of the management measures are recorded, and this ensures that the management and future habitat improvement measures can be adapted. Causality analyses are also possible. However, the forest reserve was only established in 2006 and has not existed for long enough to make definitive conclusions. The second important management indicator for example, the number of capercaillie, has not yet reacted positively to the measures implemented. We cannot exclude that other factors such as human disturbances or climate change are counteracting the habitat improvement measures. Therefore, policy makers are called upon to sustainably protect the forest reserve from negative impacts in the future.

An important prerequisite for the success of this project is that the community of Amden and policy representatives of the canton of St. Gallen support the project and its objectives. Hence, communication and information are important accompanying measures in the project management. The forest reserve has strengthened the identification of the community with its forest and with the resident capercaillie population. The reserve has become a frequently used excursion destination for students and naturalists and thus contributes effectively to environmental education and sensitisation. The awarding of the renowned Binding Forest Prize to the local community of Amden in the year of the forest reserve's foundation was a great opportunity to publicise and explain the aims of the project. The community generally accepts the forest reserve, and the municipality of Amden is grateful for the employment generated by the forest reserve. These jobs are very important to this community. In summary, the forest reserve is on the right track, and should be further developed according to the defined targets.

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Fig. C30.12. Overview of the special forest reserve Amden (Photo: Kurt Bollmann).

Box C 18

Re-introducing pine marten to English woodlands – regulating grey squirrel populations

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Once a common small predator in English woodlands, the pine marten *(Martes martes)* numbers declined dramatically during the nineteenth and early twentieth century. This resulted from the combined impact of continued habitat loss, their valued fur, and an increase in predator control associated with the growth in Victorian game shooting estates. The pine marten thus became one of Britain's rarest predators and considered functionally extinct in England. They did survive in small numbers but were not able to recolonise the landscape even when their persecution stopped. The pine marten was given protected status in Ireland in the 1970s. Britain placed martens under protection in the 1980s.

Fig. 1. Red squirrel *(Sciurus vulgaris),* affected by the spread of the squirrel pox virus, which is carried and dispersed by the introduced grey squirrel (Photo: Ulrich Wasem).

Grey squirrels *(Sciurus carolinensis)* were first introduced to England from North America in the 1870s, i.e. during the period when pine martens were persecuted and populations were in dramatic decline. Owing to the lack of predators, the grey squirrel populations rapidly increased and by the early- to mid-twentieth century had spread across the whole of Great Britain. The first reports of grey squirrels introduced to continental Europe date to 1948 in Italy, where a population has become established.

In addition to habitat loss, the grey squirrel is one main reason for the decline of the endemic red squirrel *(Sciurus vulgaris).* The squirrel pox virus, carried by grey squirrels without causing them harm, is fatal to red squirrels and leads to severe decline in populations once present. Evidence also suggests that grey squirrels competitively exclude red squirrels, not by occupying or driving them out of an area, but rather by monopolising food resources. Thus, the red squirrel is officially classed as near threatened in England, Wales, and Northern Ireland.

There have been numerous attempts to exterminate grey squirrels from prime red squirrel habitats, but such measures are costly, need to be applied over the long term, and have very often failed. Because of conservation efforts and an increasing population of pine marten, the fortunes for the red squirrels have shifted. Studies in the Central and Highland regions of Scotland are confirming that grey squirrel populations tend to collapse if there is a sufficient number of pine martens in a particular habitat. Grey squirrels, which often feed on the ground, are not very agile and thus easy prey for pine martens. Red squirrels are lighter and more agile, and can more effectively escape their predators. The decline of grey squirrels in turn releases red squirrels from the pressures of food competition and reduces the probability of disease infection. Consequently, their population numbers are increasing.

Currently substantial funds are spent on measures for grey squirrel suppression. The re-introduction of the pine marten provides a viable option to support these measures, and not only for red squirrel recovery, but also for limiting damages caused to broadleaved trees by the grey squirrel. However, there are costs to be weighed against these benefits. As pine martens are good climbers they may enter pheasant or poultry pens and cause considerable damage. So, it will be important to ensure that the benefits they bring to forests and their support to preserving endemic species is in balance with other interests.

A balanced strategy is needed that builds on scientific evidence while taking into consideration the concerns and demands put forward by different stakeholders. Well-designed, equal partnerships between landowners, foresters, conservation bodies, and other parties will surely positively affect the attitudes towards re-introducing the pine marten. Allowing predators such as the pine marten to re-establish as an integral part of forest ecosystems will contribute also to making woodlands more resilient in the years to come.

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Black Forest National Park – Managing conflicting goals for protected areas

C31

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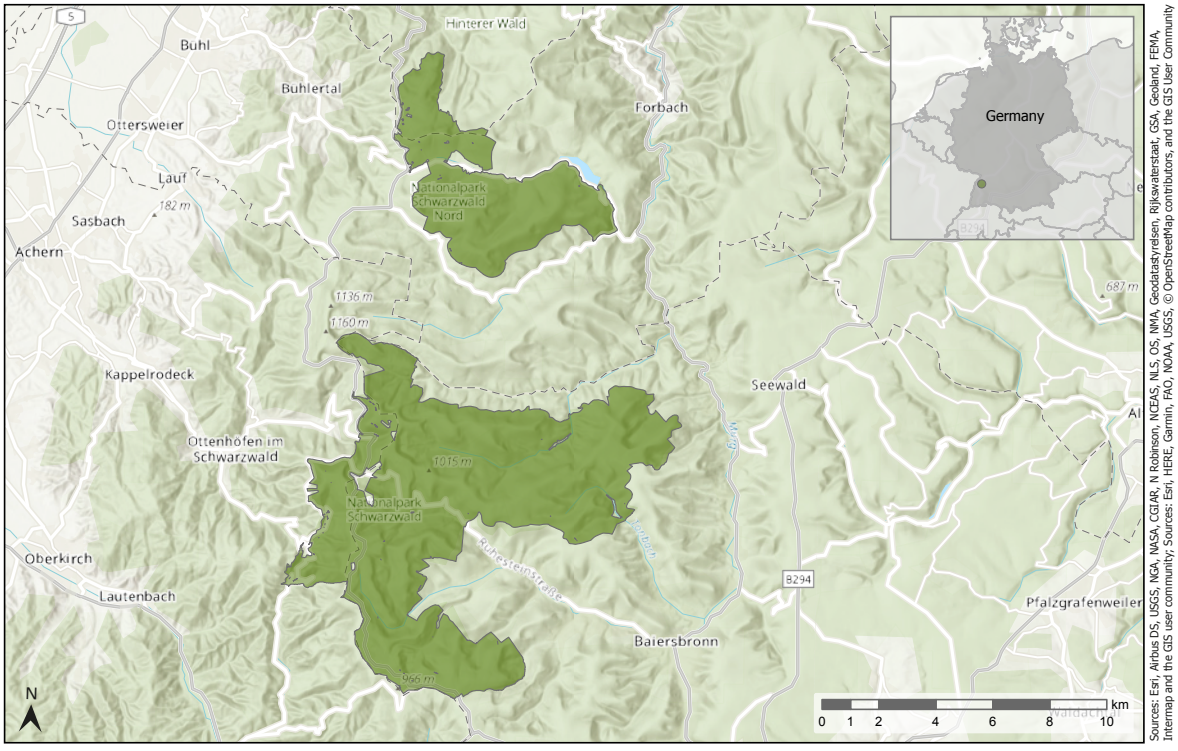
Background: Rational behind National Parks

In Germany national parks are designated under the environmental law (Bundesnaturschutzgesetz, BNatSchG; Federal Nature Protection Act). According to BNatSchG §24(1) each of the national parks must be large in area, contiguous, and of a special character. A condition for the designation is that they are either completely uninfluenced or only slightly influenced by humans, so as to be able to develop solely as a result of natural processes



< Fig. C31.1.The Eurasian pygmy owl *(Glaucidium passerinum)* is the smallest owl species in Europe, it is typically found in conifer rich, montane forests and it is a mascot of the Black Forest National Park and called 'Karli Kauz' (Photo: Arne Kolb).

Statement

"Together with the people of the region and all who value nature, the park administration aims to make a valued nature conservation project as well as place for education and recreation."

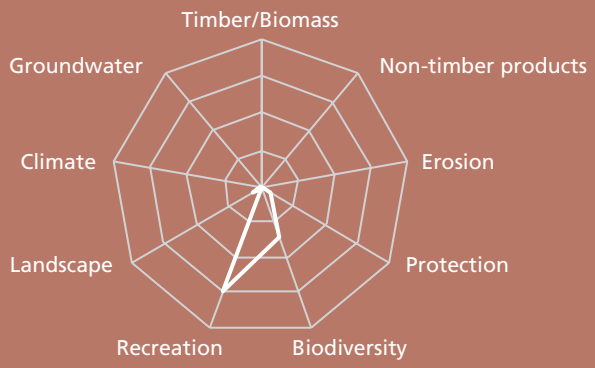


Table C31.1. Basic information about the Black Forest National Park.

Total park area	10 062 ha
Management	No management for resource extraction, except for species and habitat conservation, visitor safety and to protect neighbours – see the description of the zoning concept in the next section.
Total timber volume	281 m³/ha in the southern part (Ruhestein)
Annual growth	Not relevant
Annual cutting rate	3500 m³/yr, until 2044 including the management and transition zone
Deadwood	no data available yet
Ownership	State forest and municipal forest (~470 ha)
Climate	Average annual precipitation 2200 mm; average annual air temperature 4 to 7 °C (January –3 °C – July 13 °C)
Geology	Bunter/red sandstone, with occurrences of granite and gneiss in lower valleys
Soils	cambisol, podzol, and gley; often very acidic and low in nutrients
Protected area	100 % national park
Natura 2000 area	Special Areas of Conservation (SAC; FFH in German) 2747.1 ha

Data in part from PricewaterhouseCoopers & ö:konzept (2013)

(Europarc 2012). However, given the cultural landscape of central Europe, almost no primary forests remain (Parviainen 2005). Therefore, most of the German national parks are initially designated as 'transitional national parks (Entwicklungs-Nationalpark)'. This allows for a 30-year transition period until 75 % of their area is deemed to be strictly protecting natural dynamic processes (Europarc and IUCN 2000). This designation is a criterion necessary to be recognised as a national park under IUCN category II protected areas. For this protection category, the primary objective is to protect natural biodiversity along with its underlying ecological structures and supporting environmental processes (Dudley 2008). Additionally, national parks provide an opportunity for environmental education, to experience nature and for recreation, as well as serving as a reference point from which to learn about natural dynamics through a scientific ecological monitoring programme (fig. C31.2).

Portrait of the Black Forest National Park

The Black Forest National Park was designated on 1 January, 2014 by the parliament of Baden-Württemberg (Nationalparkgesetz, NLPG; National Park Act). It is the second youngest of the 16 national

Fig. C31.2. Northern Black Forest landscape – with its steep slopes facing westwards descending into the upper Rhine Valley (left, Photo: Carmen Richter) and a gently slanting high plateau with deep valleys and tarns to the east (right, Photo: Charly Ebel).

parks in Germany and the first in Baden-Württemberg. It was established only after heated discussions and a regional participatory process. To integrate the national park into the region, it was given a unique structure. Management is done by the national park administration which falls under the 'Ministry of the Environment, Climate Protection and the Energy Sector' of Baden-Württemberg. The administration consists of a directorate with a director's office and five departments, namely: (1) Administration; (2) Ecological Monitoring, Research and Species Conservation; (3) National Park Plan, Regional Development and Tourism; (4) Environmental Education and Visitor Information; and (5) Forest and Conservation.

The most important strategic decisions considering the management of the national park are made by the national park council which is divided into two parts: one part consists of representatives from the region and assembles representatives of the municipalities, counties and city districts, and includes the presidency; and the other part has representatives from the national park administration and the state ministry. The national park council is consulted by an advisory board consisting of external administrational and NGO representatives with different affiliations including conservation, tourism, industry, sports, and religion.

Each national park protects a specific landscape type with its close-to-natural ecosystems and associated flora and fauna. In the Northern Black Forest, it is the mixed mountain forest dominated by beech *(Fagus sylvatica),* silver fir *(Abies alba),* and Norway spruce *(Picea abies)* interspersed with bogs, tarns, boulder slopes, and remnants of former land use (pastures), the typical high mountain meadows (called 'Grinden') and adjacent peat bogs. The last two are also protected in the Natura 2000 network under the Habitats and Birds Directives.

Today the forest is dominated by conifers (92 %). The dominant species are Norway spruce 70 %, silver fir 12 %, and Scots pine (*Pinus sylvestris,* 6 %). Of the broadleaved species, beech is the most common with 5 %, followed by birch (*Betula pendula,* 1 %) and rowan (*Sorbus aucuparia,* 1 %). This species distribution is a result of centuries of agricultural land use and forest management, but also a consequence of natural drivers.

After the last Ice Age, a slow, long-term natural recolonisation process by different tree species occurred. In the case of Norway spruce, this natural process took millennia and continues today (Ludemann 2014). New research shows that Norway spruce arrived in the northern part of the Black Forest long after beech and silver fir had recolonised the area (Ludemann *et al.* 2020).

Because of the unfavourable conditions – cold, wet, nutrient poor, and rocky soils – the Northern Black Forest was settled relatively late by humans compared to the surrounding areas with more favourable conditions. For centuries, the Northern Black Forest was seen as a barrier and Germans and Romans only passed through without settling.

The first lasting footprints date from the Middle Ages: small monasteries and castles were established, and farmers settled and cleared the forest,

with hermitages and inns appearing along trade routes. Wood was used for building, as fuel, and for everyday objects. Because the narrow valley bottoms were used for settlements and fields, livestock were driven up the forested slopes to graze, where in time, woodland pastures developed. The naturally occurring mountain peat bogs of the Northern Black Forest were also used as summer pastures. Tree growth was limited using controlled (and sometimes uncontrolled) pasture burning, thereby maintaining and expanding pastureland (today protected as SAC sites – dry heath).

From 1500 onwards demand for wood increased steadily. As on other mountain ranges of central Europe, the production of charcoal, glass, and iron required enormous quantities of wood which were obtained by clear-cutting which ate deeper and deeper into the Northern Black Forest. Additionally, streams were used for log drives, not only for firewood but also for massive conifer logs which were rafted on the Rhine to Holland to be used in ship building for ship masts and as the piles on which cities such as Amsterdam were built. As a result the forest was almost completely cleared by 1800. All large predators (wolf, lynx, brown bears, golden eagle, eagle owl) and large herbivores (e.g. aurochs, European bison) inhabiting the large forest were gradually eradicated within this time period.

As in other parts of Europe, the devastation stimulated the change away from unregulated exploitation of the forest and the transition to planned and sustainable forestry. The first step was to ban forest pastures. Large parts of the Northern Black Forest were reforested with fast growing conifers, mainly Norway spruce but also Scots pine. In addition to the wood, people also harvested branches, twigs, and leaves for livestock fodder and bedding leading to further impoverishment of the already unfertile soils. While on some sites even-aged monocultures were established, on others, due to farmers needs for a variety of wood sizes, continuous cover forestry (Plenterwald) developed, dominated by silver fir and Norway spruce.

Following a large forest fire around 1808 the area around the Wild Lake was set aside as a non-commercial forest and was subsequently declared a strict forest reserve in 1911 which today is one of the core areas of the national park.

The two World Wars led to the forests being overexploited once again as most everything, including wood, was in short supply. After World War II, France was entitled to large amounts of wood as war reparation. The resulting clear-cuts were later reforested. Although there were trials with species mixtures, it was mostly spruce which was planted and flourished in the extreme conditions. The relatively even-aged conifer forests suffered widespread windthrow in 1990, (storms Wiebke and Vivian) and in 1999 (storm Lothar). Thus, forest conversion to more site adapted species mixtures and to more structured forests, were initiated in the early 2000s. It was these large storms which initiated real changes in Northern Black Forest management practices.

Management – the zoning concept

The Black Forest National Park is designated as a national park 'in transition' according to the BNatSchG. One main feature of a national park in development is an area designated temporarily as the so-called 'transition zone'. At the latest, after 30 years (by 2044), this zone will be completely integrated into the core zone which will then comprise 75 % of the national park area. This is required to comply with the international national park definition of the IUCN. The remaining, existent management zone cannot consist of more than 25 % of the area. This zoning concept affords an opportunity to reach the different, and at times contradictory, goals of a national park (fig. C31.3).

