European forest ecosystems

State and trends

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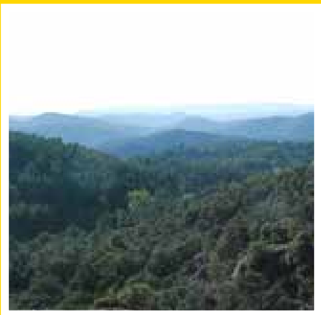

European Environment Agency

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Acronyms

7EAP	Seventh Environment Action Programme
CABI	Commonwealth Agricultural Bureaux International
CAP	Common agricultural policy
CBD	Convention on Biological Diversity
CDDA	Common Database on Designated Areas
CICES	Common International Classification of Ecosystem Services
CO_2	Carbon dioxide
COP	Conference of Parties
Daisie	Delivering Alien Invasive Species in Europe
DG	Directorate-General
DG AGRI	Directorate-General for Agriculture
DG ENV	Directorate-General for the Environment
DG JRC	Joint Research Centre Directorate-General of the European Commission
DG RTD	Directorate-General for Research and Innovation
DPSIR	Drivers, pressures, state, impacts and response
EBCC	European Birds Census Council
EBM	Ecosystem-based management
EEA	European Environment Agency
EFDAC	European Forest Data Centre
EFFIS	European Forest Fire Information System
EFI	European Forest Institute
EFT	European Forest Type
Eionet	European Environment Information and Observation Network
EPPO	European and Mediterranean Plant Protection Organization

ETC	European Topic Centre
ETC-BD	European Topic Centre on Biodiversity
ETC-SIA	European Topic Centre on Spatial Information and Analysis
EU	European Union
EU-27	The 27 EU Member States between January 2007 and July 2013
EU-28	The 28 EU Member States as of July 2013
Eufgis	European Forest Genetics Information System
Euforgen	European forest genetic resources programme
EUNIS	European Nature Information System
EUR	Euro
Eustafor	European State Forests Association
EUTR	EU Timber Regulation
EVD	European Vegetation Database
FAO	Food and Agriculture Organization of the United Nations
Faostat	Food and Agriculture Organization of the United Nations Statistics Division
FAWS	Forest available for wood supply
FCS	Forest Certification Scheme
FLEGT	Forest Law Enforcement Governance and Trade
FMP	Forest management plan
Forest Europe	Ministerial Conference on the Protection of Forests in Europe (MCPFE)
FOWL	Forests and other wooded land
FRA	Forest resources assessment
FSC	Forest Stewardship Council
GDP	Gross domestic product
GHG	Greenhouse gas
GVA	Gross value added
H1	Helsinki Resolution 1 (under Forest Europe, formerly MCPFE)
HNV	High nature value
IAS	Invasive alien species

ICP	International Cooperative Programme
IEA	International Energy Agency
IFF	Intergovernmental Forum on Forests
Integral	Future-oriented integrated management of European forest landscapes
IPA	Instrument for Pre-Accession Assistance
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPF	Intergovernmental Panel on Forests
ISSC	International Social Science Council
IUCN	International Union for Conservation of Nature
IWR2014	Inclusive Wealth Report 2014
JRC	Joint Research Centre
LBA	Legally binding agreement
LCL	Lifting condensation level
LULUCF	Land use, land-use change and forestry
MAB	Man and the Biosphere
MAES	Mapping and Assessment of Ecosystems and their Services
MCPFE	Ministerial Conference on the Protection of Forests in Europe (also known as Forest Europe)
MEA	Millennium Ecosystem Assessment
NECD	National Emission Ceilings Directive
NGO	Non-governmental organisation
NLBI	Non-Legally Binding Instrument on All Types of Forests
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
NPP	Net primary production
NUTS	Nomenclature of Territorial Units for Statistics
NWFP	Non-wood forest product
OECD	Organisation for Economic Co-operation and Development
PEBLDS	Pan-European Biological and Landscape Diversity Strategy
PEFC	Programme for the Endorsement of Forest Certification

PES	Payment for ecosystem services
PfA	Proposal for action
ppm	Parts per million
PWN	Pinewood nematode
REDD	Reducing emissions from deforestation and forest degradation
RSPB	Royal Society for the Protection of Birds
SDG	Sustainable development goal
SEBI	Streamlining European Biodiversity Indicators
SFM	Sustainable forest management
TBFRA	Temperate and Boreal Forest Resource Assessment (also known as FRA)
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total economic value
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Convention on Environment and Development
UNECE	United Nations Economic Commission for Europe
Unesco	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
USD	United States dollar
VOC	Volatile organic compound
WFD	Water Framework Directive
WWF	World Wide Fund for Nature

Glossary

Forest	Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 %, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use (Working definition used by FAO, UNECE, Forest Europe, the European Commission, Eurostat and the EEA).
Other wooded land	Land not defined as 'forest', spanning more than 0.5 ha, with trees higher than 5 m and canopy cover of between 5 % and 10 %, or trees able to reach these thresholds, or with a combined cover of shrubs, bushes and trees above 10 %. It does not include land that is predominantly under agricultural or urban land use (Working definition used by FAO, UNECE, Forest Europe, the European Commission, Eurostat and the EEA.).
Forest ecosystem	Can be defined on a range of scales. It is a dynamic complex of plant, animal and microorganism communities, and their abiotic environment, that interact as a functional unit that reflects the dominance of ecosystem conditions and processes by trees. Humans, with their cultural, economic and environmental needs, are an integral part of many forest ecosystems (as defined by the Convention on Biological Diversity (CBD)).
Forest ecosystem functions	The key functions of forest ecosystems are energy capture from the sun through photosynthesis and its conversion to organic substances, which leads to processes such as the production of biomass, the cycling of water and nutrients, and decomposition (Kimmins, 2008).
Forest ecosystem services	Defined as 'the direct and indirect contributions of forest ecosystems to human well-being'. These include the following services (according to the Mapping and Assessment of Ecosystems and their Services (MAES) working group): supporting services that maintain the conditions for life on Earth, such as the capture of light and nutrient cycling; provisioning services, such as food and water; regulating services, such as flood and disease control; and cultural services, such as spiritual, recreational and cultural benefits.
Roundwood	All roundwood felled or otherwise harvested and removed. It comprises all wood obtained from removals, that is, the quantities removed from forests and trees outside the forest, including wood recovered from natural losses and felling, and logging losses during the period, calendar year or forest year. It includes all wood removed with or without bark, including wood removed in its full form, or split, roughly squared or in other forms (e.g. branches, roots and stumps), and wood that is roughly shaped or pointed. It is an aggregate comprising wood fuel, including wood for charcoal and industrial roundwood (wood in the rough). The reporting unit is the volume (in m^3) under bark (i.e. excluding bark).
Sawn wood	Wood produced from both domestic and imported roundwood, either by sawing lengthways or by a chipping process that exceeds 6 mm in thickness.
Wood fuel	Roundwood for fuel purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees and wood for the production of charcoal, wood pellets and other agglomerates. It also includes wood chips directly produced for fuel. It excludes wood charcoal, pellets and other agglomerates. The reporting unit is the volume (in m^3) under bark (i.e. excluding bark).

Plantations	Forest stands established by planting and/or seeding in the process of afforestation or reforestation; intensively managed stands of introduced or native species (only one or two tree species) that are even aged, with a regular spacing of trees in a stand. Established plantations with no forest operations for a significant period (considered to be semi-natural forests) are excluded.
Semi-natural forests	Forest stands that have close to the natural structure, composition and function but are modified through forest operations. Most semi-natural forests have a long forest-management history.
Primary forests	Forests in which natural structure, composition and function have been shaped by natural forest dynamics with no or little human interventions over a long period allowing for the re-establishment of natural species composition and processes.

Executive summary

The importance of forests with regard to supporting human needs is considerable.

Forests are rich in biodiversity and valuable for recreation, water regulation and soil protection.

As well as for providing timber and other non-wood forest products, forests are important for mitigating climate change and for the renewable energy sector.

Forest ecosystems are exposed to a range of environmental, economic and social pressures that challenge their sustainability. The forest sector is influenced by the unprecedented pressures arising from climate change and the growing demands of society on natural resources. These changes place enormous pressure on the health and resilience of forest ecosystems and affect biodiversity and human well-being.

Human activities and management have modified more than 96 % of Europe's forests.

Healthy and diverse forest ecosystems?

Old-growth and natural forests are particularly valuable for biodiversity (including the genetic variety) and carbon storage.

Forests and other wooded land cover more than 40 % of the total land surface in the European Environment Agency (EEA) region (33 member countries and six cooperating countries — the EEA-39). Forest extent and growing stock are still increasing. However, some countries in northern and south-western Europe are experiencing a decline in forested areas.

There is a great diversity of forest habitats across Europe, with 81 different habitat types identified according to the Habitats Directive. The tree species composition of managed forests in the EEA region is becoming more diverse, with an increasing variety of broadleaved and coniferous tree species.

Forestry in Europe is, to a large extent, based on native tree species. However, some countries have a significant share of introduced forest tree species. Nonetheless, invasive alien species still cover only 0.5 % of the total forest area in Europe.

For the 2007–2012 period, the 27 European Union (EU) Member States reported that only 26 % of forest species and 15 % of forest habitats of European interest, as listed in the Habitats Directive, were in 'favourable nature conservation status'.

According to recent reports by the International Union for Conservation of Nature (IUCN), 27 % of mammals, 10 % of reptiles and 8 % of amphibians linked to forest ecosystems are considered to be under threat of extinction within the EU.

There are concerns with regard to the genetic biodiversity of important commercial trees, especially in connection with the current transfer of tree genetic material between countries and across the globe. Although certain tree species might produce higher timber yields, genetic variety in regionally adapted forests is essential for adapting to new environmental conditions, such as those resulting from climate change.

Climate change affects biodiversity in forests. Climate change is likely to impact, both the zones where tree species can live in and the range of tree species. Increased periods of droughts and warmer winters are expected to further weaken forests against invasive species.

International processes related to forests, biodiversity conservation and climate change must be supported and reinforced by creating synergies that favour the success of these processes over time.

Are Europe's forests sustainably managed?