The national park plan must cover a period of 10-years and include several modules (topics) (NLPG §6). The first plan for the Black Forest NLP had to be completed by 2019. The plan consists of, different modules related to forest management: 'forest

Table C31.2. Changes in zoning area since the designation of the Black Forest National Park.

Zone	2015		2020	
Core zone	3281 ha	32.7 %	5115 ha	50.8 %
Transition zone	4163 ha	42.4 %	2088 ha	20.8 %
Management zone	2645 ha	24.9 %	2857 ha	28.4 %

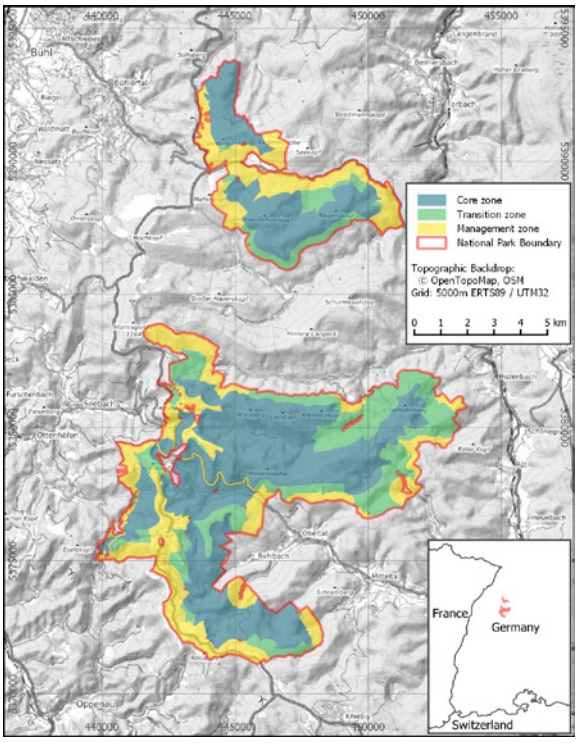


Fig. C31.3. Map of the Black Forest National Park with zoning information.

development' (2017); 'bark beetle management' (2015); 'wildlife management'; 'zoning'; 'trails'; 'habitat and species protection'; as well as 'research and documentation'. The zoning concept was one of the first strategic decisions made by the national park council in 2015. The first extension of the core area occurred in early 2020 adding almost 20 % to the area already strictly protecting natural processes. Visitors must stay on designated trails throughout the park.

Core Zone

Aim 1: Protect natural processes – Leave nature to its own devices

The core area reflects the main purpose for designating a national park. It is not another protection category. The main purpose is to protect natural processes (fig. C31.4).

Strategies:

– No resource extraction is allowed, i.e. no harvesting of trees or non-timber products (e.g. fungi or berries).
– No nature conservation measures are allowed, i.e. no habitat improvement for species protection (except in urgent cases).
– Reduction in the number of trails.

Aim 2: Allow visitors to experience wilderness

Strategies:

– Guided tours led by park rangers.
– Opportunities for hiking, horse riding, cycling, cross country skiing, or snowshoeing only on designated trails.
– Maintain trails for visitor safety.
– Provide infrastructure, i.e. benches and picnic tables at scenic viewpoints.

Aim 3: Educate and study – enhance the knowledge and awareness of students, the public and the scientific community

Strategies:

– Provide educational institutions and young people of the region with an opportunity to spend time in the park with teachers i.e. school classes, kindergarten, junior ranger programmes.
– Educate the public by offering specialised tours, talks, social media posts, and press releases.
– Conduct intensive long-term ecological monitoring programmes investigating forest development and its impact on a large range of organisms.
– Present research results at conferences and in scientific journals.

Transition Zone

Aim 1: interventions for habitat and species protection

Strategies:

– Temporal habitat management of NATURA 2000 species. For example, improvement of forest structure for capercaillie *(Tetrao urogallus)* by opening up spruce thickets.
– Temporal habitat management for other rare and protected species (e.g. Red Listed Species).

Aim 2: wildlife management to protect neighbouring stakeholders

Strategies:

– Because of a lack of predators, red deer *(Cervus elaphus)* populations in particular are managed.
– Intensive consultation with stakeholders is carried out because the NLP is a main stakeholder in the 'red deer management strategy' developed

Fig. C31.4. Stand in the core area (since 1911 strict forest reserve – Bannwald Wilder See) (Photo: Marc Förschler).

by the Forest Research Institute of Baden-Württemberg (FVA).
– Intensive monitoring of wildlife with camera traps and by telemetry.

Aim 3: one-time measures for initiating direct succession towards more naturalness
Strategies:
– In young stands, originating after storm Lothar (1999), one-time measures to reduce the dominance of spruce regeneration in favour of other species can be carried out.
– In case it is necessary to cut trees (e.g. to clear trails), Norway spruce or non-native tree species – i.e. Douglas fir *(Pseudotsuga menziesii),* or red oak *(Quercus rubra)* – should be cut.
– Trees older than 100 years are not to be cut.
– Research: One-time silvicultural experiment to speed up wilderness development (Pyttel *et al.* 2020) – create standing deadwood by girdling live trees, and create lying deadwood by pushing over standing trees to simulate storm damage.

Management Zone
A 500 m buffer (i.e. a strip on the perimeter of the national park; inside the national park in the case where the national park borders privately and municipality-owned forests, and outside the national park in case where the national park borders state forest) provides the forests outside the park with a buffer from natural processes from spreading outside the park. This buffer-strip is constantly monitored, especially for outbreaks of the spruce bark beetle *(Ips typographus).* Additionally, the buffer contains historic openings (Grinden) maintained for nature conservation.

Aim 1: Protect cultural ecological heritage
Strategies:
– Maintain and extend (connect) the SAC type dry/wet moorlands by grazing with livestock – sheep, goats, 'Hinterwälder' cattle (a regional heritage breed), 'Heck' cattle (this breed is the result of an attempt by Heinz and Lutz Heck to 'breed back' to extinct aurochs), and Konik horses – according to the Habitats and Birds Directives (fig. C31.5).
– Permanent habitat management of NATURA 2000 species, e.g. by improving forest structure for capercaillie – by opening up spruce thickets.
– Permanent habitat management for other rare and protected species (e.g. Red Listed Species).
– Motor manual and manual reduction of succession where livestock is not able to maintain early successional stages.
– Monitoring and evaluating effectiveness of conservation measures.

Fig. C31.5. High elevation pastures (Grinden) protected by Natura 2000 (Photo: Carmen Richter).

Aim 2: Protect the neighbouring stakeholders
Strategies:

- Intensive monitoring of bark beetle (especially *Ips typographus*) outbreaks – attacked trees are marked, felled and withdrawn from the forest within two weeks.
- Intensive monitoring and cooperation with hunters and forest owners outside of the park boundary regarding wildlife management – especially for red deer.

Main national park services and benefits

Economics – regional development and tourism

As stated above, a national park has no economic goals therefore natural resource extraction is not permitted. However, the 'national park brand' provides opportunities for the regional economy, and specifically for tourism (Kraus and Job 2015). Based on visitor interviews, Kraus and Job found that for about 10 % of the visitors it was 'important' or 'very important' that they were visiting a national park. Calculated for the whole year, this group accounted for a gross income of € 3.9 million in the region, equivalent to 72 jobs (Kraus and Job 2015).

The budget of the national park administration is funded by the state of Baden-Württemberg. An analysis of the invoices paid by the administration and the related postal codes, showed that in 2018: € 1.3 million (33 % of the budget) stayed within the national park region (network of municipalities) and an additional € 1.4 million (35 %) remained in the counties within the area of the national park (Nationalparkverwaltung 2019).

Social – benefits for education and health

The contribution of national parks goes beyond nature conservation, regional development, and tourism. They also have a positive impact on human health, well-being, and personal development (Ensinger and von Lindern 2019).

From the very start, the Black Forest National Park administration had the goal of connecting with the people in the region. Besides the institutionalised participation of representatives in the national park council or the advisory board, there is a strong emphasis on citizen participation.

Individuals can take part by attending specific activities or as citizen scientists. As well as participation in planning, they may take part in decisions around the development of the different modules of the national park plan, e.g. through developing a trail concept, which was accomplished in workshops, online-surveys, or on public tours.

Fig. C31.6. Birds at risk of extinction according to the Red List of Baden-Württemberg (Bauer *et al.* 2016) occurring in the Black Forest National Park. The Eurasian three-toed woodpecker (*Picoides tridactylus,* Photo: Walter Finkbeiner, left) needs old-growth structures, while the meadow pipit (*Anthus pratensis,* Photo: Marc Förschler, right) depends on the managed open meadows and peat-bogs (Grinden and moors). The capercaillie (*Tetrao urogallus,* Photo: Walter Finkbeiner, centre) occurs in strictly protected forest areas with disturbances and old-growth structures (i.e. bark beetle or windblown patches) as well as managed half-open heathland and clearings.

A key part of the mission of the national park is environmental education. In the annual programme of 2018, there were 216 educational events. Additionally, 809 events were provided such as talks and guided tours given to the public to specialists and students of all levels from kindergarten to university (Nationalparkverwaltung Schwarzwald 2019).

Resilience – Protecting natural dynamics and learning from them

According to Schultze *et al.* (2014), in regions such as central Europe with a long land-use history, the underlying assumption is, that in national parks (as strictly protected forest reserves) 'natural forest development processes' such as disturbances and succession will lead to more complex structures (e.g. Pickett and Thompson 1978), even if these reserves initially continue to show the effects of past anthropogenic influences, e.g. absence of old-growth structures (e.g. Müller and Bütler 2010).

Especially in times of rapid global change, in managed forests outside of protected areas, there is an economic need to adjust the management regime, for example, by changing species composition or by decreasing rotation periods. Especially in such instances, there are references needed where natural processes are not interrupted. Therefore, national parks can be seen as areas where ecological baseline data is available to enable the detection of gradual changes and to predict harmful changes to ecosystems that humans depend upon (Sinclair 1998). In the Black Forest National Park, a long-term ecological monitoring programme has been established which provides the opportunity to document and analyse the interactions and functions of the natural system.

Biodiversity – every protected area contributes to global biodiversity conservation

Protected areas are the fundamental building blocks of almost all international conservation strategies, which are supported by governments and international institutions such as the Convention on Biological Diversity (Dudley 2008). According to the IUCN, protected areas are the core of the efforts to protect the world´s threatened species, and are set aside to maintain functioning natural

ecosystems, to act as refuges for species, and to maintain ecological processes that cannot survive in most intensively managed landscapes (Dudley 2008).

In the Black Forest National Park, we aim at protecting natural processes and dynamics on 75 % of the area by 2044. By having a large enough area where nature can develop unrestricted, natural disturbances like storms, snow breaks, or bark beetle outbreaks can result in patch dynamics with different forest development stages. In an expert report written prior to the national park designation (PricewaterhouseCoopers & ö:konzept 2013), 450 Red Listed Species were recorded for the area, 206 of these species would benefit from a strict protection of forest dynamics and the resulting old-growth structures like standing deadwood, root plates, and the accumulation of large deadwood with its long habitat continuity (fig. C31.6).

However, there are an estimated 53 species that would be detrimentally impacted by the cessation of forest management practices. These are mostly species associated with the high elevation pastures, managed for centuries, and because of their habitat value are protected by Natura 2000. These habitats were integrated into the 25 % area of the management zone and can, therefore, be maintained by management practices (Förschler *et al.* 2013; Förschler and Richter 2020).

Conclusion

Management in national parks, mainly means the management for people. To provide opportunities to learn and recreate, but also to protect the neighbouring stakeholders. Furthermore, it can be necessary to preserve specific habitats and species communities (in the case of the Black Forest National Park heaths, meadows and peat bogs).

Natural forest with its characteristic patch dynamics can only establish if an area is large enough and permanently protected to allow for the accumulation of large deadwood in high quantities which provide the necessary habitat continuity. This is only possible in strictly protected forest reserves like national parks. These are the only places where the scientific observation of natural forest dynamics is possible to gain knowledge important for the management of cultural landscapes.

Portrait

National parks are very special places, especially today, when so few areas in densely populated Germany remain where nature can develop unhindered. But the principle behind 'Let nature decide', the central idea behind a national park, is also important to our wellbeing as it provides the insights necessary to preserve natural processes. We learn by observing what changes occur, especially if this is done scientifically like it is in the Black Forest National Park.

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Fig. C31.7. Summer pasture for Heck cattle (a breed that has been bred to resemble the extinct aurochs) as a means to effectively supress succession of woody species on the SAC type dry/wet moorlands (Photo: Marc Förschler).

Box C 19

Relaunching higher education in management of renewable natural resources in the Democratic Republic of Congo

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Starting point

Beginning in the 1980s, the training of forest engineers in universities and technical colleges in the Democratic Republic of the Congo (DRC) was progressively weakened owing to a lack of resources; this led to a considerable deficit of competent personnel (RDC 2011). The area of forests in this country (155 million ha, or 67 % of the national territory in 2014, according to VADE-MECUM 2015) and the ecological, social and economic role they play, make it the most forested country in the Congo River Basin and one of the most important forest countries worldwide.

Drawing conclusions from this situation, the Government of the DRC, through the Ministry of Universities and Higher Education (Ministère de l'Enseignement Supérieur et Universitaire, MINESU) and the Ministry of the Environment, Nature Conservation and Tourism (Ministère de l'Environnement, Conservation de la Nature et Tourisme, MECNT), launched a 'National 2020 Strategy for university and technical education in the management of renewable natural resources (MRNR)' (RDC 2011). The aim was to upgrade the training system in the field of MRNR, in accordance with national legislation, the directives of sub-regional organisations, as well as the rules of the Bologna Process – bachelor (or licence)–master–doctorate system (REESAO 2008). The Bologna Process is the mechanism promoting intergovernmental cooperation between European countries in higher education systems, and participating countries agreed to three-cycle higher education system consisting of bachelor's, master's and doctoral studies. This latter point is important because it reflects the need of the DRC's academic community to work towards improving equivalence and international exchange opportunities, in particular with Europe and North America.

At the quantitative level, the goal assigned to the strategy (DRC 2011) was to set up, by 2020, a network of universities and technical institutes capable of training each year up to 300 students at a bachelor's degree level (higher certificate or International Baccalaureate + 3), 200 students at a master's degree level (International Baccalaureate + 5), and 10 to 15 scientific staff (PhD level) in the field of MRNR.

It should be noted that the concept of 'renewable natural resources' goes well beyond the former education in forestry, and also includes nature protection and management of protected areas, biodiversity, soil and water, agroforestry, payments for environmental services, as well as the human-resources interface.

Implementation of the National 2020 Strategy

The implementation of the 2020 Strategy started actively in 2012 under the guidance of MINESU and MECNT, and the support of some cooperation organisations in the environmental sector. From the beginning, the strategy has received significant support from the 'Deutsche Gesellschaft für Internationale Zusammenarbeit' (GIZ) through its Biodiversity Conservation and Forest Management programme (Conservation de la Biodiversité et Gestion des Forêts, BGF) in Kinshasa.

Several large workshops were organised in 2012 in order to finalise the implementation modalities, bringing together the higher education institutions participating in the Strategy 2020 network, representatives of ministries, and other decision-makers, professionals of the environmental sector in the DRC, and experts in the field of higher education and education policy.

The achievements of the workshops can be summarised as follows:

- bringing all participants up to speed with regard to the objectives of the National 2020 Strategy and the Bologna Process;
- compiling the list of the institutions entering the 2020 Strategy, which will comprise four universities and three higher technical institutes;
- presenting curriculum development tools and relevant examples from different parts of the world;
- establishing professional benchmarks/competencies/educational needs, with a significant expansion of the range of professions involved in the field of MRNR;
- finalising course lists, describing the minimum content of each course, defining teaching units, and defining semester programmes;

– setting up of study plans for the overall education scheme (described in more detail in the following section).

At the start of the 2012–2013 academic year, the selected institutions officially adopted the 2020 Strategy, including the transition to the bachelor's–master's–doctorate system.

Overall education scheme

The study plans provided for an academic education articulated at three levels:

a. Domain: management of renewable natural resources;
b. Subjects: ecosystem management, biodiversity conservation, agroforestry;
c. Vocations: research (universities), professional (technical institutes).

Modernisation of study plans

It should be noted that the new education in MRNR was intended to replace the former education in Forestry (Water and Forests).

The former study programmes have been thoroughly modernised taking advantage of the lessons learned from Africa, North America, and Europe. They have been adapted to: (i) current international scientific standards, and (ii) the bachelor's–master's–doctorate system (REESAO 2008), but with a dose of contextualisation. To the extent possible, the revised programmes taken into account the needs of the professional world.

The following documents were produced and widely distributed to all actors involved, including the students:

– a 'Methodological Guide - Programmes and Content to be Applied for Education in the Management of Renewable Natural Resources' in paper and electronic formats (MINESU 2014);
– a summary version of the above-mentioned guide in pocket format (MINESU 2016).

Complementary steps

In the given context, Strategy 2020 has contributed in a significant way to the modernisation of equipment, the capacity building of the actors involved, as well as the structural and legal reforms that are supposed to accompany the reform process.

Many of these complementary tasks have been supported by GIZ. The most important are:

– setting up of draft bachelor's–master's–doctorate tuition rules on general organisation, admission, and registration of students, support for students, examination guidelines, etc.;
– preparation of guides on specific issues such as internships (MINESU 2015);
– supply of computer, teaching and measurement equipment, setting up Internet facilities within the network;
– information, extension and capacity building campaigns (LMD education pedagogy, information and communication technologies, teaching evaluation methodologies, etc.) for the different university departments involved in the reform, differentiated for decision-makers, teachers, students, administrative, and technical staff;
– annual evaluation of the academic year to review the implementation of the 2020 Strategy; periodic evaluations of the bachelor's–master's–doctorate process and teaching;
– definition of the needs of the establishments in terms of visiting teachers and support in this field;
– coordination with other institutions and ministries to share experiences;
– specific training for students who are in the final stage of their studies to facilitate their professional integration.

Validation of the process

Over the years, it has become increasingly clear that the National 2020 Strategy, implemented for seven educational institutions only, should serve as an example for a broader reform, which would affect the entire higher education system of the DRC.

The implementation of the National 2020 Strategy requires a reliable institutional framework to guarantee the sustainability of the approach. Validation of the process has been a permanent objective of the strategy. A first decree validating the study plans, the duration of the studies, and the diploma issued as part of the training in MRNR was enacted at ministerial level in 2013. A framework law for National Education was adopted by the Parliament of the DRC in February 2014. This law provides for the gradual transition to the bachelor's–master's–doctorate system of all universities and colleges in the country. Finally, and this is undoubt-

edly the most important achievement pedagogically, legally and administratively, the bachelor's–master's–doctorate system has been provided with a normative framework relating to the management of training institutions, the management of the system, the teaching methodology, student assessment and teaching, desirable infrastructure and equipment, etc. (MINESU 2018). Currently, the normative framework, which was validated in 2018, is entering its implementation phase.

Outlook

Today, the key word in the implementation of the National Strategy 2020 is 'consolidation'. It is indeed particularly important that the actors do not relax their efforts, and that the institutions take ownership of this instrument of educational reform.

Capacity building is crucial for the different actors involved in the reform. However, the information available shows a contrasting picture of the implementation of the reform. The modernised curricula have been accepted. At the same time, the majority of establishments in the Strategy 2020 network have retained the former training courses in Water and Forests, one of the reasons being the lack of confidence in the sustainability of the reform that was undertaken. Overall, the actors have not yet really adopted the bachelor's–master's–doctorate process pedagogically. Some partners have clearly remained within the old system and are putting up strong resistance to the ongoing reform.

More precisely, we observe:

- a certain motivation for the National 2020 Strategy and the bachelor's–master's–doctorate system within the teaching staff, particularly among the younger staff members;
- a good knowledge of the strategy, including the bachelor's–master's–doctorate system among leaders and decision-makers;
- a rather confusing situation for students, whose demands are often related to the practical issues that they face rather than issues concerning reform;
- low knowledge and, probably, low motivation for administrative and technical staff.

The biggest problem lies in the willingness of the different actors to take ownership of the reform, which is sometimes very low, especially in the smallest educational institutions. For example, a recent evaluation (Konate 2018) listed the main difficulties and obstacles encountered in the implementation of the reform as:

- lack of a genuine strategy for national ownership of the reform;
- absence of real policies and strategies for linking the institutions of the Strategy 2020 network to the bachelor's–master's–doctorate system;
- insufficient human and material resources (information and communication technologies, infrastructures, etc.);
- limited alignment of pedagogical methods with the requirements of the bachelor's–master's–doctorate system;
- lack of real professionalisation and employability strategies for students.

Taking stock nearly 10 years after the design and implementation of the strategy, it is clear that the strategy has had mixed results. With the validation of the normative framework, considerable progress has been made in legal and administrative matters. The bachelor's–master's–doctorate system has become mandatory for all higher education in the country. The example of the network of Strategy 2020 institutions shows, however, that there are still many difficulties, as well as reservations. There is no doubt that capacity building is essential for the success of the reform.

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Bad Windsheim – Maintaining insect diversity in oak dominated coppice forests

C32

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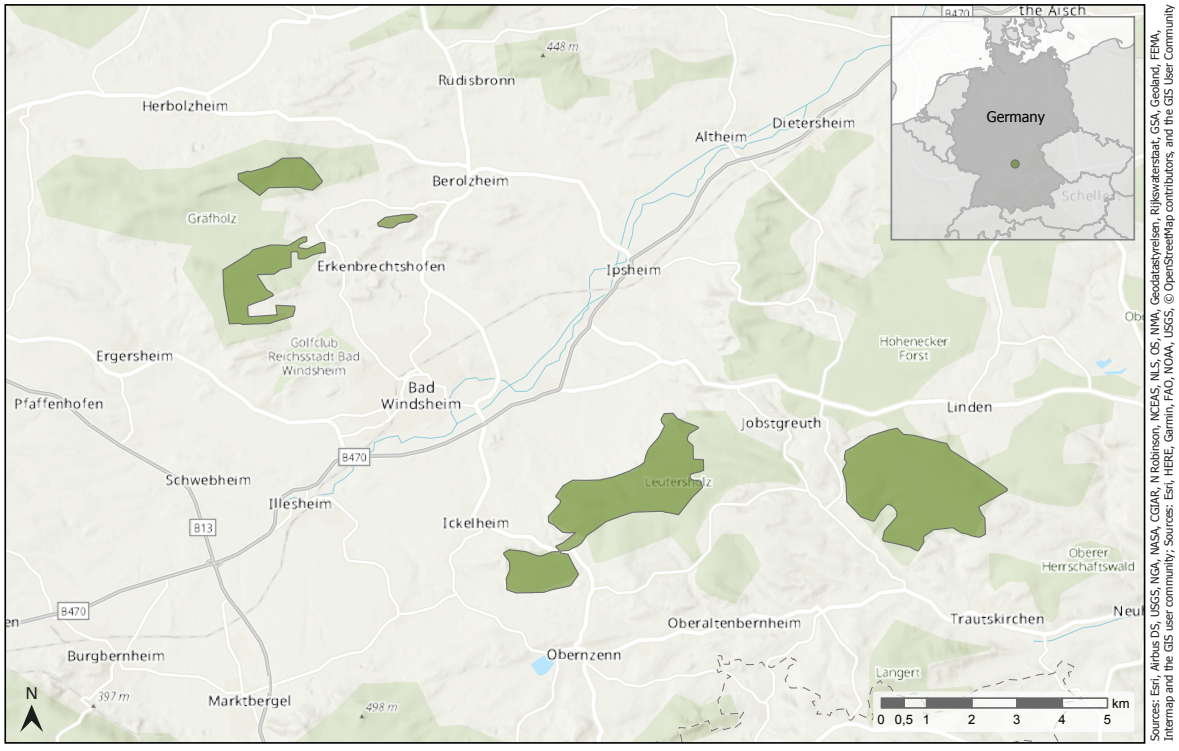
The town of Bad Windsheim owns 1480 ha of forest in the Windsheim Bay, located between the southern Steigerwald and northern Frankenhöhe region along the Aisch River. The region belongs to the Keuper uplands (mid-Triassic period) of Franconia between Rothenburg ob der Tauber and Nürnberg in northwestern Bavaria. Approximately 490 ha are dominated by conifers (mainly Norway spruce *(Picea abies)* and Scots pine *(Pinus sylvestris)* and 990 ha are dominated by broadleaves (oak (*Quercus* spp.) being the dominant species with 553 ha, followed by beech *(Fagus sylvatica)* with



< Fig. C32.1. Reactivated coppice with standards in the Bad Windsheim forests. The canopy closure has been reduced to 30 % (Photo: Heinz Bußler).

Statement

"We bring light back into the forest."

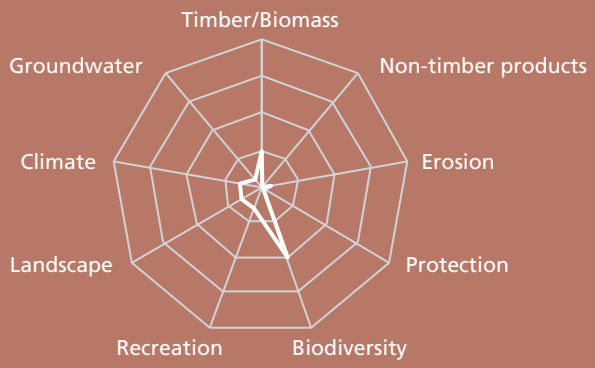


Table B 32.1. General information on the Bad Windsheim forests.

Total forest area	1480 ha; high forest 1034 ha // cws 369 ha
Main management types	Coppice with standards (cws)
Total volume	High forest: 221 000 m³ // cws 40 933 m³
Annual growth	High forest: 7.0 m³/ha // cws: 2.0 m³/ha
Cutting rate	High forest: 5.8 m³/ha; 6000 m³ // cws: 12.3 ha per year 980 m³
Deadwood	ca. 15 m³/ha
Ownership	Community forest
Climate	9.2 °C mean annual temperature, 595 mm mean annual precipitation
Geology	Mostly Keuper – gypsum and dolomite marls, clay- and sandstones that were deposited during the Middle and Late Triassic epochs (about 220 million years ago)
Soils	Small-scale mosaic of sandy, marly or clayey soils, mostly nutrient rich
Protected area	
Natura2000 area	Special Areas of Conservation (SAC) 750 ha Special Protection Areas (SPA) 294 ha

98 ha). All forests designated as Natura 2000 areas are recent or former coppice with standards forests. After a break of about 60 years, coppicing was reintroduced on an area of 100 ha in one forest district in 2010 . The stands of this district have gained a reputation of national importance for its rare Lepidoptera and Coleoptera fauna. However, it has to be mentioned that many insect species that are abundant in these stands are considered as forest 'pests' elsewhere and are important factors contributing to oak dieback. These include the two-spotted oak borer *(Agrilus biguttatus)* (fig. C 32.2), the oak processionary moth *(Thaumetopoea processionea),* and the gypsy moth *(Lymantria dispar)* (Petercord 2015, 2018). Initially concerns were raised that reactivation of coppicing would create microclimates that are favourable to such insects through the opening of the canopy and the accumulation of large dimensioned crown deadwood that was left to decay. Several scientific projects are accompanying and monitoring the effect of insects on tree mortality and coppicing capacity of the oaks after strong openings and active deadwood accumulation.

Reactivating a medieval form of forest management for biodiversity

The forests of Bad Windsheim, and especially the coppice with standards stands, have gained a reputation as having a flora and fauna of national importance (Bußler 2016). Among the 560 saproxylic beetles that are known in the region, 180 species are threatened and on the red list, six species are from the list of 'Urwald' relict species. Around

Fig. C 32.2. The two-spotted oak borer *(Agrilus biguttatus)* is the most abundant buprestid beetle in the coppice with standards forests (Photo: Heinz Bußler).

800 day-flying butterfly species (macrolepidoptera) have been found in these stands, especially those species depending on warm and light (inner) forest edges with relatively high soil moisture, such as *Euphydryas maturna, Euplagia quadripunctaria,* and *Eriogaster catax* from Annex II, and *Lopinga achine* from Annex IV of the Habitats Directive. Such conditions are usually found in floodplain forests or on seasonally wet sites.

Closely associated with, and benefitting from, the cyclic gradations of *Lymantria dispar* and *Thaumetopoea processionea* are the rare carabid beetles *Calosoma inquisitor* and *C. sycophanta* (fig. C 32.4).

Coppicing as a forest management practice has a tradition in Bad Windsheim of more than 1000 years. In the year 1414, the income of the town is documented as being exclusively from coppice forests (Rabl 1982). Especially in the nineteenth century fuel wood was the main product after oak bark for tanning. The different forms of coppicing were continuously practised until the mid-twentieth century. The last coppice cuts occurred in 1958, and after this about 150 ha were left to convert to broadleaved high forests, and in another 50 ha coniferous species (mainly Norway spruce and Scots pine) were planted. Since this time, the coniferous stands have been partially degraded by windstorms, drought, and bark beetle infestations; in some cases the coniferous stands have completely vanished.

With the aim of the conservation and maintenance of rare and threatened species, the former practice of coppicing with the retention of old standards was reactivated in 2010 on about 100 ha with the support of public funds from the Bavarian Government (Vertragsnaturschutzprogramm, VNP). Currently, there are 370 ha of forest stands managed as coppice with standards. Usually the coppicing is done on areas of about 3 ha, by reducing the canopy closure to 30 % (i.e. the retention of old oaks as standards). In the remaining high forests natural regeneration of oak and other light-demanding species is promoted by creating small openings (minimum 0.3 ha) where all living trees are removed to mimic gap dynamics of falling giant trees in primeval forests (Dolek *et al.* 2008).

Fig. C32.3. A wide range of species from different groups are benefitting from the warm and light conditions in coppice with standards forests (e.g. *Lopinga achine, Calosoma sycophanta, Rosa gallica, Saperda perforata, Potosia aeruginosa, Cerambyx scopolii*) (Photos: Heinz Bußler, Sven Finnberg).

Fig. C32.4. Larvae of *Calosoma sycophanta* preying on a caterpillar of *Lymantria dispar* (Photo: Sven Finnberg).

Seasonally wet coppice forests as a surrogate habitat for floodplain forests

The biodiversity of the coppice with standards forests in the Windsheim Bay is a result of different factors. The site conditions are mainly determined by seasonally wet soils on gypsum marls as well as clay and sandstones of the Early Keuper formations. The area harbours mostly oak–hornbeam forests of the *Galio sylvatici-Carpinetum* and *Stellario holosteae-Carpinetum* associations. It has been largely disputed whether oak–hornbeam forests are anthropogenic forest ecosystems that would not exist without human interference (Zollner 2018). However, we argue that the site conditions in the Windsheim Bay are just perfect for such forests to develop naturally. Another characteristic is the hot and dry climate and the continuous habitat tradition with a great diversity of tree and shrub species as well as a species-rich herb and grass layer where flowers are available throughout the complete vegetation period. The coppicing practices create a mosaic of very open to closed stands in a way that the harvest of timber mimicks the natural dynamics of a landscape that has been lost by the strong regulation of rivers. From geological maps it can be seen that on 83 km along the Aisch River there are 4200 ha alluvial floodplain areas that were historically stocked with floodplain forests, and swamp and mire forests. In this context, seasonally wet coppice with standards forests can serve as surrogate habitats for the foregone hardwood floodplain forests; the lepidopteran and coleopteran fauna from Windsheim Bay shows a high degree of similarity with the lepidopteran and coleopteran fauna from the floodplain forests of the Rhine and the Danube. An important common element with the floodplain forests is the presence of aspen *(Populus tremula),* and especially old specimens, across the area. In high forests aspen is largely missing because of the past thinning practices; sometimes only young specimens are retained along forest edges or roads (Dolek *et al.* 2008). Many lepidopteran and coleopteran species feed on poplar species, and thus the presence of such trees is a key resource.

Crown deadwood and coppice stools: key microhabitats

In general, coppice forests do not contain a lot of lying deadwood owing to the intensity of the management practice. However, the lack of this type of deadwood is partially overcompensated by the high volumes of crown deadwood in living oaks: up to 20 m³/ha were measured on old trees in coppice with standards forests (Müller *et al.* 2004). Another important microhabitat are the living coppice stools that can be up to 100 years old. Interestingly, the coppice stools mostly do not resprout from the stool itself (fig. C 32.5a), but rather produce 'suckers' from the roots (fig. C 32.5b), even when the stools were considered to be dead. The same phenomenon has been observed on the stump of a 140-year-old standard oak, felled in May 2016. The reproduction from the roots through polycormonal cloning is well known from aspen and wild service tree *(Sorbus torminalis),* but already in 1889 Gayer mentioned that this also plays an important role for oaks and hornbeam *(Carpinus betulus).*

These stools provide a habitat complex consisting of multiple structures such as living and dead tissue, mycelium covered wood and small cavities. As an example, the stag beetle *(Lucanus cervus)* occurs in stable and abundant local populations in Bad Windsheim, its larvae develop in the dead roots of living coppice stools. Also, the smallest and rarest lucanid beetle of central Europe *Aesalus scarabaeoides* (fig. C 32.6) can be found in the coppice with standard forests, one of only three known locations in Bavaria.