- Sustainable forest management (SFM) is the global forestry sector's response to the need for sustainable development. SFM is a strategic goal that encompasses social, economic and environmental dimensions.

- Most evidence suggests that the European forestry sector does practice SFM; however, there are some causes for concern.
- More than 95 % of the forests in the EEA region are under management and the degree of human intervention is controlled. Around 10 % of these are managed intensively as plantations. The principles of SFM apply to the vast majority of forests.
- The better management of forests would involve the adoption of further adaptive management approaches that integrate research and the monitoring of outcomes to improve the effectiveness of management interventions. Furthermore, mechanisms should be expanded to compensate those who provide ecosystem services that make the sustainable management of forests a more attractive land-use option.
- Baseline data are needed to track changes in forest cover and condition. Despite the comprehensiveness of national forest inventories and monitoring across Europe, no systematic and harmonised European-wide forest information is available.
- The share of forests that are public is less than 40 % of the total forest area in the EEA region. The remaining 60 % of forested area is privately owned. Given this, forest ownership and the importance of the forest sector for the national economy are key factors that affect forest management and, consequently, biodiversity.
- Research needs to be strengthened in order to identify and enhance the understanding of the main components of the 'drivers, pressures, state, impacts and response' (DPSIR) analytical framework. Focus should be on the complex interactions between these drivers of change and their direct and indirect repercussions on forest ecosystems and their services to society.
- The increasing demand for forest products and forest-based biomass energy creates new production and employment opportunities. Capturing these opportunities requires intersectoral coordination, and landscape-scale planning and development approaches that simultaneously focus on different economic activities and on social and environmental values.
- New professionals are needed for a broader, multidisciplinary understanding of the forestry sector and its role in meeting humanity's needs for ecosystem services, in fostering rural development and in ameliorating the impacts of climate change.
- Learning how to facilitate the ability of natural forest systems to self-organise, adapt and evolve, and to guide them towards a desired appropriate state, are some of the challenges.
- The increasing importance of engagement, capacity building and participation in landscape management is a first step towards maintaining the provision of ecosystem goods and services.
- Partnerships, collaborative platforms and networks can foster stakeholder participation and participatory policymaking. Consensus building on shared objectives and strategies is increasingly needed in light of the increased multifunctional values of forest ecosystems.
- Managing changing forests reveals new approaches to managing forests for wood and other ecosystem services, in response to local impacts brought on by global changes, which address current challenges and elements of an emerging management paradigm, based on ecological and socio-economic systems. Such a framework recognises the complexity of systems, their hierarchical structures, their interactions and their capacity for self-organisation.
- Such approaches, so-called ecosystem-based management (EBM) approaches, include SFM but also allow the forestry sector to look and engage beyond itself. EBM allows synergies and trade-offs in the delivery of different forest goods and services to be identified and negotiated.
- Forestry certification mechanisms should be encouraged in order to embrace the EBM principles.
- International, European and national forestry policymakers should actively participate in the further development of EBM across a wide range of sectors.
- EU agencies and research centres, such as the EEA and the Joint Research Centre (JRC) can support the development of EBM through the provision of common frameworks and systems, the provision of data and its analysis, and broader communication.

1 Introduction

Photo 1.1 Forested landscapes in the Alps

Forests are the dominant natural habitat across most of Europe. In the past, forests probably covered more than 80 % of Europe's land surface (Bradshaw and Sykes, 2014). Over time, human activities have impacted upon nearly all of Europe's forests. Multiple uses of forests, together with population growth and economic expansion in Europe, led to widespread deforestation in order to make way for agriculture and new settlements. During the industrial development of Europe, forests became a source of commercial energy. Trees provided charcoal when coal was scarce to power steam-driven machines and engines. Forest cover declined dramatically — over half of Europe's original forest cover disappeared some 200 years ago (Wallerstein, 1976). In response to shortages of fuelwood and timber, and, in some regions, in response to the need for the regulation of sand flight, avalanches, and soil and wind erosion by forests, more formal forest management practices emerged. The implementation of active policies for forest protection, reforestation and afforestation, as well as improved forest management, aimed to preserve, expand and manage forests sustainably (Pile et al., 2012).

The current distribution of forests in Europe, as well as the composition of tree species, is determined more by management than by natural factors (Rackham, 2008). Forests and other wooded land (FOWL) now constitute the largest land-cover type in Europe, extending over more than 43 % of the land surface. In many European countries, forest cover has increased by a few per cent in recent years to the current coverage of 35–40 % of the total land surface. The natural expansion of forests, mostly on abandoned land, has also contributed to the increase in the area of forests. In contrast to Europe, forests are shrinking at the global level, as a result of degradation and deforestation. Globally, forests cover 31 % of the world's land surface. Alarmingly, large areas of tropical and boreal forests are disappearing and are being replaced by land for other uses.

Forests host a myriad of living organisms and contain a major assemblage of terrestrial species. Forest ecosystems provide a range of ecosystem services that are vital to society and human well-being (Thompson et al., 2014). A recent study conducted by the European Environment Agency (EEA) estimated that around 60 % of Europeans live in, or close to, forests (EEA, 2015a). The immediate presence of forests allows the use of forest-related services, especially non-marketed services such as clean air, recreational use, and spiritual and aesthetic values. Forests provide protection against soil erosion, regulate local and global climates, enhance water retention, facilitate pollination and improve landscape aesthetics.

Forests play an important role in the mitigation of climate change, as they are the Earth's main carbon sink. In each year between 2005 and 2010, forests removed around 430 million tonnes of atmospheric carbon dioxide (CO_2), thanks to the process of photosynthesis and the growth of tree biomass growth, in the European Union (EU) (Pan et al., 2011). Around 10 % of Europe's greenhouse gas (GHG) emissions are stored in forest ecosystems. Increased forest cover has a significant impact on the amount of water retained in a basin and forests help to regulate floods and the provision of clean drinking water (EEA, 2015a). These services provided by forests are known as 'forest ecosystem services'. Without forests, or in the case of inadequate forest management, these resources could be degraded, damaged or even destroyed.

Levels of income and consumption are increasing, as is human dependence on space and ecosystem services. The world population is expected to exceed 9 billion by 2050. Within Europe, in 2014, the population was around 614 million in the 39 countries ([1]) of the EEA region EEA-39 and over 500 million in the 28 EU Member States (EU-28). However, recently, population growth has slowed down in Europe and has even fallen in some European countries. The longer life expectancies of Europeans might prove challenging if we are to meet future needs (Sanderson and Scherbov, 2015). As a consequence, demands for forest ecosystem services are expected to rise.

Increased pressures and threats on forest ecosystems have led to a rethink with regard to how to protect and maintain forest ecosystems, in order to secure their health, diversity, productivity and resilience (Folke et al., 2004). Wood production and forest management need a framework that ensures the long-term fulfilment of environmental sustainability and the supply of the wide range of ecosystem services that society requires. Ultimately, if nothing is done to maintain and restore forest ecosystems, and to halt the loss of forest biodiversity, we might lose forest ecosystems altogether (Mery, 2010). There is a need to act using current knowledge in order to support the resilience of forests and to improve the sustainability of the use of forests. The management of forests must follow a holistic approach that ensures protected and well-functioning forests, and their provision of ecosystem services.

This EEA report follows up on the 2008 report on the state of ecosystem conditions and the sustainable use of European forests (EEA, 2008). The aim of this report is to assess the current state of forest ecosystems in Europe on the pathway to healthy, diverse, resilient and productive forests for the benefit of present and future generations. These aspects are fundamental for the sustainable development of forests. The report applies the components of the 'drivers, pressures, state, impacts and response' (DPSIR) analytical framework and considers their direct and indirect repercussions on the state and development of forest ecosystems and their services.

The present report is based on the most comprehensive information available on forest resources in Europe, compiled by Forest Europe (also known as the Ministerial Conference on the Protection of Forests in Europe (MCPFE)), the United Nations Economic Commission for Europe (UNECE) and the Food and Agriculture Organization of the United Nations (FAO) (see Box 1.1).

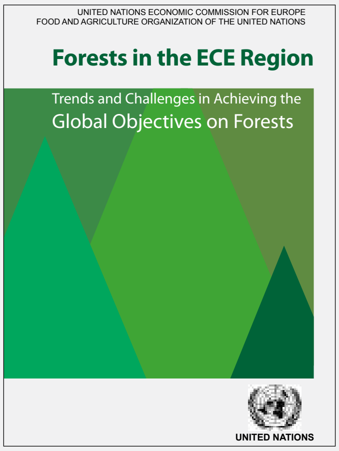
([1]) Includes EU-28 Member States, Iceland, Liechtenstein, Norway, Switzerland and Turkey as well as the six West-Balkan countries: Albania, Bosnia and Herzegovina, Kosovo, former Yugoslav Republic of Macedonia, Montenegro and Serbia.

Box 1.1 Forest information in the pan-European region

European countries collect data and information on forests for pan-European reporting based on the joint Forest Europe/UNECE/FAO questionnaire on pan-European quantitative indicators for sustainable forest management. The questionnaire contributed to three forest reports in 2015: *State of Europe's Forests 2015* (Forest Europe et al., 2015); *Global Forest Resources Assessment 2015 — How are the world's forest changing?* (FAO, 2015a); and *Forests in the ECE Region — Trends and challenges in achieving the global objectives on forests* by the UNECE (UNECE and FAO, 2015). The questionnaire, its output tables and the three reports deliver the best available data set on forests across Europe. Thanks to this coordinated effort, the variables used for the corresponding processes are consistent and help to communicate, in a coherent and reliable way, the state of forests in the pan-European region.

The reports assess all aspects of forests, and their resources, functions and services in the pan-European region. Information on the state of forests and forest-related trends is communicated and made available to the public, policymakers and any individual or organisation interested in forests. This reporting is carried out in close cooperation with partners in countries, international organisations and the scientific community. The collected high-quality information complies with agreed standards and rules to ensure international comparability. The national forest resources assessment (FRA) correspondents report on 28 quantitative indicators, whereas international data providers supply information on the seven remaining indicators. The UNECE/FAO Forestry and Timber Section in Geneva, Switzerland, and the Forest Europe Liaison Unit in Madrid, Spain, support countries with their reporting and coordinate the reporting process.