While most xero-thermophilous species can also use smaller structures to breed, some threatened species are more dependent on large veteran trees with more complex habitat structures. Such trees are rare to absent owing to the past manage-

Fig. C 32.5. (a) Classic oak coppice sprouting from sleeping buds directly from the stool. (b) Five-year-old 'suckers' from the root with faster height growth than the coppice shoots from the stool (Photo: Heinz Bußler).

Fig. C32.6. *Aesalus scarabaeoides* (Photo: Heinz Bußler).

ment practices and could only be found in adjacent pasture forests with longer habitat tradition.

Among the most common species found in the coppice stools is *Synanthedon vespiformis,* a moth of the Sesiidae family (fig. C32.7). This species is mostly dependant on cankers developing on large oaks, but can use oak stools as an alternative habitat. The caterpillar develops in the bark of the stools (Blum 1997).

Insect diversity – not a threat to oak vitality!

Although *Agrilus biguttatus* is the most common beetle found in the stools there is no relation between the presence of the species and the mortality of single stools. The highest average number of *A. biguttatus* individuals per stool was even observed in 'extraordinarily vital' shoots (Finnberg and Bußler 2019).

The presence of the two relatively large cerambycid beetles, *Rhagium sycophanta* and *Cerambyx scopolii,* in the coppice stools depends very much on the availability of large stools but has no influence on their mortality. It is remarkable that

Fig. C32.7. Colourful and common, but largely unknown: *Synanthedon vespiformis* (Photo: Heinz Bußler).

Fig. C 32.8. In 2016, gauze cages were used to protect oak stools from insect colonisation one year after the cut to investigate the effect of insects on oak mortality (Photo: Heinz Bußler).

both species can be found already only one year after the cut, since the time required for maturation of these beetles is usually known to be at least two to three years (Bense 1995). The shortened development time may be a consequence of global warming; the average annual temperature in this area is over 10 °C nowadays, and the extended warm period enables a shorter development cycle for these beetles.

A very different species assemblage from the coppice stools can be found on lying deadwood that has accumulated as a more recent measure to enrich the traditional coppicing practices: only 25 % of the species found on large logs and strong dead branches are also found on the oak stools. The most dominant species are usually the bark beetles *Scolytus intricatus* and *Xyleborinus saxeseni.* Interestingly *Agrilus biguttatus* is rarely found on the lying deadwood. The reason for that may be that the breeding places in the bark are often already occupied by larvae of e.g. *Plagionotus arcuatus, P. detritus* (fig. C 32.9), *Xylotrechus antilope,* and *Cerambyx scopolii.*

Conclusion

Despite the presence of almost all forest pest species that are known to contribute to the phenomenon of oak decline, there has been no increase in tree mortality in the coppice with standards forests in Bad Windsheim. However, the very open stands and the additional enrichment with oak deadwood has often created negative reactions from visitors. Often they regard this management practice as too radical. Very often the prevailing opinion is that the only way to maintain or increase biodiversity levels is to set forest aside from management. Here we argue that the practice of coppicing with retained standards is necessary to preserve species that lack their original natural habitat such as floodplain forests, but also to preserve the richness of trees and shrubs. Additionally, to setting aside forests from management we urgently need a discussion about dynamics in forest ecosystems!

Fig. C32.9 Adult *Plagionotus detritus* on an oak log. The larvae of this species often compete for breeding sites with the two-spotted oak borer *(Agrilus biguttatus),* a pest of oak (Photo: Heinz Bußler).

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Box C20

Large carnivores and forest habitats: what can we learn from the Naliboki Forest?

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The Naliboki Forest is a vast swamp forest along the River Biarezina located in the hemiboreal zone of central-western Belarus. This transitional zone between boreal and temperate climates supports high levels of biodiversity with a great range of European species of flora and fauna, including the large carnivores, such as grey wolf *(Canis lupus),* lynx *(Lynx lynx)* and bear *(Ursus arctos).* Approximately half of Naliboki Forest is protected as a landscape reserve with legal restrictions on hunting. However, hunting is allowed in large areas surrounding the reserve and wolves are persecuted each winter. In such vast forested areas, the large carnivores often come into contact with humans and forestry. Of these species, especially wolves have settled quite successfully into the European cultural landscape. They use and habituate to the structures provided by forestry very effectively, but they also need an (irregular) mosaic of natural succession within the managed area to find sufficient food and places to retreat for denning and raising their pups. Thus, it is important to consider these aspects of the animal behaviour and ecology when managing forests.

There has been extensive research carried out in Naliboki Forest for many years on how large carnivores use their forest habitat, and how they are affected by different forestry measures. In the past, different methods of investigation (from telemetry studies of lynxes to autopsies of wolves) have been used to study wolves and lynxes and their interactions within the ecosystem. Today, mainly non-invasive methods (e.g. habitat inspections, snow-tracking, reading of activity signs, and camera traps) are used to examine the ecology and behaviour of these animals. The findings from these studies have

Fig. 1. (a) canal system created by beaver dams; (b) typical birch forest in autumn; (c) spruce forest with tree falls; (d) typical swamp forest (Photos: Vadim Sidorovich, Maximilian Hetzer).

paved the way for unprecedented investigation of behaviour and ecology of lynxes and wolves. In this box we share some insights for forest enterprises and forest owners in other parts of Europe where wolves and lynxes are reclaiming their territories after decades of absence, and where practical knowledge of their management is limited.

The Naliboki Forest is made up of mostly flat lowland terrain interspersed with larger or smaller complexes of sand dunes. In total, Naliboki Forest and its surroundings cover an area of 2750 km², of which approximately 1900 km² are densely forested. Coniferous and small-leaved broadleaved trees predominate: Scots pine *(Pinus sylvestris)* stands can be found on 40 % of the area and black alder *(Alnus glutinosa)* swamp forests are found on 27 %. Only 7 % of the forests are older than 80–100 years, and only 1 % are broadleaved old-growth stands with an age between 200–400 years. The river density is about 0.9 km/km² and there are many canals (about 2–9 km/km²). The typical forest management practices are clearcuts, creating a mosaic of clearfelled areas of between 3 % to 7 % over the whole terrain (see figs 1). Usually there are a lot of logging remains or rotten log piles on the cutting areas. Additionally, there are often a lot of fallen trees around such clearcuts. Tree fall is also quite a widespread phenomenon in the swamp areas. Such tree falls can occupy an area of several hectares. Usually these groups of fallen or inclined trees stay untouched by forestry measures and are naturally overgrown by the regenerating forest.

The importance of the forest habitat: Denning behaviour of wolves

Wolves are able to adapt and live near human settlements or managed forest just as they are able to inhabit forests that they are not used to. They do not have particularly high demands of the forest, or other environments that they live in. Therefore, the structure of the forest is not a decisive factor determining the distribution of wolves in a specific area. A more important factor is the supply of prey and territorial space for the settlement of wolf packs and safe shelter places for denning and raising pups. Counting wolf pups is a very effective method for the study of the breeding behaviour of grey wolves. Over the years, more than 75 dens with healthy pups have been found. The denning behaviour of the wolves is strongly affected by the environment. This means that wolves often change locations and adjust their behaviour according to the environment; there are no particular 'rules' or 'normal features' of favoured wolf habitat.

The Naliboki wolves locate their den close to the main roads in the area in which they breed. The parent wolves need to know what people do in the area by monitoring human activities from the den or nearby. Furthermore, the roads provide convenient routes for parent wolves to access hunting areas and bring the food back to the den. Marking of borders of the denning area on the road also seems to be important for the parent wolves. In addition, roads and other paved paths offer convenient and quick routes back to the den. Nevertheless, that does not mean that wolves like breeding close to busy roads. The parent wolves were observed to check on the roads up to 60 times a day. Another important consideration is that wolves from outside the area use roads and forestry tracks to enter the territory and denning areas.

Suitable wolf denning areas include: areas with a large amount of tree fall; thickets with many uprooted trees (especially spruce); abandoned thickets in logging areas with a lot of tree stumps and logs; abandoned peat cuttings; and sand dunes with young pines and small openings. Tree falls and logging areas are used by wolves after giving birth. We found that from July to September, about 30 % of the wolf family home range habitats (n=135) were in areas with fallen trees in old spruce forests (fig. 2).

For denning of wolves, it is important that the dens are well sheltered from attacks by other predators like lynx or brown bears. Additionally, large ungulates like red deer *(Cervus elaphus),* elk *(Alces alces)* and European bison *(Bison bonasus)* can be a threat to wolf cubs: especially red deer stags have been repeatedly observed attacking and killing wolf cubs (fig. 3). Other important aspects in wolf denning include: a rather low occurrence of mosquitoes, good views of the surroundings, and good shelter for the pups and parents from the weather.

During the denning period it is important to distinguish 'breeders' from 'non-breeders' (i.e. the yearling wolves). The pattern of track trails left by 'non-breeders' is likely to be more random or absent. Furthermore, the 'non-breeders' carry and leave useless things like human rubbish (rubber boots, plastic bottles) and they collect and gnaw on ungulate bones and antlers.

Fig. 2. (a) typical denning habitat of wolves; (b) young wolves in late summer at a treefall; (c) wolf pups under an uprooted tree; (d) wolf on a forestry road (Photos: Vadim Sidorovich, Maximilian Hetzer).

Fig. 3. (a) red deer stag checking on wolf den with pups; (b) wolf cubs killed by red deer (Photos: Maximilian Hetzer).

Lynx – a deep interaction with wild forests and trees

Tree falls, and especially inclined trees leaning against other trees and thickets, are very important for lynx ecology and behaviour. In mid-autumn, male lynxes start searching for, and guarding, suitable habitats for mating and rearing young in their home range. These habitats should have a low density of large ungulates and provide shelter against possible wolf attacks. Suitable den sites include spruce thickets and rotten trees or tree falls with several layers (figs 4). In the home range of a mating lynx pair there must be a few (3–5) of these sheltered sites. During mating, the mother leaves

Fig. 4. (a) Mating lynx pair in a spruce thicket; b) young lynxes in their homesite; (c) lynx kittens under a root plate of an uprooted tree; (d) pregnant female lynx checking a former wolf burrow as a potential denning site (Photos: Vadim Sidorovich, Maximilian Hetzer).

the new kittens in such sites to keep them safe. These sheltered spots are guarded by male lynxes with frequent visits and intensive scent-marking in a large area (several kilometres in diameter). Within the home range of an adult male lynx there may be several 'house areas' (distinct patches of the home range of a lynx containing several such mating spots and dens). These house areas can be relatively poor in prey (in Naliboki, 14 out of 24 house areas had relatively low densities of potential prey), as the male chooses the winter house area mainly for the quality of shelter, rather than the availability of prey. At the mating spots, male lynxes choose elevated positions and often climb tall trees to call for mates. During the mating season, adult females seem to actively search for adult males with suitable house areas and mating spots.

In mountainous or rocky regions, it is known that female lynxes usually create lairs in cavities between rocks. In contrast, very little is known about lynx denning in forests in non-rocky areas. Our research shows that there is a relation between the presence/absence of badgers *(Meles meles)* and den selection by lynx in Belarus. In some areas, lynx give birth, and raise their kittens in the early post-natal stage in former wolf burrows, abandoned badger setts, or beaver burrow networks. In other areas, where the badger population density is high and most burrows are occupied by badgers, lynx dens are more often situated in tree fall areas. The kittens are hidden under the compressed remains from logging or in the spaces where spruce trees fall on other large spruces so that a sheltered platform is created. A tree fall consisting of several large fallen spruce trees, with one crown laying down on the top of the other creates a favourable shelter underneath the compressed green spruce branches where mother lynxes can safely leave their kittens. Under this thick layer of spruce branches, kittens are well protected from rain and mosquitoes. The compressed remains left after logging can provide a similar kind of shelter.

From May until June 2018, we discovered three lynx dens in Naliboki Forest during 40 days of obser-

Fig. 5. Lynx family playground and sheltered place on an abandoned log pile (Photo: Maximilian Hetzer).

vation; two were found in tree falls and one was found under an abandoned/rotten log pile in a boggy pine stand with dense *Ledum palustre* (syn. *Rhododendron tomentosum* subsp. *tomentosum*) shrub cover. Later, the kittens were hidden by their mothers under piles of logs that were abandoned by loggers on the clearcut (fig. 5). We found remains of three different roe deer *(Capreolus capreolus)* that had been eaten by the lynxes on the log piles. So, on the one hand, the log piles provided a sheltered place for the kittens while the mother is hunting, and on the other hand a safe place to eat the prey that was brought by the mother.

Out of 11 lynx dens, in two cases lynx kittens were discovered on raised platforms where one spruce tree had fallen against another large spruce. The kittens were found at a height of 5–7 m on platforms formed by the spruce branches. Three other types of dens connected with trees were distinguished: a closed cavity of a root plate of an uprooted tree; a lair under the green crowns of recently fallen spruces; and the remains of a large tree fall overgrown with dense vegetation.

The role of trees in hunting by lynx is very important. In the warm season, when there are plenty of mosquitoes in Belarus, lynxes prefer to wait and watch for their prey from trees (at heights from 3 to 10 m above ground, where the mosquitoes are less numerous). Amongst 54 known lynx ambush sites on trees, most (78 %) had similar characteristics: a tree trunk (usually spruce with a dense

Fig. 6. Lynxes regularly use tree trunks for ambush hunting (Photo: Maximilian Hetzer).

crown) that was inclined against another tree. The ambush sites in trees were mainly situated along prey pathways (91 %). The lynxes mainly used these ambush sites during the snowless periods, they could wait and watch in these sites for long periods (fig. 6). The longest time we observed a lynx staying at one point was 32 hours. At a rough estimate, during the warm season lynxes may spend about 90 % of the hunting time waiting and watching for prey from tree ambush sites; during this period lynxes almost completely stop more active methods of hunting (patrolling and stalking), when mosquitoes become numerous.

In Belarus, lynxes have quite often been observed in concrete road drains. In the warm season, they mainly use road drains without running water. In winter, when the temperature is below 0 °C, almost all drains that are large enough are used by lynxes.

We investigated this use of road drains and identified four different uses (fig. 7):

1 Road drains are often something that visually stand out from the habitat structure of the forest road. Such spots are often marked by carnivores, including lynxes. Snow-tracking data suggest that about 90 % of visits to road drains by lynxes (more than 200 cases were observed) were, at least, partly for territorial marking.
2 In approximately 60 % of the cases, lynxes were observed walking, hidden in the road–forest ecotone, then they use the road drains to surprise possible prey. On one occasion a lynx was observed to have killed a roe deer close to a drain entrance. On another occasion a raccoon dog *(Nyctereutes procyonoides)* was killed by a lynx using such an approach.
3 During rainy weather or wet snow, lynxes have been observed using the drains to dry out and shelter from the weather (17 observations).
4 Sometimes the lynxes even rest inside the drains (5 observations at least). On two of the five occasions, the lynx may have been waiting and watching for prey at the same time; on these occasions the lynx stayed for a long time in the drain (7 to 11 hours). While inside the road drain, the lynxes use the sand or the dry remains of vegetation to rest on.

Fig. 7. Lynx entering a concrete road drain (Photo: Maximilian Hetzer).

Marking behaviour and competition between large carnivores

Wolves and lynxes are territorial carnivores that typically use visual- and scent-marking to delimit their territory. Crossings on forestry roads, root plates of fallen trees, forestry poles, or essentially anything that protrudes from its surroundings are often marked. Forestry roads are popular routes for marking by wolves and lynxes. The analysis of our snow-tracking data shows that wolves use such roads in about 60–80 % of marking events. The intensity of marking varies over the course of the year. For instance, during the mating season wolves mark up to 60 times within 24 hours. In comparison, during denning wolves only use 2–3 marking points, mostly along forestry roads. When marking their territory, male lynx can walk approximately 15–40 km and place 5–20 territorial marks per kilometre. The intensity of scent-marking remains more-or-less constant over the year; however, there

Fig. 8. (a) typical scratch marks on a road by wolves; (b) lynx hair after marking on a root plate; (c) lynxes marking on a forestry pole; (d) wolf aggressively gnawing on the same pole; (e) female wolf in front of her den with pups inside; (f) lynx leaving the same burrow den after having killed the litter (Photos: Vadim Sidorovich, Maximilian Hetzer).

is a two-fold increase in marking before the mating season in mid-February.

However, marking is not only done to delimit the territory. More specifically, marking behaviour is also an indicator of wolves and lynxes sharing the same habitat. For example, wolves start erasing lynx marking points. In more than 1000 km of lynx snow-tracking, we found cases in which wolves start to 'over mark' lynx marking points but never vice versa. Another example of erasing lynx marking points was documented by a camera trap: a male wolf started to gnaw a forestry pole (fig. 8d) which had been marked by different lynxes in numerous ways (urinating, scratching, and rubbing).

We found that lynxes can have a deep impact on reproduction, pack composition, and immigration/emigration of wolves: lynxes were repeatedly documented to target wolf dens and kill the wolf pups. This behaviour is so effective that wolf reproduction can decrease to zero over several years, although the adult wolf population is still relatively high. As a consequence, in Naliboki wolf packs lack the typical family structure and consist largely of only adult animals. However, wolves were also observed to be able to react to such situations by more carefully selecting protected dens, changing denning habitats, but also by 'multiple breeding' (while it is normally only the alpha pair in a pack that breed, other wolves in the Naliboki group have also produced offspring). The pack has also been observed to use 'pup sitters' (i.e. wolves that are not the mother or father) to guard the pups.

Conclusions

Even in vast forest landscapes, like in Belarus, large carnivores are always in contact with humans; this is especially true for forestry work. Wolves have settled quite successfully into the European cultural landscape. For both lynxes and wolves, it is crucial to have sufficient food and places to retreat for denning and to raise their young. To a certain extent, these species can modify their behaviour, and adapt to the available habitats very effectively. However, they do require a range of sites for different purposes (giving birth, rearing young, shelter from the weather, hunting), and it is important to manage the forests irregularly so that the full range of such sites is available. Foresters have to learn to forget the 'Prussian cleanliness' and delight in the wilderness of nature.

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View into a forest landscape in lower Austria with dominant mixed broadleaved forests with some conifer plantations with Norway spruce and European larch. Integrated forest management promotes timber production and at the same time a high biodiversity value resulting in an attractive landscape (Photo: Andreas Rigling, WSL).

Synthesis: Improving biodiversity conservation in European managed forests needs pragmatic, courageous, and regionally-rooted management approaches

D

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Preamble from the authors

There is an ethical obligation to protect the biodiversity of our planet and make an important contribution to the promotion of biodiversity in our European forests.

We also have a societal obligation to cover our own wood consumption in Europe in a sustainable and regional way. We should not rely on satisfying our wood demands in less well protected forests elsewhere, but rather ensure that we can sustainably produce wood from our European forests.

The use of the sustainably produced and renewable resource wood instead of energy-intensive materials such as concrete and steel will result in substantial substitution effects. Wood use will thus be important for reducing our carbon footprint, and hence, contribute to climate change mitigation.

In times of climate change, increasing diversity is the order of the day. The promotion of biodiversity and the design/provision of resilient forests can provide the common basis for synergies between the provision of the full range of forest products and services.

Growing human population and changes in demography and lifestyle result in increasing global demand for multiple forest goods and services. Besides wood and biodiversity, those include non-wood forest products, recreation, protection against natural hazards and erosion, and clean water. The provisioning of such goods and services will be of paramount importance for the well-being of societies today and in the future.

Introduction

We are currently confronted with a myriad of topics that concern European and global forests. These topics are addressed by a wide range of stakeholders and interest groups, all with their own demands and agendas. When the first discussions about this book production took place in 2016, the framework conditions were actually quite different from today: the modern concept of integrated forest management as presented by Kraus and Krumm (2013) was the starting point. Kraus and Krumm presented the basic guidelines of the concept on how biodiversity conservation and wood production could be combined in a given forest area. The concept was well received and as a consequence it was translated from English into German and French to reach a wider audience, especially at the implementation level. Further initiatives addressing integrated forest management followed, including the set-up of the European Network Integrate. This network is an alliance of representatives of different European countries that promotes the integration of nature conservation into sustainable forest management at the policy, practice, and research level. The network encourages the exchange of successful management practices and experiences amongst its members, as well as the generation of science-based knowledge as input to policy debates and processes. The work of the network is also supported by project activities. The InForMar[1] project, for example, aimed at improving the understanding of ecological, socio-political, and economic drivers of integrated forest management. The results provided input to the formulation of a set of policy relevant conclusions which support outlining a favourable socio-political framework for integrated forest management in Europe. In close connection to these initiatives, a need was expressed to compile a book that not only further analyses the ecological and socio-economic framework conditions, but also provides an extensive collection of good practice examples from across Europe, showing where a form of inte-

[1] https://integratenetwork.org

grated forest management has already been successfully applied.

Despite biodiversity promotion in managed forests already being an important topic in 2013 (Kraus and Krumm 2013), the discussion about the global biodiversity crisis has intensified in recent years (IPBES 2019). Even though an increase of climatic extremes has been predicted for the coming decades (IPCC 2019), the intensity and spatial extent of what has occurred to date has exceeded the predictions. Parts of northern and southern Europe were strongly affected by severe droughts in 2016 and 2017 (García-Herrera *et al.* 2019). The extensive heat and drought in summer 2018 was epochal for large areas from the Alps to Scandinavia. This was followed by supra-regional extreme dry periods in 2019 and also in 2020. The forests in large parts of Europe have been badly affected by these consecutive events, and the condition of the forest deteriorated on a large scale, followed by unprecedented tree mortality. Following droughts, there have been reports of record bark beetle *(Ips typographus)* infestations in Norway spruce *(Picea abies)* (Schuldt *et al.* 2020). However, even supposedly more robust tree species such as European beech *(Fagus sylvatica)* and silver fir *(Abies alba)* have been affected by the drought conditions over large areas (Schuldt *et al.* 2020). All these developments had not yet occurred when starting the work on this book; hence, relatively little consideration was given to them in the case studies. Today, almost five years later, it is obvious that, in addition to forest fires and storms, other large-scale disturbances such as biotic threats and climatic extremes can change our forests within a very short time (Batllori *et al.* 2020), and in such a way that current forest management approaches become difficult to conceive and justify, especially as climate change scenarios assume that these trends are likely to become even more severe in the future (IPCC 2019). It is, therefore, obvious that such severe biotic and abiotic extreme events need to be considered in the planning of our future forests so we can ensure they provide all desired goods and services, including biodiversity. However, what will the forests of the future look like and which goods and services will they still be able to provide? How can we steer the forest succession to support a desired development? Will we still want to produce wood as renewable natural resource regionally and sustainably in 100 years in Europe, and thus contribute to satisfying the global demand for wood? Will we want, in this way, to contribute to reducing the pressure on other forest ecosystems in other continents? How should biodiversity in our future forests be maintained and promoted so they can continue to play an important role as biodiversity hotspots? How will biodiversity in our forests be affected if we assume that tree species composition is altered as a consequence of impacts of climate change and also introduced new species?

In this synthesis we have compiled the main messages arising from the different chapters. We draw conclusions and reflect on follow-up developments, activities, and implications for European forest policy. We also highlight the most important take-home messages derived from the theoretical contributions (chapter B), the diverse good practice examples (chapter C), and the box contributions. In addition, this synthesis chapter is partly based on a working paper of the European Network Integrate (Winkel 2020).

Ecological and historical boundary conditions and societal framing of forest management to supply multiple goods and services, including biodiversity

The contributions in chapter B present the broad variety of boundary conditions and influential drivers of forest management including biodiversity conservation in European forests. There is a multitude of societal demands from forests, ranging from those for wood and non-wood forest products for the bioeconomy to the essential importance of forests as habitats, and for climate mitigation, recreation, protection of human infrastructure, and public health. The need to balance these partially competing demands makes management decisions highly complex and multifaceted, and hence, a holistic and differentiated view is needed that considers all different and relevant aspects across sectors and interest groups. Considering the European focus of this book it is evident that stable and predictable framework conditions need to be provided at a continental level that nonetheless respect national forest management traditions and regulatory approaches. At the same time, it is clear that when developing integrated forest management concepts, not only local environmental and societal peculiarities should be considered but also their his-

torical origins. These often multifaceted starting points make clear that improving biodiversity conservation in Europe's managed forests will only be successful if pragmatic, courageous, and regionally-rooted management approaches are developed and applied. Given this, forest management still takes place in a highly complex framework with repercussions at different spatial scales and decision levels. Not all driving factors can be steered or influenced by management at the enterprise level. Many of the factors are also affected by interest groups and their demand for goods and services, the consumer behaviour, as well as the higher-level policies. In the long-term, observable continuous changes such as the steadily increasing temperatures or land-use changes, including hunting regimes (chapter B 7), not only affect forest management but also impact markets and consumer behaviour, and thus require anticipatory action.

Disturbances or extreme climatic events (droughts, heat waves) can have sudden and fundamental impacts on ecosystem functioning, on all forest goods and services, and directly on the economics of the forest enterprises (Thom and Seidl 2015). These factors cannot be controlled, but they still need to be considered when aiming to steer the forests to becoming more resilient to climate change in the long term. Moreover, post-disturbance management is important to promote forest restructuring and transformation.

The following paragraphs synthesise the state, the challenges, and the promises of an integrated management approach for biodiversity conservation.

1) European forests are largely shaped by their cultural heritage resulting in a high regional diversity

Forests in Europe are characterised by their cultural heritage over thousands of years and only small remnants of primary forests are left (fig. D 1). The majority of the European forests is in a semi-natural state regarding tree species composition and forest structures. The forests are characterised by local land use and forest management reflecting the natural template and ownership structures (chapter B 4). The interplay of societal needs, related human management, and natural processes has impacted the forests and generated specific biodiversity features that are valuable from a conservation perspective. Hence, when answering the fundamental question of which type of biodiversity should be aspired to (chapter B 8) targeted integrated forest management should be considered. However, integrated forest management is not a universal solution and needs contextual application. On the one hand, European forests are highly diverse ranging from boreal forests in the North to Mediterranean forests in the South, from mountain forests to lowland forests, and from forests growing on rich soils to forests growing on degraded and poor soils. On the other hand, forest management regimes and intensity vary greatly, from intense plantation forestry (e.g. C 12, C 13, C 15, C 18, Box C 9), to multipurpose forestry with different management intensities (e.g. C 1–C 5, C 27), and to low intensity management (e.g. C 25, C 31). The management approaches vary from region to region and from enterprise to enterprise. As nicely illustrated by the good practice examples (C 1–C 32), this variety depends on management objectives set by individual forest owners, biophysical conditions, socio-economic demand, and resources available for management. Both the biophysical boundary conditions and the socio-economy are important for context dependent and locally rooted integrated forest management approaches (chapters B 3, B 4).

2) The need for a differentiated view on wood production and biodiversity conservation

Management schemes that are strictly oriented towards wood production can have negative effects on forest biodiversity (chapter B 1); in such schemes old-growth structures, deadwood, and natural forest dynamics are often diminished and soil functioning can be negatively impacted (chapter B 1). However, forest management can also have positive impacts on conservation-related objectives, for example by creating more diverse forest structures, by increasing tree species and genetic diversity, or by traditional management regimes such as coppicing and different active conservation and habitat management measures (chapters B 1, B 2). The good practice examples clearly demonstrate that forest management needs to actively include biodiversity conservation aspects (e.g. by increasing tree species diversity, retaining old-growth structures and deadwood in stands (fig. D 2), or moving from clearcutting to single-tree or small-scale cuttings); this might require compromises with other management objectives. However, such measures to

Fig. D 1. Large diameter deadwood, such as this silver fir in the primary forest of Sinca (Romania), are valuable resources for many species. This is still a rare element in managed forests and should be widely promoted (Photo: Andreas Rigling).

promote biodiversity also have the potential to increase the resilience of our forests to secure other demanded goods and services including wood and biomass under climate change. Hence, they have a great potential for synergies and this is an important argument to support integrated management approaches (chapter B 9) for the promotion of a sustainable wood-based bioeconomy balancing increased wood demands and other urgently needed ecosystem services including biodiversity (chapter B 5).

3) Societal expectations towards provisioning of forest goods and services

The characteristic that many European citizens appreciate most about forests is for 'being nature'. The most valued ecosystem services for the broad society are the recreational opportunities, biodiversity conservation and the positive effects of forest for the local and global climate. This is also reflected in several case studies throughout the book (e.g. C 4, C 5, C 18, C 20, C 28, C 30). Wood is also seen positively as a renewable natural resource. This view is, however, combined with the expectation that management of forests is carried out in a sustainable way. Many landowners also give high priority to more than one objective for their forest, and multipurpose forestry is performed on large parts of the public owned lands all over Europe, often with consideration for nature conservation. Thus, policies to increase environmental values of forests can build upon general support of the European population that is also, at least partially, mirrored by the priorities of forest owners and forest managers. There is, however, a necessity to improve communication between forest and conservation managers and the population concerning the possibilities of integrative forest management. Such approaches can combine the provision of multiple ecosystem services and allow both the use of wood as a renewa-

Fig. D 2. Preserving habitat trees in large-scale monocultures might be an initial, but minimum, measure to promote biodiversity. Habitat trees can act as 'stepping stones' to connect further measures such as old-growth islands, deadwood, canopy openings, and forest reserves. How effective such measures are depends on their frequency and spatial distribution, and on how well they are connected to the other measures and biodiversity elements. The photo shows a gnarled beech with a broad, irregular crown in the middle of a Norway spruce plantation in the Eifel mountains in North Rhine-Westphalia (Germany) (Photo: Andreas Rigling).

ble resource and the promotion of biodiversity. There is a general understanding that forestry is not just wood extraction from ecosystems, but also the responsible management of forest resources to respond to the demands of European societies.

At the same time, it is important that conditions are established that allow landowners and forest managers to align their own preferences (with respect to economic expectations) with the societal demands (e.g. with respect to nature conservation). The successful balancing of these needs and demands (fig. D 3) is needed to achieve sustainable resource production for the bioeconomy (chapters B 4, B 5). This is also true for hunting, which has developed in some regions from a 'right of the nobility' to a necessary and fundamental task of forest management – today it must be seen as an ecosystem service, often requested by non-professional hunters who have specific expectations that potentially create conflicts with forest managers and conservationists. Hence, alternative concepts and solutions are needed that promote a dialogue and possibly strengthen synergies between these interest groups (chapters B 7 and C 27).

4) Climate change adaptation means increasing the diversity of our forests in all respects as a measure for risk distribution

Climate change is increasingly affecting European forests, mainly through the growing impacts of disturbances such as storms, pests and pathogens, forest fires, and extreme heat and drought (chapter B 9). Whereas economic damage has been caused in the past particularly in monocultures with species planted outside of their natural range, climate change is increasingly affecting also native forest trees and stands (Hanewinkel *et al.* 2013; Schuldt *et al.* 2020). The impacts of climate change are increasingly affecting both the ecology of forests and the economics of their management, and will probably do even more so in the future (chapter B 6) (fig. D 4). On the forest management side, adaptation strategies such as the promotion of mixed stands, increasing genetic diversity of trees,

Fig. D 3. Forests, water surfaces, agricultural land, and settled areas are typical elements of European landscapes. The management in such mosaic landscapes should not stop at the edge of the forest patches. Hence, integrative forest management could be taken as a model for holistic biodiversity promotion for all landscape elements (Photo: Andreas Rigling).

and enhancing natural regeneration in case appropriate tree species can be used to incentivise natural adaptation. In addition, selection cuttings can be applied to keep the forest climate cool (Schwaab *et al.* 2020) and variable cutting approaches can be used to support a variety of microclimates and provide the structural basis for maintaining or increasing typical forest biodiversity. In contrast, forest management responses increasing the share of potentially better adapted non-native tree species, decreasing rotation periods to reduce risks, or applying pesticides to combat increasingly severe biogenic disturbances, can create new conflicts and trade-offs between biodiversity conservation and forest use. These conflicts can be minimised if such practices are not generally used but are rather applied with care and spatial and temporal restrictions. Overall, the increasing vulnerability of forests towards disturbances provides support for the arguments for integrative forest management approaches as high diversity in species and structures increases the resilience of forest ecosystems (chapter B 9). Higher diversity can be also seen as a kind of natural insurance and has thus an indirect economic value (chapter B 6). This widens the potential for synergies between conservation and other forest management goals compared to the past. Consequently, there will be further opportunities to adjust biodiversity conservation and other forest management goals in an integrated manner.