This information is the basis for forest-related work at the EEA and has contributed to indicator development, analysis and assessments on all aspects of forests, including the present report, at the EEA.



1.1 Report content

Following the brief introduction provided in this chapter, Chapter 2 provides a description of the global and European policy contexts that have an impact on the sustainable management of forests and, thus, on their state and development. It presents the broader targets and visions of Europe, and the implementation of the forest-related EU policies that are relevant to achieving these objectives. Although there are no specifications on forests or forestry in the founding treaties of the EU, several EU strategies and action plans concern forests directly, as well as indirectly. Chapter 2 gives examples of the relevance of other policies to forests. In addition, several forest-related EU policies and strategies emphasise the need for a coordinated approach to the sustainable management of forests across Europe and a better integration of forest-related issues at the EU level. The main objectives of the sustainable management of forests are to ensure that forest functions are balanced and vital ecosystem services are delivered, and that the forest sector remains competitive and contributes to the bio-based economy.

Global changes threaten the state and the condition of forest ecosystems. Chapter 3 identifies the challenges for, pressures on and threats to forest ecosystems. The interdependencies among forest ecosystems, climate change and other human-made changes are extremely complex. Forest ecosystems may be more prone to disturbances, such as storms, fires and infestations, in the future than they are now. Most importantly, forests are under pressure from many different sources. However, little is known about the cumulative effects of these pressures, and the threats to forest ecosystems in the short and long terms. The report briefly considers the pressures, and their synergistic effects, on forests from other sectors. These sectors are mainly wood-based industries, agriculture, energy and the complex array of pressures resulting from growing urbanisation and the increasing demands for forest products and ecosystem services.

Although forest cover has increased over the last 70 years, this does not necessarily imply a favourable nature conservation status (see Chapter 4). The state of the conservation of protected forest species and habitats is critical, and has not improved since the last report under the Habitats Directive in 2006. Forests in Europe have been highly modified over the last centuries. However, they are one of the ecosystems in Europe with the highest degree of biodiversity, despite this high level of human intervention. Nonetheless, there are concerns over the degradation of forest biodiversity within and outside Europe, and the capacity to maintain diverse, healthy and productive forests in the whole EEA region. The increasing demand for land might lead to more urban sprawl and land fragmentation, which in turn would lead to highly fragmented forested landscapes and a reduction in the quality of forests.

Traditionally, forests have been a source of timber. Forest ecosystems are still managed in order to maximise the provision of biomass, frequently at the cost of other services. Forests, however, provide more than wood-related resources, and the interest in the ecosystem goods and services that forests provide is increasing. Chapter 5 emphasises the importance of forest ecosystems in Europe with regard to the provision of a broad range of ecosystem services to society. Forests are critical for climate regulation and the provision of key ecosystem services to humans. Forests deliver essential services, such as hydrological regulation, carbon sequestration and recreation. The protection of forest ecosystems is critical for ensuring the provision of these services, as is their restoration if they become degraded or overused.

Chapter 6 reflects on the state and trends of forest ecosystems in Europe and considers whether or not forests are healthy, diverse and productive. Forests are an integral part of the land-resource base and rural development. The maintenance of Europe's forests is paramount to Europe's biodiversity, and to the forest ecosystem services on which European societies and people depend. Chapter 6 describes how forests contribute directly to the economy by providing employment and income in rural areas, both in formal and informal sectors.

There is a long and predominant tradition in Europe of managing forests in accordance with the principles of sustainable forest management (SFM). This report intends to broaden the concept of SFM. More integrated approaches to social and natural resource management are on the agendas of several EU policies, including those related to land, water and other natural resources, along with forests. This should allow a more balanced approach — at the broadest landscape level — to the effective use, protection and maintenance of these natural resources for the benefit of present and future generations. The report introduces ecosystem-based management (EBM) in the context of forest management, as reflected by recent developments related to the sustainable management of forest ecosystems. This EBM approach involves managing human activities in forest ecosystems in ways that are compatible with the complete functioning of forest ecosystems.

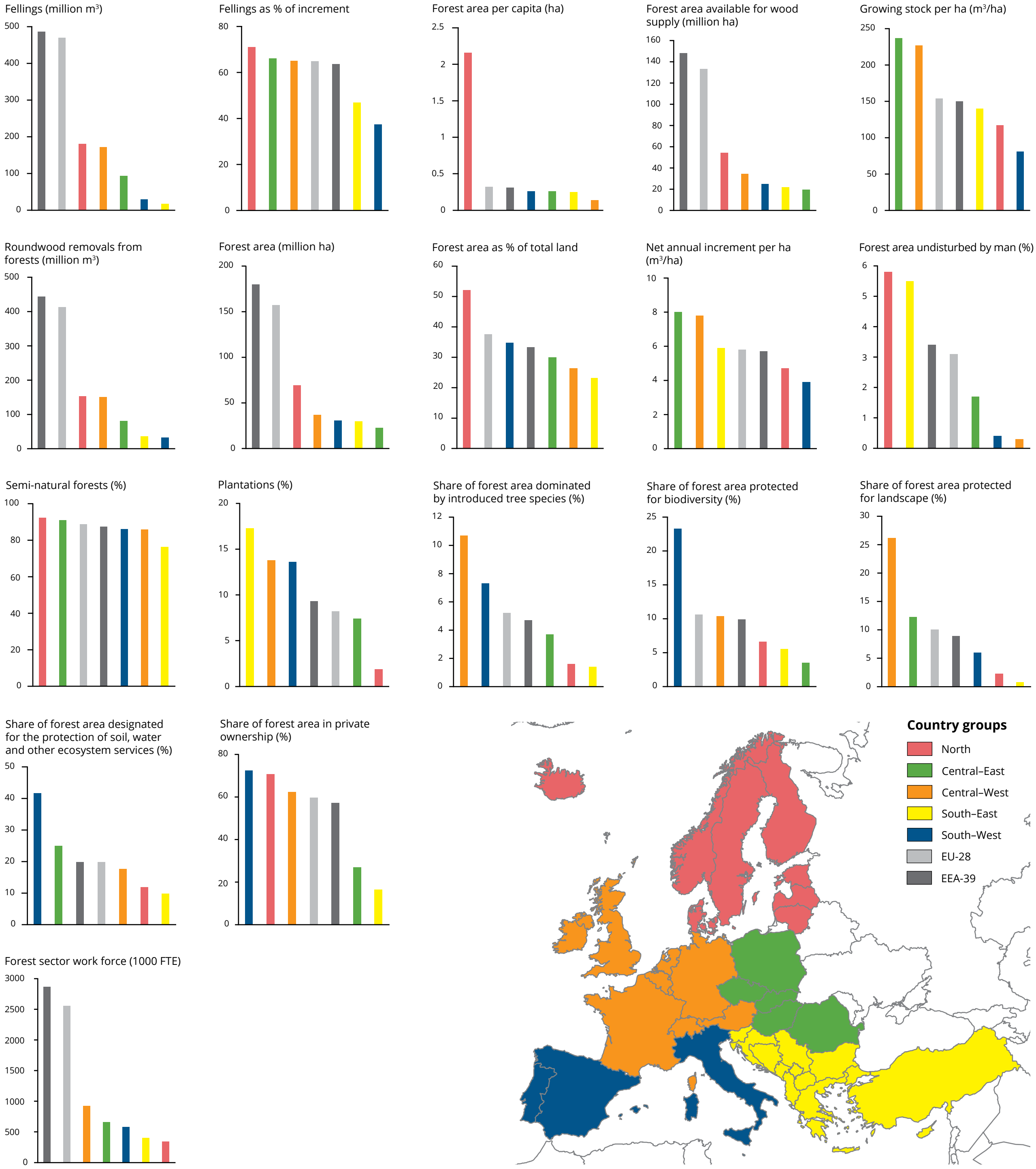
Forest management decisions have profound effects on biodiversity, climate and, in the long term, human well-being. Chapter 7 presents different tools and instruments have been developed to evaluate the degree of sustainability of forest management, and to support decision-making with regard to integrating biodiversity and forest management. Finally the chapter emphasises the essential role that forest governance plays in determining the use and function of forest ecosystems, as well as the importance of reliable and available forest information, and the forest knowledge base, for the protection and maintenance of Europe's forests.

1.2 Europe's forest ecosystems: some key characteristics

In 2015, forests ([2]) covered 161 million hectares (ha) of the EU-28 (and 186 million ha of the EEA-39 region), which equates to more than 40 % of Europe's land surface (see Figure 1.1 and Map 1.1). European forests have increased in area by about 10 % since 1990 (Forest Europe et al., 2015). However, this increase seems to have stabilised. In the last decade, the rate of afforestation decreased substantially as the

([2]) According to the globally recognised reference definition (see Glossary).