5) Biodiversity promotion may be expensive – it is worth something, but who should pay?

Forest management in Europe needs to be profitable or at least cover its costs in the long term. Furthermore, wood as an important natural resource in Europe is one key pillar for the sustainability transition of the European economy, including ensuring that Europe is largely self-sustaining in this area (chapter B 5). However, economic aspects (relating to either the demands coming from the wood market and/or the profitability of forestry) can be a critical factor decelerating or even inhibiting the implementation of integrative forest man-

Fig. D 4. The extensive drought period in 2018 caused massive damage in beech forests in many central European regions. This example from the Jura plateau in northwestern Switzerland illustrates the extent of the effects of climate change; the range and intensity of such effects has exceeded all expectations. There are immediate and long-term consequences for most forest goods and services, including biodiversity (Photo: Valentin Queloz).

Fig. D 5. This Tengmalm's owl *(Aegolius funereus)* is an example of a species with specific habitat requirements; a patchy land cover mosaic, including open forest structures, but also area of dense regeneration and disturbance. The presence of cavity trees is crucial; the cavities are often created by the black woodpecker *(Dryocopus martius).* Such specific requirements mean that targeted silvicultural interventions are needed, and this raises the question of who pays for such measures? (Photo: Frank Krumm).

Fig. D 6. Burned tropical rainforest in Bolivia transforming forests into agricultural land. Whereas primeval forests are considered worthless in many regions, conversion to agricultural land can yield short-term profits, through the sale of the harvested timber and also through subsequent agricultural production, such as cattle farming (Photo: Jürgen Bauhus).

agement. Conflicts with timber targets and financial goals might be thus one of the most important challenges to advance the integration of biodiversity measures in forest management (C 2). This calls for a further, transparent economic assessment of different strategies to integrate biodiversity conservation in managed forests, also in comparison to alternative, non-integrative strategies. Moreover, policy measures need to be developed and implemented that support forest managers and forest owners to deal with trade-offs (chapter B 4). It is, therefore, also crucial to calculate and communicate the true costs behind production, but also conservation (fig. D 5) (Boxes C 1, C 2, and C 3; C 27).

6) Integrated forest management: Europe's answer for a responsible and sustainable use of global forest resources

Beyond Europe, forests are also under pressure. Deforestation and forest degradation are major challenges in many tropical countries, resulting in alarming environmental impacts (fig. D 6). Among the most important consequences are the exacerbation of climate change, the increase in biodiversity loss, and the intensification of soil erosion. The various pressures on global forests require consideration of integrated forest management strategies from different perspectives. It is only with integrated forest management strategies that balance wood production and biodiversity conservation that a European 'wood autonomy' can be reached without compromising nature conservation goals in Europe. Integrated forest management aiming to connect biodiversity conservation and sustainable wood production may serve as a model specifically also for tropical forestry allowing both the use of the natural resource while maintaining their outstanding biodiversity. To be an effective and sustainable model for integrated forest management, appropriate policy instruments need to be developed and implemented that support European forest owners to adapt their management concepts. Such policy and management related concepts can then be communicated to other regions (chapter B 4).

7) Integrated approaches must interlink management and conservation in the forest and beyond

Integrated forest management approaches (Kraus and Krumm 2013) are not only 'technically' convincing, but also politically attractive and ethically compelling. They are expected to combine the many different and potentially conflicting goods and services that a forest can deliver and that society demands – from wood to recreation, from security against natural hazards to provision of berries and habitats for birds – be it in our own neighbourhoods or in protected forest areas elsewhere. If integrated forest biodiversity conservation approaches are to be advanced, it is of utmost importance to achieve a serious commitment across both the conservation and the forest sector to sincerely support integrative approaches in policy design, resources, and implementation. Considering our cultural landscapes and the many densely populated areas in Europe where different ecosystems and habitats are interwoven, such integrative approaches should be developed further from a more holistic perspective and should be applied at a landscape scale (fig. D 12). Moreover, also the interfaces to the neighbouring agricultural, water, and urban areas need to be included in a successful planning of biodiversity measures, which should not stop at the forest edge. Hence, integrated forest management should be postulated as a successful model for biodiversity promotion outside of the forest area in managed landscapes.

8) Integrating biodiversity conservation in forest management: learning from the many good practice examples

Finally, the variety of forest management approaches that have been developed by practitioners across Europe holds powerful potential. Close-to-nature forestry, 'Plenterwald', continuous cover forestry,

Fig. D 7. The great spotted woodpecker *(Dendrocopos major)* is the most common woodpecker species in European forests. Small diameter trees with nesting sites for the woodpeckers are, however, a rare element as the habitat value of small-diameter trees is underestimated and they are often removed in thinning operations (Photo: Ulrich Wasem).

reduced impact logging, and retention forestry – a rich and varied portfolio of management approaches that aim to achieve the integration of biodiversity conservation in forest production management has developed across Europe (see chapters C1–C32). This means there is a wealth of practical experience that is in many regards unique globally. Europe combines the legacy of partially historically grown 'close-to-nature' approaches with 'modern' concepts integrating biodiversity conservation measures, including segregation measures at different spatial scales, such as forest reserves or habitat trees (fig. D7). These approaches are informed by more than three decades of conservation research. Hence, the continent has many unique 'good practice' examples that can be drawn upon, concrete cases where integration is practised, in many cases well-grounded in the belief and passion of forest managers to work with rather than against nature. Combining both practical expertise and a supportive policy environment is the departure point for making integrated forest management that aligns conservation and production goals in Europe, a widespread reality.

Good practice examples of integrated forest management: A Tour d'Europe

This collection of good practice examples from across Europe (chapters C1–C32) compiles a diversity of approaches about how to improve nature conservation in managed forests. It is an impressive collection of innovative programmes, concepts, and attitudes from 19 European countries with highly varying environmental, societal, and legal conditions. Of course, there are many other interesting examples in the many different countries and regions that were not included or did not fit into this compilation. As each case is individual and highly regionally specific, the examples cannot be directly transferred from one local context to another. However, they can serve as examples of what is possible, and of what might be of interest in my own region – the presented cases should stimulate and motivate promotion of biodiversity in managed forests under highly varying conditions.

As described in the introduction and throughout section B, Europe can draw from rich traditions in land management, and especially in forest management. In other continents the discussions are very similar, and it is thus worthwhile to take a look at what is happening outside Europe, although scales, socio-cultural and political systems are most often not directly comparable. Understanding the consequences of production processes and their impacts is crucial for the evaluation of expected ecosystem services in forests. In particular, nature conservation is affected when demands for timber products are fulfilled across different continents. When we produce less forest products locally in Europe but consume the same amount or even more, the wood must come from elsewhere. This might result in unsustainable forest management in countries with weak institutions and low commitment to sustainable management. Even if the main focus of this book is on Europe, examples, experiences, and ideas from other continents are embedded with many box contributions, from North America (Boxes C11 and Box C12), South America (Box C8), Africa (Box C19), and Asia (Box C14). These contributions present a variety of interesting concepts from which we can learn.

Forest enterprises in Europe provide a variety of forest goods and services, which are, depending on the local conditions and needs, given different priorities (fig. D9). The first section of the practice examples reflects on enterprises with a very diverse portfolio in goods and services. These examples (C1–C5) are located in areas with generally favourable growing conditions for forests, with traditionally a main focus on valuable timber production for local people, markets, and industry. Auberive (C1), Ebrach (C2), and OAK Schwyz (Box C7) were temporarily owned and managed by monasteries in rather rural areas and have long management traditions, where e.g. coppicing with and without standards have traditionally provided fuelwood and construction timber. Kottenforst (C4) and Kandern (C5) are situated in highly diverse landscapes where rural, mountainous areas are mixed with proximity to highly urbanised areas, impressively showing how wood production, and increasingly also recreation, safety for important transportation routes, water retention, and biodiversity promotion can be simultaneously considered. The Kottenforst (C4) in the Upper Rhine Valley is characterised by immense recreation pressure since surrounding cities have grown together during the past decades. The recreation value, however, is derived from the historic forest management that is still

Fig. D 8. A typical forest stand in Sweden with a high value for the industry but also for aesthetics and recreation. This birch forest hosts a variety of typical species and is therefore also important for nature conservation (Photo: Daniel Kraus).

applied today producing highly valuable oak of large dimensions. These are crucial for biodiversity promotion as they comprise old 'methuselah' trees that are rich in tree microhabitats. Timber production is still important in the Danish Rold forest (C 3), but in parallel there are also efforts to promote biodiversity conservation by reintroducing disturbance agents – this is the result of an agreement between nature conservation, forest managers, and the society. These examples demonstrate how a long tradition in multiple services forestry with focus on timber production can be preserved but advanced towards biodiversity promotion in line with changing societal needs in densely populated areas.

In mountainous areas, priorities have shifted towards protection against natural hazards and, as a consequence, the life of the local society is directly dependent on the forests resulting in a traditionally stronger relation to the forests. Close-to-nature forest management is therefore deeply rooted in Pahernik (C 6) and Tamins (C 23), where the production of valuable timber is still a priority, within a matrix of forests managed with continuity and closeness to nature. Mountain areas are orographically highly heterogeneous and ecosystems change quickly within short distances creating highly diverse dynamic landscapes rich in species. The Piwniczna case in Poland (C 7) shows how the production of valuable timber and protection against natural hazards goes hand-in-hand with the promotion of rare large predators (grey wolf, lynx and brown bear). In Nyon-St.-Cergue (C 8) traditional management of forests and agricultural areas had resulted in an old cultural landscape where forests and pastures are intensively interwoven resulting in contrasting and species-rich habitats. This coexistence of forest and agriculture, combined with higher efforts and costs of respective management in mountain areas, has resulted in innovative associations applying old forms of integrated forest management. This is illustrated by the 'Osterwaldgesellschaft Eglofs' (C 10), the 'Grands Forêts de Hèches' (C 9) and the 'OAK Schwyz' (Box C 7) where local people strongly identify and are closely connected with their forests; local people place great value on the entire landscape including biodiversity. Biodiversity promotion occurs in these environments very much in parallel to the maintenance of their living environment based on long-term continuity and a profound understanding of local value chains that are significant to such organisations. Mountain forests and lowland forests differ in respect to their ecological and societal preconditions, and hence in their priorities for specific forest goods and services. Space and acceptance for local initiatives in order to maintain local value chains and cultural peculiarities are crucial to promote landscapes rich in biodiversity.

The cases C 11 to C 20 represent timber production forests with intensive forest management. They are highly different with respect to size and biogeographic location. Two practice examples are from Sweden: the state forest company Sveaskog (C 15) present their approach of establishing Ecoparks on 5–10 % of their managed forests with biodiversity and recreation as new priority services aside from wood production; and one of the Ecoparks, the private estate of Christinehof (C 11). This new and visionary approach arose because continuous forests and areas for biodiversity and recreation were widely missing in Sweden, a country where intensive use of forests is part of the culture, and the wood industry is an important pillar of the economy. In contrast to this large-scale approach, the Scottish private estate Dobie (C 12) puts the focus on regional plantation forestry for an explicit regional market combined with small-scale meas-

ures to promote biodiversity. The estate owned sawmill is an essential part of this very local forest enterprise promoting the local value chain. In the south of Europe, the situations in Portugal and Bulgaria are totally different. Coming from an intense management for eucalypt pulp and paper in the Companhia da Lezirias (C14) and for valuable conifer timber in the Rhodope mountains (C13), different elements to protect Natura 2000 and traditional forms of forest management were integrated into the management concepts, which led to significant improvements in biodiversity in intensive plantation forestry. In Woziwoda, in northern Poland (C18), the education of people and especially of children is an integral part of the work of forest managers. Within their highly productive pine forests, historical elements of forest management, such as beekeeping in forests, have been reintroduced. Because of an increasing awareness of missing links between humans and forests, ecosystem functioning and production processes are demonstrated and explained to the public. These examples show ways and measures to adapt intensive forest management in order to promote biodiversity and other important goods and services while still producing wood.

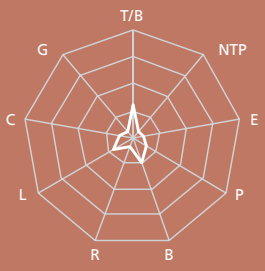
The cases from the Alps, namely the Susa Valley in northern Italy (C21), Langau (C22) in Austria, and Tamins in Switzerland (C23) showcase how mountain silviculture can combine protective issues with biodiversity promotion, touristic interests, and timber production. In Norway (C24), silvicultural systems that support more biodiversity do not yet have a long tradition, but are gaining importance as the clearcut rotation system applied is increasingly creating instability problems on the steep slopes, and has been identified to harm biodiversity. The example of the 'Fire Flocks' in Catalonia (C25) focuses on the prevention of large fire disturbances, which are dangerous for the local population and human infrastructure. The goats reduce fuel loads in forests, and although wildfires may occur to a minor extent they are less severe than they otherwise would be. The goats are also part of a local value chain and provide the local people with meat, cheese, and income, and additionally create important habitats for specific fauna and flora elements improving biodiversity. However, management to increase the safety and simultaneously also consider other goods and services including biodiversity is complex and costly, and acceptance of the management methods by the society cannot be taken for granted. Nevertheless, the protective functions of forests are crucial for people living in remote and often structurally weak areas, and provide the basis for maintaining local value chains and life in mountain areas.

Tourism and scenic beauty are services of increasing importance for modern societies. Especially in urban areas where noise, dust, pollution, heat, and traffic impact people, possibilities to retreat and recreate are increasingly requested. The Sonian Forest (C28), close to Brussels is a managed forest with a very large number of visitors per year (>5 million); these visitors arrive with the clear expectation to experience forest and biodiversity, and to find relief from urban life. Also, the Cairngorms National Park in Scotland (C26) protects a valuable landscape for biodiversity and also for touristic purposes applying targeted forest management. In the Serra de Llaberia (C29) a landscape management concept is applied where forests, vineyards, and rock formations create a highly attractive landscape for tourism. These specific practice examples with very clear priorities on specific goods and services highlight the need for targeted, integrated management.

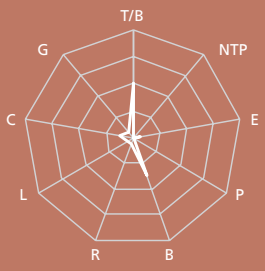
A more holistic approach of integrative forest management is applied to the regional level where the forests are understood as part of the landscape, including different habitats and special biotopes inside and outside the forest area. The cases of Amden (C30), the Black Forest National Park (C31), Bad Windsheim in Bavaria (C32), and Nyon-St.-Cergue (C8) are managed to promote species assemblages of landscape elements and management practices. Planning beyond forests, on a landscape level is clearly an issue and needs integrative thinking of all stakeholders. Especially for biodiversity issues, an overarching view is of central importance.

In all these practice examples, the provisioning of the desired forest goods and services including biodiversity is the result of a dynamic and targeted management applied at different spatial scales, with varying time horizons including temporary or unlimited protection of single trees or entire forest areas.