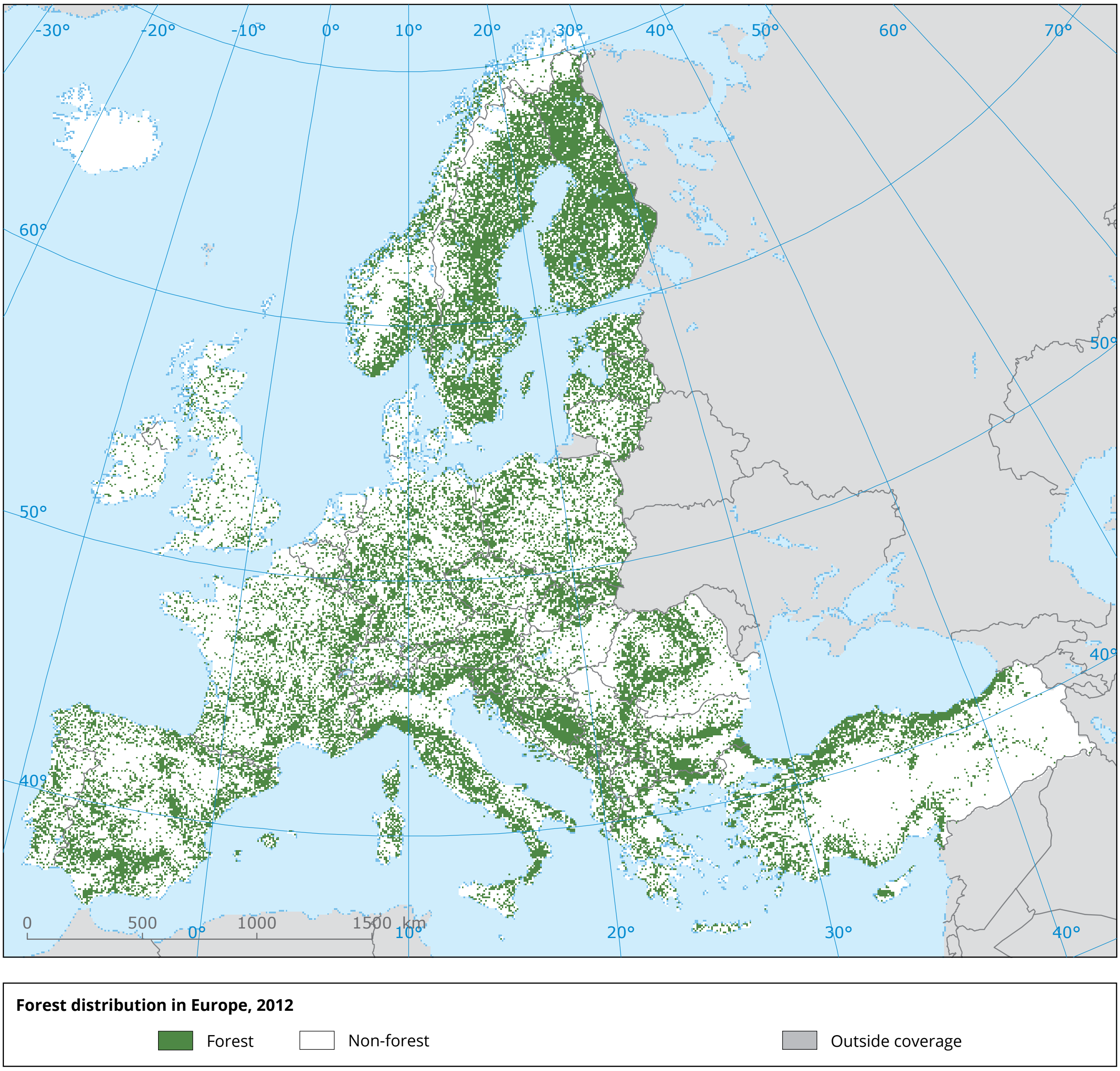
Figure 1.1 Key facts about European forests

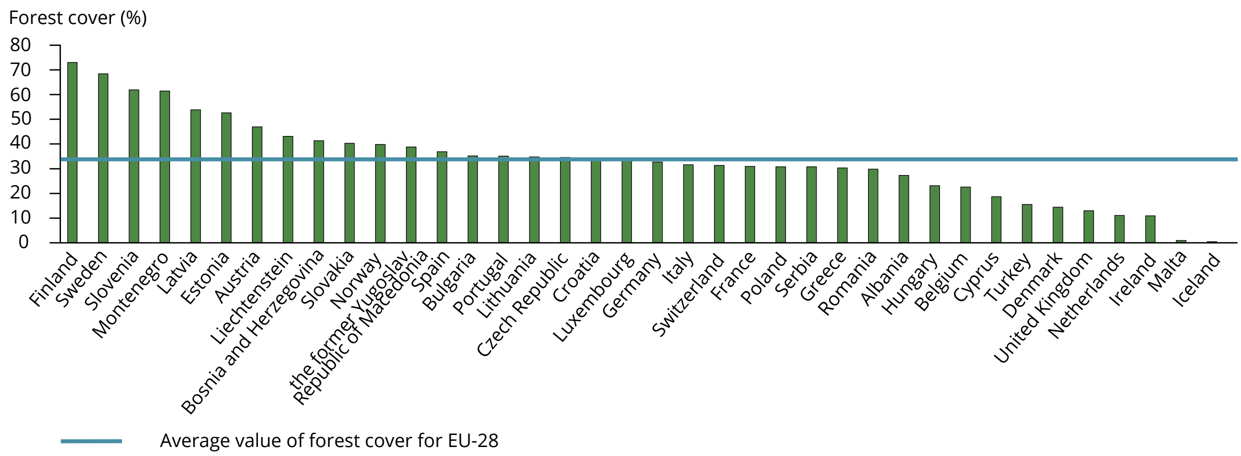


Notes: North refers to Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway and Sweden; Central-West refers to Austria, Belgium, France, Germany, Ireland, Liechtenstein, Luxembourg, the Netherlands, Switzerland and the United Kingdom; Central-East refers to the Czech Republic, Hungary, Poland, Romania and Slovakia; south-west refers to Italy, Malta, Portugal and Spain; and South-East refers to Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, the former Yugoslav Republic of Macedonia, Greece, Montenegro, Serbia, Slovenia and Turkey.

Source: Forest Europe et al., 2015; see also table in Annex 1.

Map 1.1 **Forest cover and the share of forests (%) of total land cover of a country in the EEA region in 2012**





Source: Forest Europe et al., 2015.

demand for infrastructure and the intensification of agriculture increased (EEA, 2008, 2012a). The increase in forest cover is likely to have been due to the natural expansion of forests on, for example, abandoned farmland in rural and remote areas.

Almost 70 % of the forest area of Europe is within six countries: Sweden (28 million ha), Finland (22 million ha), Spain (18 million ha), France (17 million ha), Norway and Turkey (both 12 million ha). Some countries, such as Montenegro, the Nordic countries and Slovenia, are extensively covered by forests (more than 60 % of their total land areas). Few countries have less than 20 % of their total land surfaces covered by forests. Map 1.1 underlines the strong regional differences in forest cover and the percentage of land covered by forests across Europe.

Figure 1.1 presents the key characteristics of forests in Europe. The total growing stock of European forests amounts to 26.5 billion m^3 and has increased in all regions of Europe by 10 billion m^3 since 1990 (Forest Europe et al., 2015). Growing stock has increased faster than forest area, as the average volume per hectare has been increasing. Forests are most productive in central Europe and have the lowest growing stock in south-western Europe. Forest growth is constrained, in northern Europe, by the length of the growing season and, in southern Europe, by water availability.

More than 95 % of Europe's forests are managed and modified by human activities. Forest management practices vary substantially across Europe, from full protective forest management for biodiversity conservation, to intensive short-rotation monoculture forestry for energy-related biomass production. More than 80 % of the forest area in the EEA region is managed as production forest with the potential for timber extraction (i.e. as forest available for wood supply (FAWS)). Nevertheless, according to FRA reporting, only 10 % of the total forest area of Europe is intensively managed and an increasing proportion (currently 30 %) is managed as multiple-use forest.

Europe is one of the main roundwood producers in the world and is a net exporter of wood products. In 2013, approximately 432 million m^3 of roundwood were harvested in the 27 EU Member States (EU-27). Among the EU Member States, Sweden produced the most roundwood (69 million m^3) in 2012, followed by France, Germany and Finland, which produced between 50 million m^3 and 56 million m^3 each.

2 Maintaining healthy and productive forests in Europe

Forests are critical for Europe's biodiversity, landscapes, people and economies. Countries recognise the role of forests in the stability of the biosphere, in the maintenance of biodiversity and for their ecosystem services. Forests are affected by local, national, European and global concerns. National governments often have to act as intermediaries between the global interest in forests and the local demands for forest resources. Forests are currently the primary focus of policy debates on sustainable development, and the importance of forests is addressed by several of the sustainable development goals (SDGs) of the United Nations (UN) (2016) Forest strategies at the local and national levels, and forest-relevant policies at the European and global levels, increasingly seek to integrate biodiversity into forest management and rural development, and balance economic, social and environmental aspects of forests.

2.1 Global forest policies and sustainable development

At the global level, there are no comprehensive legally binding instruments related to forests. Nevertheless, several conventions, developed at the beginning of the 1990s, such as the Convention on Biological Diversity (CBD), the UN Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the UN Convention to Combat Desertification (UNCCD), have increased the focus on biological diversity, climate change and desertification. Also, Agenda 21 (2016), the UN action plan for sustainable development, emphasises the importance of conservation and the management of resources to combat deforestation, and the role of forest industries.

These conventions could regulate many functions of forests. Forests are, at present, being actively debated within the context of the UNFCCC and the CBD. The UNFCCC recognises the huge role that forests play in regulating the global carbon stock through the accumulation of biomass and soil sequestration. The CBD is paramount for forests worldwide, as its targets comprise a reduction in the loss of natural habitats, degradation and fragmentation, while supporting sustainable management. The CBD has extended objectives regarding forest biodiversity that support the development of national measures to integrate conservation and the sustainable use of biodiversity in national forest management plans (FMPs).

Both the CBD and the UNFCCC have influenced European decision-making, as both have founded an uptake of political resolutions as part of the Forest Europe process. The UNFCCC was followed up by the establishment of a European climate change programme and led to the conclusion of a number of legally binding EU policy instruments. The requested revision of accounting rules for the UN Green House Gas inventory instrument, better known as the land use, land-use change and forestry (LULUCF) instrument, led to the adoption, in July 2013, of a decision on the harmonisation of accounting rules for emissions and removals from soils and forests across the EU. Consequently, Member States have been asked to report any increases in removals and decreases of emissions of GHGs.

The UN Conference on Environment and Development, held in Rio in 1992, also triggered the establishment of the Intergovernmental Panel on Forests (IPF) and the Intergovernmental Forum on Forests (IFF). More than 270 proposals for action (PfAs) have been formulated with regard to SFM ([3]). The *Non-legally binding authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests* (UN, 1992) and the part of Agenda 21 that covers deforestation provide the first, non-legally binding consensus on forest management, conservation and sustainable development. The UN Forum on Forests (UNFF) was established in 2000 to implement the Forest Principles. The UNFF aims to strengthen the political commitment to SFM and has four global objectives related to forests: to reverse the global loss of forest cover through SFM; to enhance forest-based economic, social and environmental benefits; to

([3]) See also Glossary.

increase the area of sustainably managed forests; and to mobilise financial resources for the implementation of SFM.

The reducing emissions from deforestation and forest degradation (REDD) mechanisms emerged in 2005 as a potential means of transferring carbon credits between developed and developing countries (Visseren-Hamakers and Verkooijen, 2013). The objective of this is to mitigate climate change by reducing the GHG emissions that result from deforestation and forest degradation in developing countries through the enhanced management of forests.

The Rio+20 (UN Conference on Sustainable Development) declaration called for 'holistic and integrated approaches to sustainable development' and for the promotion of 'integrated and sustainable management of natural resources and ecosystems. It aims to support economic, social and human development while facilitating ecosystem conservation, regeneration and restoration and resilience in the face of new and emerging challenges'. Such EBM approaches imply, for instance, the coordination of forest-relevant policies, the involvement of different actors in policymaking and that a multilevel dialogue is taking place.

As a follow-up to Rio+20, the UN recently adopted 17 SDGs that build on the eight millennium development goals. The role that forests could play in achieving these SDGs was underlined at the 14th World Forestry Congress in Durban, South Africa, in September 2015. Goal 15 of the SDGs addresses the need to sustainably manage trees and forests. Forests are critical to achieving several of the other goals, including those related to ending poverty, achieving food security, promoting sustainable agriculture and ensuring sustainable energy for all, see Box 2.1. A 5-year action plan on forests and water was launched in order to promote recognition of the role of trees and forests in the maintenance of the water cycle and also to ensure the appropriate management of one of the world's largest sources of freshwater.

At present, the international community is undergoing an assessment period as regards international agreements on forests. A number of non-legally binding agreements (non-LBAs) exist, including the Non-Legally Binding Instrument on All Types of Forests (NLBI) that sets out the four Global Objectives on Forests agreed at the UNFF in 2007. Also, the Forest Principles and Chapter 11 of Agenda 11, agreed at the UN Convention on Environment and Development (UNCED) in 1992, are still relevant. Certification schemes, such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) schemes, function as non-governmental organisation (NGO) schemes and apply instruments that affect forest-related policymaking at the EU and Member State levels (Cuypers et al., 2013). Thus, although there are no binding instruments at the European level, not being legally binding does not mean that European forest governance remains uninfluenced by these agreements. For example, the definition of policy goals for SFM and the formulation of principles for national forest programmes have been on the increase across Europe. From the discussion above, it is evident that forest policy has filtered into European legislation over recent decades (Pülzl, 2013).

Box 2.1 Forest-related targets of the proposed SDGs

Forest-specific targets

- 15.2 To promote the implementation of the sustainable management of all types of forests, halt deforestation and restore degraded forests, and increase afforestation and reforestation globally by 2020.
- 15.b To mobilise significant resources from all sources and at all levels in order to finance SFM, and to provide adequate incentives to developing countries to advance SFM, including conservation and reforestation.

Targets that address the water-supply function of forests

- 6.6 To protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes, by 2020.
- 15.1 To ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems, particularly forests, wetlands, mountains and drylands, and their services, in line with obligations under international agreements, by 2020.

Source: http://www.fao.org/3/a-i4600e.pdf, accessed on 25 February 2016.

2.2 Forest-relevant policies in the European Union and Europe

EU policymaking, in relation to forestry, is, thus, significantly interlinked with ongoing activities at global and pan-European levels. A number of forest-related legally binding instruments have been agreed and ratified. These include the Bern Convention on the Conservation of European Wildlife and Natural Habitats, which comprises the protection of some forest species. The European Landscape Convention also relates, in part, to forests, but does not provide a coherent approach to SFM. Subregional conventions, such as the Alpine and the Carpathian Conventions, are binding for a limited number of EU Member States and both of these conventions have adopted protocols on forests. The protection component for forest ecosystems seems well developed, although a comprehensive legal action for forests in Europe is still missing.

The current uptake of international forest policy initiatives in the EU and as part of the Forest Europe process will shape the forest ecosystems of the future. The implementation of Forest Europe started at the beginning of the 1990s, as a follow-up to the Rio Earth Summit (Pülzl and Mayer, 2015). The EU and its Member States are members and contribute to the Forest Europe process (MCPFE, 1993). Its members aimed, rather successfully, to develop policies on how to further protect and manage forest ecosystems sustainably (see Box 2.2). Negotiations for a LBA have been in progress since 2012; however, at present, they have come to a halt.

A potential alternative to the Forest Europe process would be for more regional treaties to issue forest protocols (like the Alpine Convention and the Carpathian Convention) that will impact on forest ecosystems. Northern and Mediterranean regions could follow this regional approach, and develop treaties and protocols that might meet their needs more precisely. This approach, however, poses the risk of increasing the lack of coherence across policy instruments across Europe.

Box 2.3 shows an example of the uptake of EU forest-related policies outside the EU. These policies may act as drivers of change and, potentially, could have direct and indirect impacts on the way in which forests are managed.

The treaties of the EU make no provision for a common forest policy and the competence of forest policies lies mainly with the EU Member States under the principle of subsidiarity, as stipulated by the Treaty of Lisbon. The

Box 2.2 Pan-European reporting on the sustainable management of forests

Several international processes that aim to safeguard the sustainable management, production and use of forests for multiple functions support the protection of the forest resource base. The regular FRA of the FAO and the Forest Europe process involves reporting on Europe's forests in order to assess progress towards the sustainable management of forests. The objectives of Forest Europe were laid out in a number of declarations and resolutions signed by the ministers in charge of forests during seven ministerial conferences, held between 1990 and 2015, based on the reported criteria and indicators at pan-European level. Forest Europe also cooperates with the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) in the implementation of the following forest-related criteria and indicators:

- the maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles;
- the maintenance of forest ecosystems' health and vitality;
- the maintenance and encouragement of productive functions of forests (wood and non-wood functions);
- the maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems;
- the maintenance, conservation and appropriate enhancement of protective functions in forest management (notably soil and water);
- the maintenance of other socio-economic factors and conditions.

Such reports are based on volunteer efforts by countries. The processes propose a common framework for recommendations that can be used on a voluntary basis. At the national level, such approaches are used as guiding principles that help to define new standards and practices for foresters. These may complement country- and regional-policy instruments to promote SFM at an operational level (Wolfslehner and Vacik, 2008). However, these instruments seem to have little impact at the regional or local level. In general, there is little feedback regarding SFM policies and their practical implementation.

Box 2.3 EU forest-related policies as drivers of change in accession countries

The West Balkan region serves as an excellent example of the impacts that EU policies can have outside the EU. The period of political and economic transition, and the aspiration towards accession to the EU, has given rise to significant political changes in recent decades in the West Balkan countries. These rapid changes are also reflected in forest policies and legislation. As it stands now, the prospect and process of entering the EU are major drivers for political and legislative reform. Some of the main challenges are the reorganisation of domestic forestry sectors, devolution processes, land ownership restitution, the adoption of rural development strategies, and changes in forest laws, forest certification and environmental impact assessments in order to comply with EU standards. For instance, direct impacts can be expected from the EU Timber Regulation (EUTR) (Regulation (EU) No 995/2010); the EUTR lays down obligations for the operators who place timber and timber products on the market. This instrument aims to prevent the trade of illegal timber; however, illegal logging remains a major issue in the West Balkans. As another example, the establishment of protected areas, compliant with Natura 2000 regulations, within the Emerald network is particularly relevant to West Balkan countries, as they are home to one of Europe's major biodiversity reservoirs.

In light of the expansion of the EU to include new members, these policy developments represent an important step towards harmonising native environmental legislation with the EU *acquis communautaire*, which is a prerequisite for accession to the EU. One of the most significant drivers of change is the EU's Stabilisation and Association Process, which stipulates regional cooperation among all of the West Balkan countries. Countries receive EU funding and support through the Instrument for Pre-Accession Assistance (IPA). This instrument strives to increase compliance with EU regulations and norms, and addresses EU policy requirements with regard to increases in woody biomass utilisation for bioenergy, forest certification and environmental protection, by establishing new protected areas and wildlife management.

roles of the EU are mainly to monitor and report on the state of Europe's forests, to anticipate global trends and challenges, and to adopt a coordinating role.

The management, conservation and sustainable use of forests are critical concerns for common policies, such as the common agricultural policy (CAP), and rural development, environment, trade and internal market research, industry and energy policies. Forest-relevant EU policies have shifted from focusing on agriculture and trade issues towards other issues. Forest ecosystems have gained attention through the implementation of the Habitats Directive and other protective legislation, such as the Biodiversity Strategy (EC, 2011a). Furthermore, a number of policy targets have been developed for forest ecosystems and are enshrined in European legislation. For instance, forests are relevant to the achievement of the '20-20-20 targets' (i.e. by 2020, GHG emissions should be 20 % lower than they were in 1990, 20 % of energy should come from renewables and there should be a 20 % increase in energy efficiency) because of their contribution to the mitigation of and adaptation to climate change, and their role as a source of renewable bioenergy (EC, 1999, 2013a). Another example is the efforts to combat illegal logging and improve forest governance abroad, and to ensure legal compliance with regard to wood and forest products imported into the EU. In 2003, the European Commission launched its Forest Law Enforcement Governance and Trade (FLEGT) action plan to prevent and combat the illegal harvesting of wood and the related trade of forest products. Moreover, targets have been set to halt the loss of global forest cover by 2030, and to reduce gross tropical deforestation by at least 50 % by 2020.

Forest-related policies are also included as part of main policy initiatives such as the Seventh Environment Action Programme (7EAP) (EC, 2013b) and the EU Biodiversity Strategy (EC, 2011a). The 7EAP, entitled *Living well, within the limits of our planet*, sets out a strategy to achieve the 2050 vision for the EU and its environment. The 7EAP emphasises the need for further action at EU and national levels for the sustainable use of forests. The main aim of the Biodiversity Strategy is to 'halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020'.

The EU Biodiversity Strategy to 2020 (EC, 2011a) aims to achieve 'healthy and diverse ecosystems' that provide multiple services for human well-being (see Box 2.4). The Strategy includes six targets (Box 2.5), several of which specifically address forests and forestry. The Member States are requested to achieve, by 2020, 'a significant and measurable improvement in the conservation status of forest species and habitats by fully implementing EU nature legislation (Target 1); maintained and enhanced (forest) ecosystems and services (Target 2); and biodiversity conservation that is integrated into other key policy sectors, with greater promotion of SFM (Target 3)', so as to increase the sector's contribution to maintaining and enhancing biodiversity (see Box 2.6).