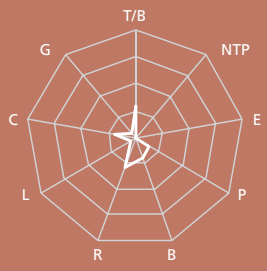
Case studies: an overview of ecosystem services rating



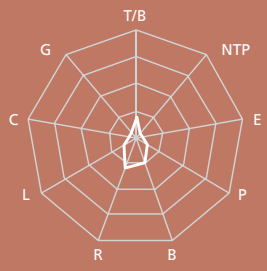
C 1: Auberive, France



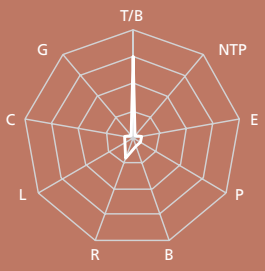
C 2: Ebrach, Germany



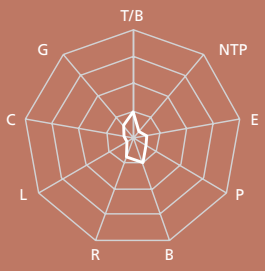
C 3: Rold Skov, Denmark



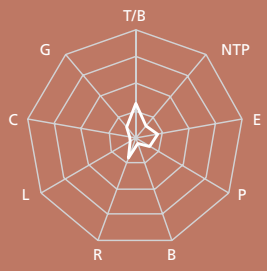
C 4: Kottenforst, Germany



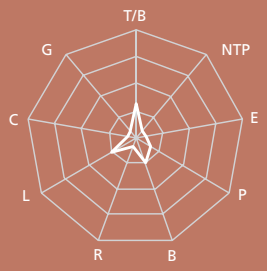
C 5: Kandern, Germany



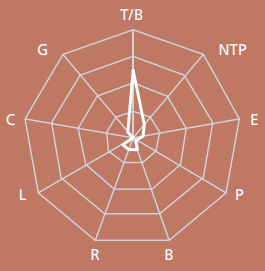
C 6: Pahernik, Slovenia



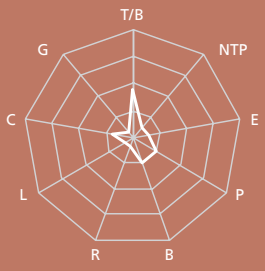
C 7: Piwniczna, Poland



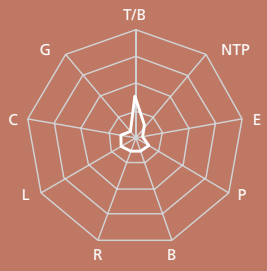
C 8: Nyon-St.-Cergue, Switzerland



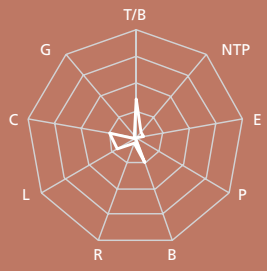
C 9: Hèches, France



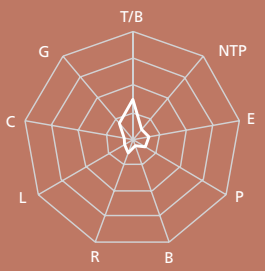
C 10: Osterwald Eglofs, Germany



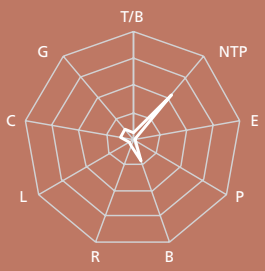
C 11: Christinehof-Högestad, Sweden



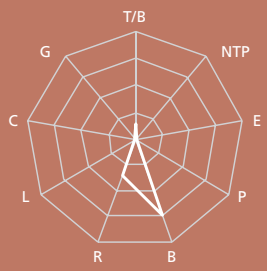
C 12: Dobie family, Scotland



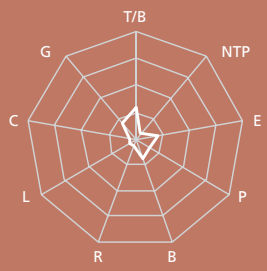
C 13: Dikchan, Bulgaria



C 14: Lezírias, Portugal



C 15: Ecoparks, Sweden



C 16: Kocanda, Czech Republic

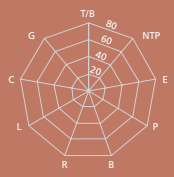
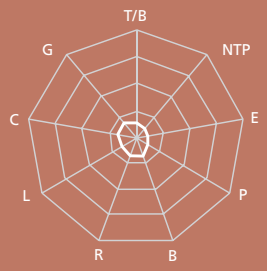
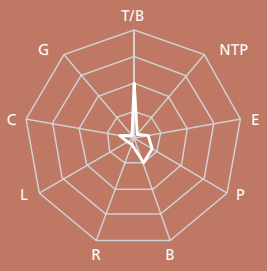


Chart legend:
T/B: Timber/Biomass
NTP: Non-timber products
E: Erosion
P: Protection
B: Biodiversity
R: Recreation
L: Landscape
C: Climate
G: Groundwater

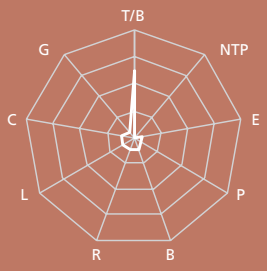
Relative investment in workpower and finances of the entreprise in different goods and services. Each line corresponds to a 20 % increase, from 0 to 80 %



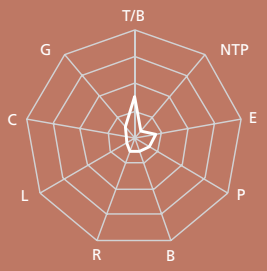
C 17: Ireland



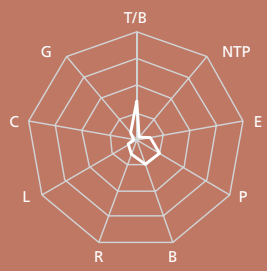
C 18: Woziwoda, Poland



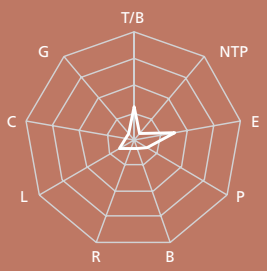
C 19: Poitschach, Austria



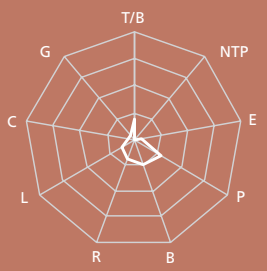
C 20: Zvolen, Slovakia



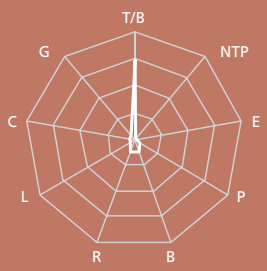
C 21: Valle di Susa, Italy



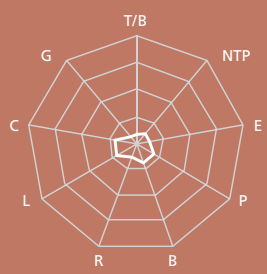
C 22 Langau, Austria



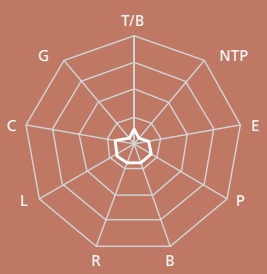
C 23: Tamins, Switzerland



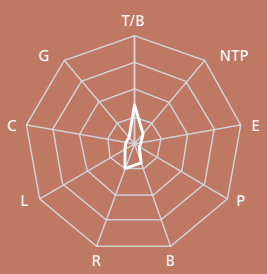
C 24: Vestland, Norway



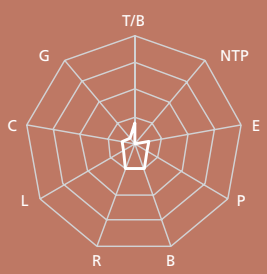
C 25: Girona, Spain



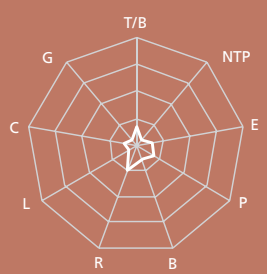
C 26: Cairngorms, Scotland



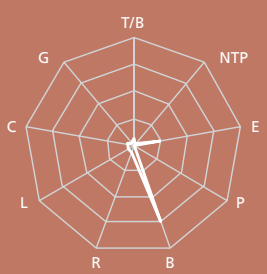
C 27: Bois Landry, France



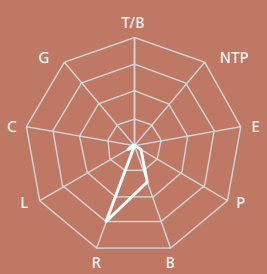
C 28: Sonian forests, Belgium



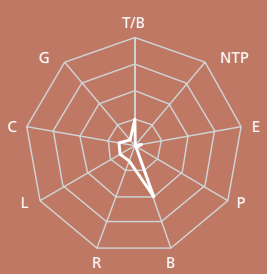
C 29: Serra de Llaberia, Spain



C 30: Amden, Switzerland



C 31: Black Forest NP, Germany



C 32: Bad Windsheim, Germany

The silvicultural toolbox of integrated forest management

The Tour d'Europe brings us through different biogeographic regions, countries, cultures, and forest management traditions. As a consequence, the collection of good practice examples presents an interesting list of individual and regional-specific approaches to the question: How can biodiversity conservation be improved in managed forests across Europe? All authors of the good practice examples were asked to indicate which measures and tools are applied to promote biodiversity integration into forest management in their corresponding enterprises. The measures are synthesised into a silvicultural toolbox (Tab. D 1) and are grouped into biological/ecological management tools and socio-economic tools. The biological/ecological tools are further grouped into separate sections indicating the spatial focus of the measures: (1) Landscape scale tools, (2) Tree- and deadwood-related tools, and (3) Species-related tools. Although the presented good practice examples show an expected great variety of different measures and tools, a surprising degree of agreement on certain measures can be observed.

Biological/ecological management tools

Landscape tools:

Forest reserves as a tool with significance at the landscape scale are widely applied in almost all of the presented examples as an important measure that allows for natural dynamics. Uneven-aged silviculture as a main principle of close-to-nature silviculture is applied in many countries in central Europe. However, this measure can also be applied in a variety of different contexts at different spatial scales to promote small-scale vertical and horizontal heterogeneity. The integration of disturbance-related processes in forest management is still rare although highly efficient (chapter B 1). Ebrach (C 2), Kandern (C 5), and Amden (C 30) leave single-tree windthrows and sometimes small-scale windthrows untouched. In Rold (C 4), disturbances by water-related dynamics (flooding, ice course) are welcome and even promoted as a part of the concept that should reinforce fauna and flora that is adapted to such a water-driven disturbance regime. The Danes are actively creating disturbed forest areas. The restoration of pasture systems as measures to promote specific and rare species compositions at the interface between forest and open land is practised in Nyon-St.-Cergue (C 8) and even in the strictly protected Black Forest National Park (C 31). Nevertheless, large disturbances such as fires, bark beetle infestations, and bigger windthrow areas are not yet accepted by society. However, there seems to be an ongoing shift in people's attitudes to such disturbances, as shown, for example, by the currently observed reaction to large-scale damage induced by disturbances all over Europe. The restoration of historic management regimes is also promoted in some cases as especially coppice with and without standards are known to create important habitats for many endangered forest species (e.g. C 1, C 2, C 32). The promotion of connecting elements is widely applied also in the presented examples in C 13, C 14, C 15 and C 16. The same is true for the use of natural regeneration; it should be applied whenever possible.

Tree- and deadwood-related tools:

The promotion and safeguarding of methuselah trees and old-growth elements is one of the most often applied tools. Almost all practice examples presented in this book protect and support big and old trees. The same is true for deadwood and the concept of protecting habitat trees. The active creation of habitat trees as a tool to promote biodiversity conservation is applied in some of the presented examples, although not yet systematically but rather on an occasional basis (C 2, C 16, C 19, C 29, C 33).

Species-related tools:

The promotion of genetic diversity often goes along with the replacement of non-native tree species and promotion of native species. The examples C 4, C 5, C 16, C 21, C 22, and C 28 have traditionally valuable genetic material and the stakeholders are investing not to lose this value. It needs to be questioned, however, whether the idea to conserve locally adapted populations or specific genetic variants on site is not too conservative in a period where climate change often requires assisted gene flow to promote evolutionary adaptation. Hunting and especially selective hunting aiming at securing or even promoting certain tree species, such as silver fir *(Abies alba)* or several broadleaved species, are of high importance especially in mountain forests (C 19, C 21, C 22, C 23) to ensure protective functions, but also in lowland forests to ensure native tree species composition (C 1–C 5). Promoting rare

Table D 1. Silvicultural toolbox, showing the different biological/ecological and socio-economic tools, clustered into different spatial scales of application.

Measures Category	Measures Level	Measure/Tool	Rationale and explanation
Biology/Ecology	Landscape	Forest reserves	Network of unmanaged forests as refuge and source areas for certain species.
		Uneven-aged silviculture	Promotion of small-scale vertical and horizontal structures.
		Disturbances	Use disturbances to initiate change. Accept the habitat created by disturbance events to increase biodiversity (e.g. deadwood).
		Promotion of processes leading to disturbances	Promote or indicate processes leading to disturbances (opening water ditches, drainages to stimulate species shifts and according processes).
		Connecting elements	Set aside small forest areas, special/rare biotopes, promote X habitat trees per hectare.
		Restoration of natural site conditions/ processes	Refer to natural conditions and the potential natural vegetation in tree species selection, open dams, close ditches, prescribed burning.
		Restore historic woodland pasture	Forest grazing, wood pastures.
		Restore historic forest management	Restore historical land-use practices that favour biodiversity (e.g. coppice, coppice with standards).
		Increase structural diversity	Promote elements that increase structural diversity – forest edges, forest roads, forests along river streams or ponds.
		Natural regeneration	Favour natural regeneration where possible.
	Tree and Dead-wood	Old trees (Methuselah trees)	Methuselah concept (e.g. retention of all trees with dbh > 80 cm).
		Habitat trees, retention and creation	Protect habitat trees and or artifically create habitat trees, by girdling, scratching bark/stems, injuring trees on purpose, creating habitats such as tree cavities.
		Deadwood	Leave dead trees standing/lying, old and deadwood concepts, leave cut crowns in the forest, actively create deadwood (e.g. high stumps).
	Species	Promotion of rare tree species	Retain/favour or plant rare tree species to increase tree species diversity or plant or favour particular species (*Quercus, Sorbus, Ulmus, Alnus,* etc.) which provide rare habitat.
		Increase tree species diversity	Plant or promote rare tree species or species that are not sufficiently represented.
		Promotion of genetic diversity	Plant or promote local provenances or provenances that fit into the local forest context
		Reduce invasive tree species	Eliminate non-native and particularly invasive species.
		Replace non-native tree species	Replace non-native with native tree species.
		Promotion of herbivores	Actively re-introduce or tolerate species like beaver, moose, European bison.
		Promotion of predators	Actively introduce or tolerate species like pine marten, lynx, brown bear, wolf.
		Promotion of birds	Actively introduce or tolerate species like capercaillie, black stork, sea eagle.
		Hunting	Hunting to reduce negative effects of high populations of game species on overall diversity.
		Selective hunting	Reduce certain species with negative impact on diversity (e.g. roe deer, sika deer, red deer).
		Exclusion of domestic animals	Exclude cattle and goats in case of overusage of forest areas (e.g. Iran).
Socio-Economy	Society	Education and training	Special programmes to educate professionals, adults, and students about ecology and management of forests (e.g. using marteloscopes).
		Creating awareness of regional production processes	Education of processes that are related to timber production on regional scales, promoting capacities on regional value chains.
		Promotion of forest-related activities - felling trees, usage of forest products	Awareness of human needs and production. Humans as users - creating understanding of necessary processes.
		Promotion of regional value-chain	Supporting local sawmill- and timber-related industry, advertising local products, such as game, meat, and furniture
		Promotion of specific forest products	Produce specific timber assortments, e.g. by aiming for big tree dimensions (veneer), or valuable trees (e.g. oak).
		"CO2 certificates (only OAK Schwyz CH Box C7, Solothurn CH Box C5)"	Compensation payments by the private sector to increase the life span of trees and extend the CO_2 sink in timber.
		Ecosponsoring	Compensation payments by local industry or private partners.

Table D 2. Overview on applied measures in the good practice examples (Criteria Table).