The EU Forest Strategy (EC, 2013c) adopted in 2013, and its multiannual implementation plan for 2015–2020, supports the targets of the EU Biodiversity Strategy. The Forest Strategy aims to coordinate the abovementioned dense regulatory framework of forest-relevant policies (Figure 2.1). The main objectives are centred on SFM. There is also a strong focus on the multifunctional nature of forests and the major challenges facing European forests and forestry. The protection of forests against increased environmental pressures and threats is essential for the provision of ecosystem services by forests. The spotlight is on resource efficiency and the contribution of forests and the forest sector to growth and job creation through ecosystem services, especially in rural areas. Finally, the strategy emphasises global forest-related responsibilities, and the promotion of the sustainable production and consumption of forest products. The EU Forest Strategy urges for more synergy with other EU policies that have an impact on forests and their management.

Finally, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012 as an independent intergovernmental body. IPBES currently conducts a set of regional and subregional assessments with the following overall scope: 'to assess the status and trends regarding biodiversity, ecosystem functions and ecosystem services and their interlinkages and the impact of pressures on human well-being. The effectiveness of responses, including the Strategic Plan for Biodiversity 2011–2020 and its Aichi Biodiversity Targets and the national biodiversity strategies and action plans developed under the CBD are also

Box 2.4 EU 2020 headline target and EU 2050 vision on biodiversity in the EU

EU 2020 headline target: to halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020 and to restore them as far as is feasible, while stepping up the EU contribution to averting global biodiversity loss.

EU 2050 vision: 'by 2050, EU biodiversity and the ecosystem services it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value and their essential contribution to human well-being and economic prosperity and so that catastrophic changes caused by the loss of biodiversity are avoided'.

Source: EC, 2011a.

Box 2.5 The six EU Biodiversity Strategy targets

1. Full implementation of EU nature legislation to protect biodiversity.
2. Better protection for ecosystems and more use of green infrastructure.
3. More sustainable agriculture and forestry.
4. Better management of fish stocks.
5. Tighter controls on invasive alien species.
6. A bigger EU contribution to averting global biodiversity loss.

Source: EC, 2011a.

Box 2.6 Target 3B) Forests: Increase the contribution of agriculture and forestry to maintaining and enhancing biodiversity

'By 2020, Forest Management Plans or equivalent instruments, in line with SFM, are in place for all forests that are publicly owned and for forest holdings above a certain size (to be defined by Member States or regions and communicated in their Rural Development Programmes) that receive funding under the EU Rural Development Policy, so as to bring about a measurable improvement in the conservation status of species and habitats that depend on or are affected by forestry and in the provision of related ecosystem services as compared to the EU 2010 Baseline'.

Source: EC, 2011a.

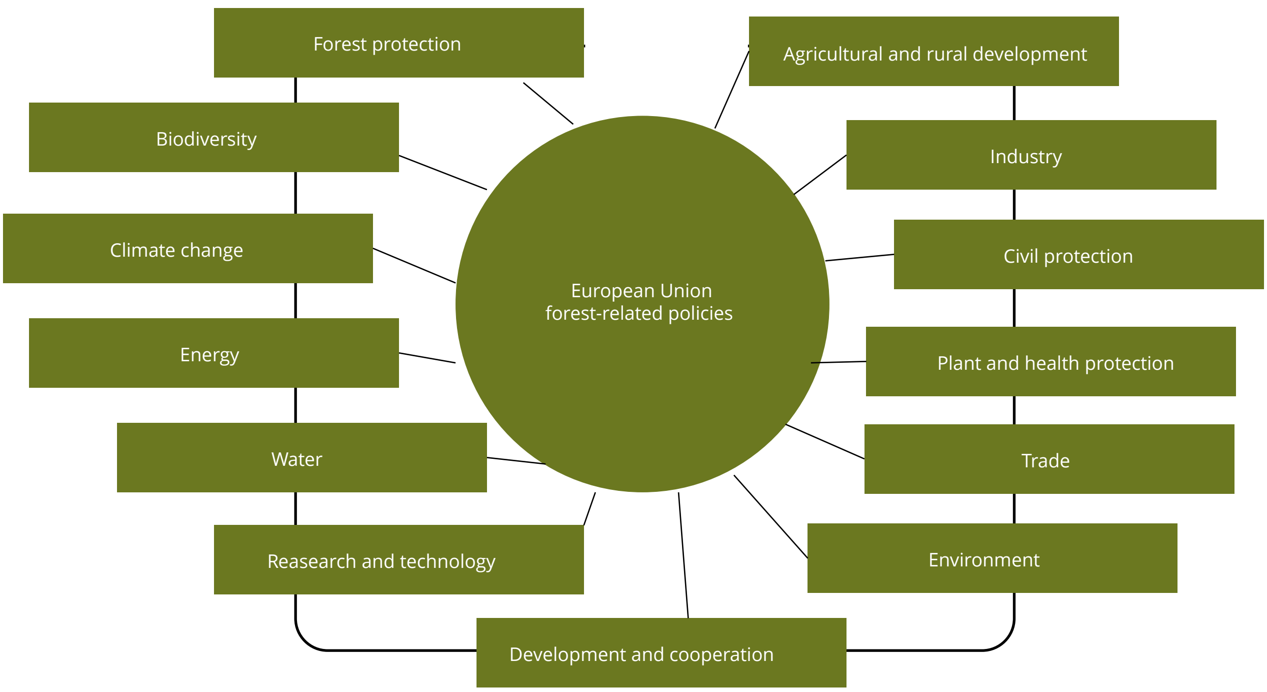
under evaluation' ([4]). The assessments carried out by IPBES also include assessments related to terrestrial biodiversity, and ecosystem functions and services.

From this overview, it is clear that EU forest governance is cross-sectoral by nature. A complex web of legal and non-legal instruments impact forests in the EU (and beyond), as shown in Figure 2.1.

EU forest strategies and action plans that directly affect forest ecosystems are voluntary, and their implementation depends mainly on the will of individual Member States. The indirect policy demands that relate to forest ecosystems have increased in the past decade, as a consequence of an increasing number of legislative acts related to forests (Pülzl, 2013; Wydra, 2013). Some of these policies are binding treaties that Member States must respect.

However, these attempts to exert an influence on the future management of forests are largely restricted by perspectives that are not necessarily relevant to forests. These varying interests create a challenge for compliance, as the implementation of several policy instruments often leads to fragmented and splintered decisions, based on different sectoral interests, whenever new targets evolve outside the forestry sector (Aggestam and Weiss, 2011; Vogelpohl and Aggestam, 2012). The conflicts arising because of trade-offs between biodiversity conservation and biomass extraction for energy are one example of this. There is an increasing risk that forests will not be included in EU policy targets in order to fill gaps in other EU policies. Although trade-offs between various forest uses exist (Wolfslehner et al., 2013), the shared EU goals of forest-based sectors have not yet been defined (see Table 2.1).

Figure 2.1 Policy areas relevant to forest-related policies in the EU



Source: Adapted from Pülzl et al., 2013.

([4]) http://www.ipbes.net/images/decisions/ipbes3/Decision_IPBES_3_1_Annex_III_Advance.pdf.

Table 2.1 Policy objectives and/or targets that affect European forest ecosystems

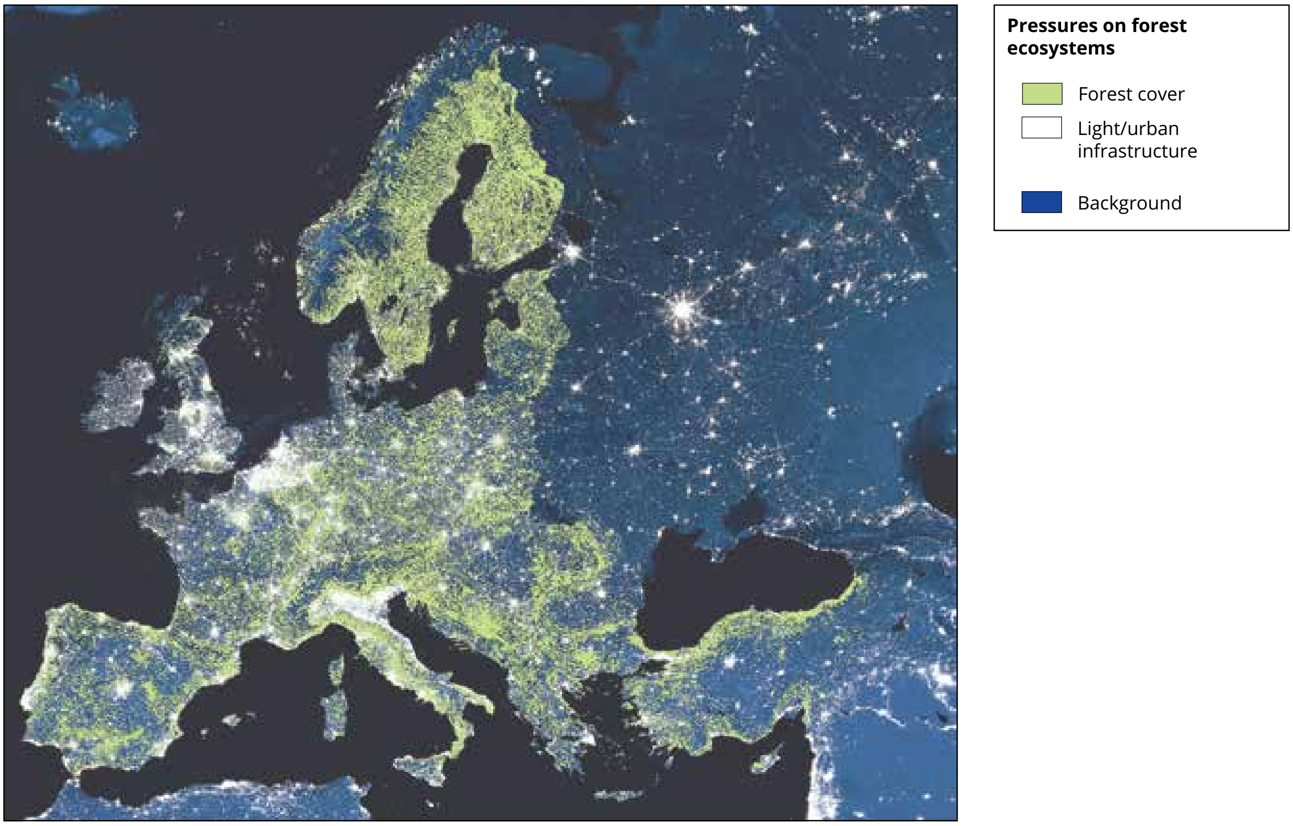
Policy document(s)	Policy objective(s) or target(s)	Timeline > 2014	Timeline 2014–2020	Timeline > 2030	Timeline > 2050
Forests in Focus					
A new EU Forest Strategy; for forests and forest-based sector (EC, 2013)	Ensure that all forests in the EU are managed according to SFM principles	■	■		
	Balance forest functions and deliver vital ecosystem services	■	■		
	Provide for forestry to be competitive and contribute to the bio-based economy	■	■		
Agricultural and Rural Development					
Common agricultural policy (Regulation 1306/2013, 1307/2013, 1308/2013)	Improving the competitivenss of agriculture	■	■		
	Balance territorial development of rural areas	■	■		
	Sustainable management of natural resources and climate action	■	■		
Rural Developmenet Policy (Regulation 1303/2013, 1305/2013)	6 rural development priorities: knowledge transfer, enhanced competitiveness, promote food chain organisations, restore and enhance ecosystems, promote resource efficiency, promote social inclusion	■	■		
Cohesion Policy					
Cohesion Fund and repealing Council Regulation (EC) no 1084/2006 (Regulation 1300/2013)	Reduce greenhouse gas emissions by 20 %; increase energy efficiency by 20 % and generate at least 20 % of the energy consumed from renewable sources	■	■		
	Reduce carbon emissions by 85–90 %	■	■	■	■
Environmental Policy and Biodiversity					
EU Biodiversity Strategy to 2020 (2011/2307(INI))	Map and assess the state of ecosystems and their services at national level	■	■		
	Forest Management Plans in line with SFM	■	■		
	Measurable improvement in the conservation status of species and habitats depending on forests (and for ecosystems services) compared to the 2010 Baseline	■	■		
Habitats and Birds Directives (Directive 92/43/EEC, 2009/147/EC)	Establish coherent network of protected areas under Natura2000	■	■		
Energy and Climate					
Climate and Energy Package (Council, 2008)	Raising the energy consumption produced from renewable resources to 20 %	■	■		
	Reduce EU domestic greenhouse gas emissions by 40 % below the 1990 level	■	■	■	
Resource efficient Europe (EC, 2011b)	Cut emissions to 80 % below 1990 level through domestic reductions	■	■	■	■
Other policy areas					
Plant Health and Reproductive Materials (Directive 2000/29/EC)	Protect forest ecosystems from harmful pests and diseases by preventing their introduction into, or their spread within the EU	■	■	■	■
Forest Law Enforcement, Governance and Trade (FLEGT), EU Timber Regulation (EUTR), and Reducing Deforestation and Degradation (REDD+) (Regulation 995/2010 EC 2012)	Prevent the import of illegal timber into the EU	■	■		
	Reduce gross tropical deforestation by at least 50 %	■	■		
	Halting global forest cover loss	■	■	■	
Bioeconomy Strategy (EC, 2012)	Promote the uptake and diffusion of innovation in the bioeconomy sector	■	■		

3 Forests under combined pressures — European issues

The state of forest ecosystems in Europe and their prospects give an indication of whether or not they are healthy, diverse, productive and able to absorb disturbance without collapsing (also known as ecosystem resilience). Forests have evolved while experiencing disturbances such as drought, storms, insect and disease outbreaks, and fire. Forests also have to cope with multiple pressures from a range of human-related activities that affect forest health. These include activities that directly affect forests, such as logging and clearing, and activities that affect forests indirectly through, for example, climate change, air pollution and invasive species. There are increasing concerns regarding the state of forest ecosystems and the long-term sustainable provision of forest products and ecosystem services. In this report, pressures are attributed to human-made factors, whereas threats relate to natural factors. This chapter focuses on pressures that are common to most forest ecosystems in Europe, and on how these pressures affect the state of forest ecosystems.

The top four pressures that affect Europe's forests are (1) habitat loss and degradation; (2) invasive alien species (IAS); (3) pollutants and the exceedance of nutrient loads; and (4) climate change (Seidl et al., 2014). These pressures may threaten the stability and health of forest ecosystems in terms of their structure, composition and function. All of these changes are connected to accelerating production and consumption, a growing population, socio-economic and cultural globalisation,

Map 3.1 Europe by night — the extent of urbanisation and infrastructure on European territory and forest ecosystems



Source: http://svs.gsfc.nasa.gov/vis/a000000/a002200/a002276/index.html and EEA Copernicus High-Resolution layer forest type (2012).

and widespread patterns of inequality (ISSC and Unesco, 2013). Map 3.1 reveals that remarkably few areas, if any, are unaffected by human influence.

The sustainable management and use of forest resources are vital for achieving sustainable development in Europe and this should play a fundamental role in maintaining or increasing forest resistance and resilience in the face of global environmental changes.

3.1 Habitat loss and degradation

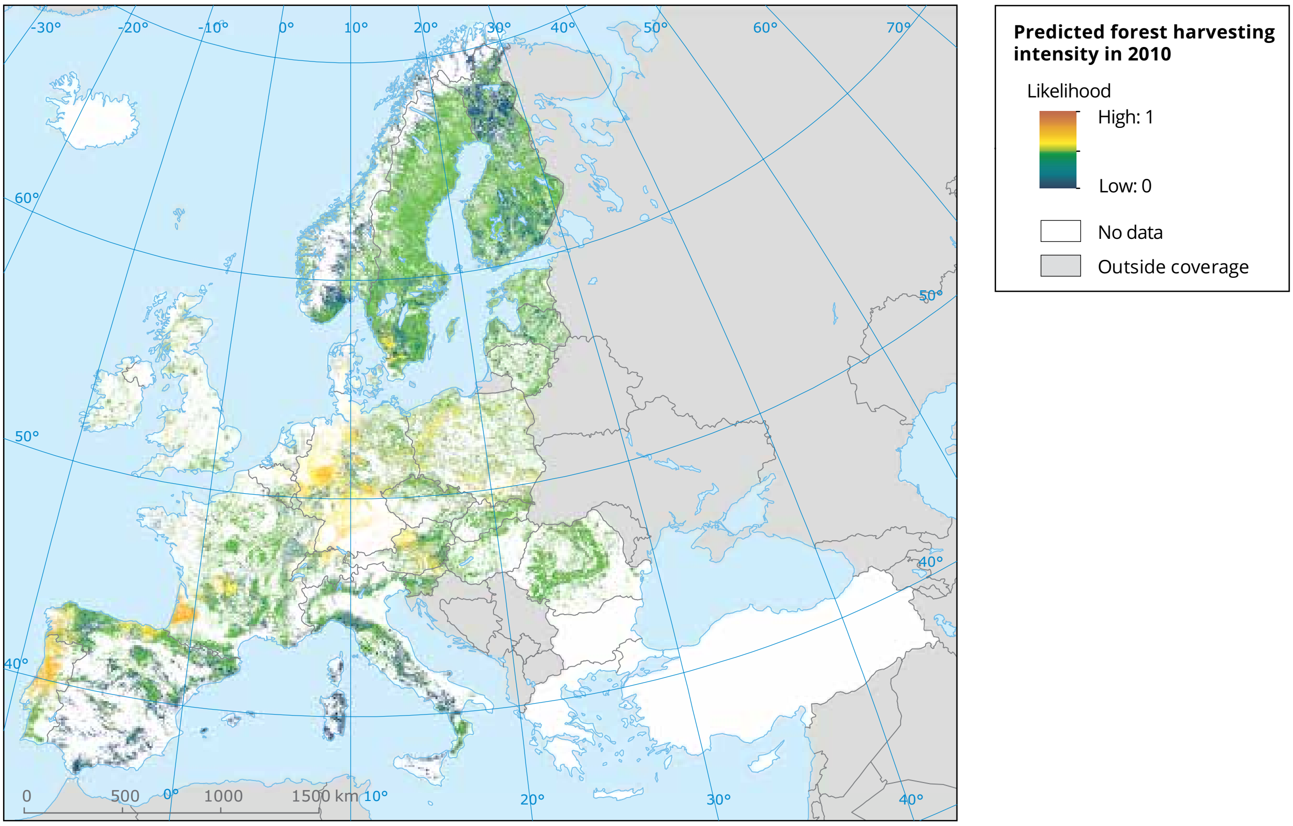
3.1.1 Resource use

Forests are human-dominated ecosystems. Over the last centuries, more or less intensively managed forests have replaced Europe's natural forests. At present, only 27 % of Europe's forests are uneven-aged forests, and 30 % have only one tree species. Furthermore, 51 % have only two to three tree species, and only 5 % of forests have six or more tree species (Forest Europe et al., 2011).

The intensity of forest management affects forest structure, soils, biogeochemical cycles, biodiversity and ecosystem services (EEA, 2015b). The increased extraction of forest products and intensified forestry practices may be a source of conflict between biodiversity and human activities, especially in northern and western European countries (Hellström, 2001). Some forestry practices impair biodiversity protection. One example is the level of removal of deadwood and stumps from forests for bioenergy purposes. Such practices can destabilise forest ecosystems and lead to changes in forest structure (Vilén et al., 2015), soils (Jandl et al., 2007) and biogeochemical cycles (Luyssaert et al., 2012; Nabuurs et al., 2013). Both biodiversity (Paillet et al., 2010) and ecosystem service provisioning (Gamfeldt et al., 2013) may be impacted as well. The type and the intensity of the disturbances that occur as a result of such forest practices can deviate dramatically from those that occur as a result of natural disturbance processes. Nevertheless, only 10 % of Europe's forests have been classified as intensively managed. Moreover, over recent decades, there has been an increased emphasis on forest management approaches that consider the protection of forest ecosystems, their services and their biodiversity.