		Main chapter	C 1 Production forests in the lowlands					C 2 Production forests in mountainous areas				
		Page	196	204	222	236	248	260	272	284	298	308
		Chapter	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Measures Category	Measures Level	Measure / Tool	Auberive, France	Ebrach, Germany	Rold, Denmark	Kottenforst, Germany	Kandern, Germany	Pahernik, Slovenia	Piwniczna, Poland	Nyon-St.-Cergue, Switzerland	Hèches, France	Eglofs, Germany
Biology / Ecology	Landscape	Forest reserves	x	x	x	x	x		x	x		x
		Uneven-aged silviculture	x	x	x	x	x	x	x	x	x	x
		Disturbances	x		x	x					x	
		Promotion of processes leading to disturbances		x	x		x					
		Connecting elements	x	x	x	x	x	x	x	x	x	x
		Restoration of natural site conditions/ processes			x	x		x				x
		Restore historic woodland pasture			x					x	x	
		Restore historic forest management		x	x	x						
		Increase structural diversity	x	x	x	x	x	x	x		x	x
		Natural regeneration	x	x	x	x	x	x	x	x	x	x
	Tree and Dead-wood	Old trees (Methuselah trees)	x	x	x	x	x					x
		Habitat trees, retention, and creation	x	x	x	x	x	x	x	x	x	x
		Deadwood	x	x	x	x	x	x	x		x	x
	Species	Promotion of rare tree species	x	x	x	x	x	x			x	x
		Increase tree species diversity	X	x	x	x	x	x		x		x
		Promotion of genetic diversity				x	x	x				
		Reduce invasive tree species				x	x	x		x		
		Replace non-native tree species	x	x		x		x				x
		Promotion of herbivores		x				x				
		Promotion of predators		x		x		x	x			
		Promotion of birds		x	x	x	x	x	x	x	x	x
		Hunting	x	x		x	x	x	x		x	x
		Selective hunting	x	x		x	x	x			x	x
		Exclusion of domestic livestock				x	x					
Socio-Economy	Society	Education and training	x	x	x	x	x	x	x		x	x
		Creating awareness of regional production processes	x	x		x	x	x			x	x
		Promotion of forest-related activities - felling trees, usage of forest products	x			x	x	x			x	
		Promotion of regional value-chain	x	x		x	x	x		x	x	x
		Promotion of specific forest products		x		x	x	x				x
		"CO2 certificates (also OAK Schwyz CH Box C 7, Solothurn CH Box C 5)"										
		Ecosponsoring				x	x					

C3 Production forests: Intensive forest management													C4 Protection			C5 Managing for scenic beauty				C6 Managing for species diversity		
322	330	346	354	368	384	402	416	424	440	452	476	478	490	498	512	522	532	546	558	574	590	
C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32	
Christinehof, Sweden	Dobie family, GB/Scotland	Dikchan, Bulgaria	Lezirias, Portugal	Ecoparks, Sweden	Kocanda, Czech Republic	Ireland	Woziwoda, Poland	Poitschach, Austria	Zvolen, Slovakia	Valle di Susa, Italy	Langau, Austria	Tamins, Switzerland	Vestland, Norway	Girona, Spain	Cairngorms, GB/Scotland	Bois Landry, France	Sonian Forest, Belgium	Serra de Llaberia, Spain	Amden, Switzerland	Black Forest, Germany	Bad Windsheim, Germany	
x	x	x			x		x		x	x		x	x		x	x	x	x	x	x		
	x	x			x		x	x		x	x	x			x	x	x	x	x	x	x	
		x						x	x	x	x	x			x			x	x	x	x	
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x			x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	
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x	x	x	x		x	x		x	x		x				x	x		x	x		x	
	x		x							x	x	x			x				x			
x					x	x	x	x	x	x				x	x	x	x	x	x	x	x	
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	x					x	x		x	x				x	x	x	x					
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and ecologically important trees, such as Sorbus or oak species is another measure that is applied in a number of examples (C1–5, C9, C13, C21, C22, C28). Allowing and even promoting herbivores in forests is an issue that has received attention for a variety of reasons. Herbivores introduce dynamics and disturbances that promote certain species (C2, C14, C18). Domesticated and can also help reducing fuel in fire-prone forests and reduce the risk of fires (C25). The return of predators is a very emotive topic, but foresters are often grateful when wolves return naturally in a region and influence the food web and trophic cascades. C7 and C20 are interesting examples of enterprises with ecosystems including large predators such as wolf, lynx, and bear. C23 showcases the potential positive impact of wolves on tree regeneration in protection forests, specifically on silver fir regeneration. The effect of the reintroduction of the pine marten in England is an impressive example on the importance of predators in an ecosystem (Box C18). The Box C20 describes the influence of large predators on forests and gives an insight on potential consequences while wolves further spread across Europe.

Socio-economic tools:
Socio-economic tools are getting more and more attention since education is changing and the general appreciation and understanding of natural processes is widely decreasing. Education and training are important for several of the enterprises showcased in this book. Children, students, but also professionals and the interested public are addressed with special programmes and tools such as the marteloscopes (Box C4). The majority of the presented cases offer or contribute to training programmes and education. This is complemented with some examples from Switzerland (Waldlabor) and overseas where major investments have been made in education programmes (Box C10, Box C12, and Box C19). Creating awareness for production processes in forests is receiving attention in some cases (e.g. C1, C18, C27) where locally produced wood and non-wood products and services, including biodiversity, are especially promoted as an important part of the value chain. This goes along with processes to educate people about the production processes; the wood for products comes from somewhere, and this means trees must be felled to produce the wood, and the forests from which these trees came are regenerated and deliver other goods and services, including biodiversity and protection against natural hazards. C2, C5, C9 and C18 promote such experiences to keep society interested in and informed about forests. Selling CO_2 certificates is a new approach based on the idea to reduce wood harvesting for a certain time immediately increasing carbon sequestration (Box C5 and Box C7). The measure is temporally limited and wood harvesting can resume if the ecological or societal boundary conditions change in the future (Box C5). The topic of ecosponsoring is another measure that enterprises have developed while cooperating with local industry and private people. One idea presented in this book is that companies and private people compensate forest owners (e.g. private forest owners or communities) for close-to-nature and biodiversity-friendly forests. Two Box contributions (Box C13 and Box C15) describe innovative approaches from Switzerland and the Netherlands that may attract interest.

The contextualisation of the applied measures is presented in table D2 which assigns the specific measures and tools to the successful application in the practice examples. This should allow us to learn from the experiences of other experts and to receive inspiration to adapt ideas to other conditions.

What is missing for widespread successful application of integrative forest management?

In this chapter, we have made the case for integrated forest management as a promising approach to meet future challenges arising from increasing societal demands and environmental change in a sustainable way. This approach allows different views and demands to be brought together and solve existing conflicts to promote and secure the forests and the delivery of their goods and services, including biodiversity, for coming generations. Nevertheless, the concept needs to be further developed and the scientific basis can be further broadened. Moreover, important policy-related boundary conditions might need to be adapted and forest policy and planning at different levels, from the Pan-European level to the regional and local levels, might consider the following points:

Fig. D 10. Tree crowns of beech, cut off at the first green branch and left in the forest with the aim to increase the amount of deadwood in managed forests. The bottom part is used and sold as valuable timber, whereas the crown is left for nature and serves as important habitat for a huge variety of species, a nutrient reservoir, and a water storing element. The cost of this is the loss of energy wood. The measure is applied in the good practice example Ebrach (C 2) (Photo: Ulrich Mergner).

1) Consider targeted integrated forest management as a core approach supporting bioeconomy and biodiversity

Until now, forest policy in Europe has remained rather fragmented. On the one hand the importance of wood as a key renewable resource to be sustainably used is emphasised, and on the other hand, forests are seen as a key place for nature and biodiversity which need better conservation and adapted measures (fig. D 10). The thorough implementation of integrated forest management concepts for the large majority of Europe's forests that are not strictly protected should be a long-term ambition to be included in new national and Europe-wide forestry strategies, bringing the two perspectives of sustainable use of a natural resource and nature conservation closer together (chapters B 10, B 11). Nevertheless, special solutions need to be developed to implement integrated forest management in private forests which cover large areas of Europe.

2) Need for a strong European forest policy to promote regional integrative forest management approaches across the continent

Climate change is increasingly putting pressure on both 'traditional' forest use and 'traditional' forest biodiversity conservation strategies (chapters B 10, B 11). Policy needs to encourage bottom-up action of forest owners, managers, and biodiversity experts to make our forests more (bio-)diverse and resilient. Moreover, transparency, information, and communication on the multiple demands towards forests and how forest management can deal with them needs to be ensured. The widespread interest among various stakeholders (forest owners, managers, and biodiversity experts) in integrating conservation aspects in forest management should be better exploited, and unsustainable forest management practices should be banned. This would help to avoid conflicts at their roots. Finally, specifically-targeted incentives to private and public landowners need to be provided to support them with the implementation of integrated forest management.

Fig. D 11. Fundamental change in species composition after bark beetle attacks. After removal of infested spruce, the remaining forest is a mixed broadleaved forest with a few conifers (Photo: Ulrich Wasem).

3) Use of disturbances to accelerate climate change adaptation and improve biodiversity

Disturbances such as storms or droughts and subsequent bark beetle infestations, newly introduced pests and pathogens like the ash dieback (Coker *et al.* 2019), or forest fires have the potential to fundamentally alter the ecological and also socio-economic conditions over large areas within very short timescales (chapter B 9). Aside from the often dramatic consequences for the forest owners and the delivery of targeted forest goods and services, they also offer the chance to immediately adapt the management objectives and accelerate change where reasonable and necessary (chapter B 1). Hence, disturbances need to become part of forest planning and should be used to initiate change, to rebuild, re-orientate, and develop the forests for the future (fig. D 11). Such an approach will provide the different forest goods and services, including biodiversity, in an optimised way, increasing temporarily open areas and the amounts of deadwood of different qualities, which are today among the most missing natural elements in managed forests (Thorn *et al.* 2018; Müller *et al.* 2019).

4) Forest monitoring must consider both production and biodiversity parameters

Information on the state of biodiversity, the structure and the functioning of Europe's forests is a prerequisite for integrated forest biodiversity conservation approaches. Only such long-term monitoring approaches provide an independent means to quantify needs and demands and to assess the success of implemented management schemes (chapters B 9, B 10, B 11). There are several long-term forest monitoring networks in Europe, including the well-established European National Forest Inventory Network (ENFIN)[2] and the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests[3]). Remote sensing technologies at the European scale need to be efficiently combined with the existing networks and new, but also already established (e.g. Forest Europe) quantitative and qualitative indicators on biodiversity and other ecosystem services should be included in the monitoring schemes to ensure that the data demanded by practitioners and policy makers is generated, is congruent/complimentary, and accessible at all policy levels, as well as for society.

5) Integrated forest management should be coordinated at the landscape level across the sectors

Integrated forest management encompassing segregated and multifunctional measures in operational planning must focus on the enterprise up to the landscape level (fig. D 12). Although the forest enterprises are fully autonomous, a coordination with respect to specific forest goods and services, specifically for measures to promote biodiversity, needs to be achieved to optimise their sustainable provision in a certain region at the landscape level. In addition, as forests are elements of landscapes, integrative forest management needs to be coordinated at the landscape level, considering the interfaces to agriculture, water areas, and settlements (fig. D 13) – hence, even if difficult to reach, an informal collaboration on the promotion of biodiversity across sectors would be beneficial for a targeted improvement of biodiversity conservation in Europe.

[2] European National Forest Inventory Network (ENFIN): http://enfin.info
[3] ICP Forests: http://icp-forests.net/

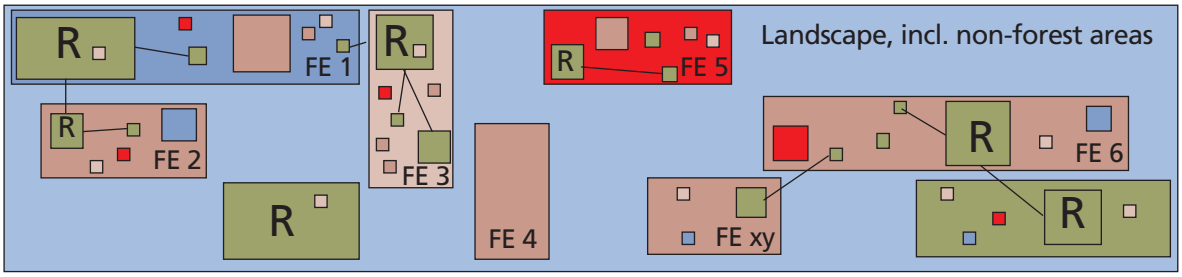

Fig. D 12. The integrative forest management concept should link forest enterprises to increase the connectivity of the biological infrastructure within and among the forest enterprises. Ideally, biodiversity measures should be coordinated at the landscape level, considering also the interfaces to agriculture, water areas, and settlements.

Fig. D 13. Diverse landscape with forests, ponds, vineyards, agricultural fields, open areas, and villages. This intensively managed area in southern Germany near Ebrach is a good example of a diverse and attractive landscape – for humans and for the many other species that benefit from such diverse and linked landscape elements (Photo: Andreas Rigling).

6) Use the motivation, experience, and support amongst Europe's forest owners, managers, and biodiversity experts to advance integrated forest management approaches

This book shows many examples of highly motivated and experienced forest owners and managers (fig. D 12) which promote the dialogue with experts from nature conservation. Both groups strive to integrate their knowledge in practical approaches, and their work has built a strong foundation for the advancement of the concept to manage Europe's forests according to societal demands (chapters C 1–C 32). The combined knowledge of practitioners and experts from forest management and nature conservation on biodiversity conservation should be made broadly available through silvicultural training and web-based information (e.g. marteloscope demonstration sites, see Box C 4). This would allow better implementation of the integration of biodiversity conservation into forest management in practice, but without constraining the diversity of perspectives and approaches. This strategy needs to include effective organisational and financial support of forest managers, especially when there are trade-offs between management and conservation goals.

7) To create the forests of the future we need to involve diverse groups and listen to a broad spectrum of views

One of the key findings of empirical social research in the last years is the increasing social pressure forest managers in Europe face from a growing urban population (Mann and Absher 2008). Integrative forest management approaches that effectively combine wood production and other goods and services, including biodiversity conservation, can be seen as a kind of 'democratic' instrument for spatially combining ecological functions, achieving synergies, and meeting as many expectations as possible. Hence, they have the potential to integrate conflicting views in society to a significant degree when they are fully implemented and transparently elaborated, documented, and communicated (chapter B 12).

8) Invest in an open science–policy–practice interface to stimulate dialogue and mutual learning across interest groups

Integrative forest management needs to implement science-based approaches and translational science is required to transfer evidence-based knowledge into practice. Even though this book highlights the success of such approaches, we need more support for cross-sectoral, interdisciplinary research, including forest sciences and nature conservation, at the science–practice interface. It is important to provide incentives for researchers to collaborate across academic sectors, disciplines, and schools of thoughts. By generating inter-, cross-, and transdisciplinary science, the ground can be paved for cross-sectoral learning and progress concerning policy/society integration. This is especially important to enable science-based decision making for sustainable forest management and biodiversity conservation in the face of future challenges with potentially increasing demand for wood products for the bioeconomy (chapter B 5) and the pressure on forest as a result of climate change (chapter B 9).

9) Promotion of pragmatic and courageous regional approaches

As we learned from the good practice examples (chapters C 1–C 32), there are many different approaches that have already been successfully applied all over Europe. There is not one solution that can be applied, but there are many local solutions, which are rooted in the regions and based on local knowledge and expertise, local needs and local traditions; these are in part highlighted in the personal statements of the responsible persons of these good practice examples. Promoting such initiatives is a straightforward and sustainable approach to increasing the diversity within the European forest area (chapters B 2, B 3, B 12).

Hopefully, this book will be a starting point, a catalyst, for upscaling from local good practice management examples and initiatives to other regions and countries in similar or diverging contexts. Reading about this selection of innovative and constructive solutions to integrate the promotion of biodiversity into forest management, and also knowing that there are many more interesting examples already practised all over Europe is a cause for optimism and should encourage open and respectful cross-disciplinary dialogue and courageous application.

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Forests cover about a third of the European land area and provide a multitude of ecosystem services. They are subject to constant change and increasing demands with respect to the ecosystem services they provide. As well as provision of timber, non-timber forest goods (e.g. berries and mushrooms), clean water, carbon sequestration, and protection against natural disasters, there is increasing emphasis being placed on conservation and promotion of biodiversity within forests. However, the state of biodiversity in European forests varies widely. Because of the different biogeographic, sociocultural, political, and climatic conditions at small scales, there is a wide variety of situations, approaches, and legacies across the continent.

This book strives to show the challenges that forest managers are faced with to fulfil the societal demands with regard to forests, and especially to integrate the promotion of biodiversity.

In a first section (12 chapters), 44 authors from science, policy, and practice describe the driving factors of forest management; these factors include national laws and legacies, ownership structures, forest history, and socio-structural conditions. In a second section, 113 authors present 32 case examples from 19 European countries that demonstrate the different approaches to integrate the locally requested ecosystem services. These experiences are synthesised in a final section, and a toolbox of integrative measures is presented that is intended to support forest owners and managers to choose appropriate measures for targeted integrated management in their forests.

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