Understanding the spatial patterns of the intensity of forest management and its drivers is essential for the assessment of environmental trade-offs related to forestry and for the identification of opportunities for the sustainable management of forest ecosystems (Map 3.2). According to Member States' projections

Map 3.2 Predicted forest harvesting intensity in 2010



Source: Levers et al., 2014.

under LULUCF, harvest rates were expected to increase by approximately 30 % between 2010 and 2020, and would, therefore, reach marginally unsustainable levels (Ellison et al., 2014; EC, 2013d). Furthermore, while maintaining harvest rates below production rates is a necessary condition for sustainability, it is not sufficient on its own, as the ratio does not capture any qualitative information on whether or not forests are being managed for biodiversity.

Substantial increases in food and biofuel production are expected globally during the remainder of the 21st century. It has been estimated that global food needs could increase by more than 100 % (Alexandratos et al., 2012). The competition for land for urban areas, infrastructure, agriculture, nature conservation and biomass production (including wood for energy needs) is very likely to increase.

Agricultural production in Europe has intensified on already available and suited farmlands and vast areas of farmland have been and are expected to be abandoned over the next 20 to 30 years (Renwick et al., 2013). Such land abandonment could provide opportunities for afforestation, especially in highly fragmented landscapes (Keenleyside et al., 2010). However, there are concerns about this development because of the associated risks of fire in southern Europe, the loss of farmland biodiversity in northern regions and overall rural depopulation. Farmland abandonment in Europe may, nevertheless, lead to the displacement of land use to regions outside Europe, such as South-East Asia and South America with substantial environmental trade-offs (Meyfroidt et al., 2010; Sayer and Collins 2012; Laurance et al., 2014; Persson et al., 2014).

Concerns over energy security and the prices of energy feedstock have created demands for alternatives to fossil fuels, and woody biomass has attracted attention as one potential alternative. Currently, most wood fuel comes from forest industry residuals; the forest industry very efficiently recycles waste products for energy (EEA, 2013). Wood can be used for energy needs including traditional heating and cooking with fuelwood and charcoal. However, increased demand for wood for bioenergy may lead to more intensive management, shorter rotations and less deadwood in some forest ecosystems in the future. This, in turn, may lead to the loss and degradation of some forest habitats and species. Energy crops that are grown using short-rotation forestry (which is not considered forestry) compete for the same land resource. Therefore, in the future, land abandonment is likely to decline and forest areas are likely to stabilise or expand.

The demand for fuelwood is expected to grow further in light of the EU renewable energy targets for 2020 and beyond (EC, 2009a; EEA, 2011; Havlík et al., 2011). The targets for GHGs and the dependency on fossil fuels might encourage more imports of wood for bioenergy purposes to the EU. Currently, more than 30 % of the net primary production (NPP) of wood used in the EU stems from imported biomass and biomass products (Haberl et al., 2012).

Recent studies document that this trade is ecologically unequal, as considerable environmental costs are displaced to less developed countries, which increases the pressures on natural resources. EU Member States are among the highest land-consuming countries that depend on land resources outside their territories.

Photo 3.1 Rural land cover and land use

Another study claims that efforts to promote environmental sustainability in some countries are based on land displacement to elsewhere in order to meet their demands (Meyfroidt et al., 2010). Around 75 % of consumption in Europe relies on land use outside Europe according to Yu et al. (2013). Between 30 % and 70 % of forest land in developing countries has been displaced for consumption in the EU and the USA, which import roundwood and other wood products for infrastructure.

3.1.2 Land-use changes, deforestation and fragmentation

Land-use changes are considered major causes of the degradation and loss of forest habitats and species in Europe.

Deforestation — the change of forest land to land for other uses

Deforestation occurs if forests are converted for other land uses. Currently, this conversion, particularly the conversion of forests to agricultural land, represents the single largest driver of deforestation globally: about 13 million ha of forests are converted every year (Weinzettel et al., 2013). Recent studies estimate that agricultural expansion accounted for 53 % and approximately 80 % of the global deforestation that occurred in the periods 1990–2008 and 2000–2010, respectively (Cuypers et al., 2013). The EU is the main importer of deforestation-related commodities. The products most associated with deforestation are meat products (which account for 57 % of deforestation), particularly beef products, soy for European pig farms, palm oil and cocoa (Brack, 2013). In addition, deforestation is one of the major human-made causes of emissions of carbon to the atmosphere (approximately 17 % of total emissions). A range of initiatives is needed to improve the sustainability of the production of these agricultural products in Europe, and to reduce the impacts on forests at the global level. The import of many of these products is consumer driven, and, thus, supply-chain controls, similar to those aimed at addressing unsustainable timber extraction, might improve the situation.

The logging of forests is not considered deforestation as it is part of normal forestry practice. Trees are replanted, as required by national forest acts in Europe, immediately after the forest stands have been clear-cut. However, deforestation is occurring in Europe. Individual country submissions ([5]) to the Kyoto Protocol in 2011 (for the period 1990–2012) estimate that, on average, each year approximately 100 000 ha of forests are permanently converted to non-forest land in EU-28, Norway and Switzerland (Gerard et al., 2010; UNECE and FAO, 2015). The main drivers of land-use changes and deforestation in Europe are urban and infrastructure (e.g. transport, markets, energy and mining) developments, and the expansion of services from other ecosystems, such as the intensification of agriculture, which lead to the removal of small forest patches from formerly mosaic landscapes (EEA, 2008, 2010).

Deforestation severely impacts upon forests, as forest habitats and species disappear and forests become fragmented into smaller forest stands; such fragmentation is associated with the risk of severe habitat degradation, the loss of species and the replacement of forests with other habitat types (Vandewalle et al., 2010; Zimmermann et al., 2010; Bajocco et al., 2012).

Fragmentation of forested landscapes

The fragmentation of forest ecosystems and habitats threatens their ecosystem functions and services. Changes in the distribution of forests in the landscape have an impact on ecological processes, such as habitat provision, gene flow, pollination, wildlife dispersal and pest propagation, in different ways (Aitkenhead-Peterson et al., 2010; Reynolds and Clay, 2011; Jeltsch et al., 2013; Harsh, 2015). There is strong evidence that a decrease in the extent of habitats causes a decline in species richness and abundance. The population sizes of remaining species will decrease until species exist in only small, isolated populations, which is associated with an increased risk of extinction (Kuussaari et al., 2009). After fragmentation, the remnant forest is typically surrounded by a matrix of agricultural, urbanised and other developed land; this alters ecosystem processes, such as the movement of water and nutrients across landscapes (Ewers and Didham, 2006; Cousins, 2013). Likewise, many animals are threatened as they cannot survive in small fragmented forests. In particular, large mammals need extensive areas of forest in order to obtain sufficient food. Many studies document that species are more likely to become endangered in fragmented landscapes.

While forest cover in Europe is increasing, the spatial pattern of forests across the landscape is also changing. Forest fragmentation is increasing at the local scale as a result of multiple habitat gains and losses. This is driven by land take for agricultural expansion, housing, transport infrastructure and recreation. The mapping of landscape fragmentation pattern trends gives an overview of areas with significant fragmentation,

([5]) http://unfccc.int/national_reports/annex_i_ghg_inventories/inventory_review_reports/items/6617.php.

increased connectivity and stable conditions. Between 2000 and 2006, the expansion of residential areas and construction sites into forest land in Europe was relatively small (approximately 13 %) in comparison with the uptake of agricultural land (more than 45 %) ([6]). However, more than 75 % of Europe's population live in urban areas and this has a significant impact on consumption demands for water, fuel and other natural resources that are generated by forests, which, therefore, impacts on forest ecosystems (Hannah et al., 1995; Hannah, 2010).

More than 35 % of European forests are in mosaic landscapes that are significantly fragmented by agricultural and artificial lands. Two-thirds of forests are within mixed, still predominantly natural lands. One-third of forests are embedded in predominantly agricultural or artificial landscapes with only some natural lands (EEA, 2016). Landscapes with high levels of fragmentation (more than 30 %) represent more than 60 % of the EU. In most countries, the number of fragmented landscapes (> 50 %) was either stable or increased between 2000 and 2012. This suggests that landscape permeability and the distance between forest areas are not sufficiently accounted for in management and planning strategies.

Efforts are being made to halt landscape fragmentation and re-connect environments through land and forest management (e.g. through the establishment of Natura 2000 sites). The large areas of managed forest land in Europe are considered central to Europe's ability to alleviate biodiversity loss (EEA, 2015b).

3.1.3 Illegal logging

Vast areas outside Europe are subject to illegal logging. More than half of the deforestation that occurs for commercial agriculture, mainly for export, that takes place in tropical forests is considered illegal (Brack and Bailey, 2013; Persson et al., 2014). For instance, in Indonesia, forests are clear-cut for timber and oil palm plantations and, in Brazil, deforestation is associated with soy and beef cattle production (Gasparri and de Waroux, 2014).

Within the EEA region, illegal logging is an issue of concern in the Baltic states, the Balkan region and, to a lesser extent, some central-eastern European countries (Forest Europe et al., 2011). However, statistics on illegal logging are sparse, see also Box 3.1. For instance, for south-eastern Europe, estimates suggest that between 1 % and 35 % of the timber supply comes from illegal sources, with significant differences across countries. The main driver for illegal logging in this region is poor socio-economic conditions, with individual households logging for firewood or small-scale trading on local markets. The effects of illegal logging include the loss of habitats and biodiversity, erosion and land degradation, desertification, social disruption and adverse economic impacts, both with regard to stealing resources from lawful owners and lost tax revenues for governments (Markus-Johansson et al., 2010).

3.2 Invasive alien species and introduced non-native species

IAS are non-native plants, animals, pathogens and other species that may cause harm to the native biodiversity and ecosystems of Europe. Damage can result from the competition between these species and native species for food; from their consumption; through the spread of disease; through genetic changes caused by interbreeding with native species; and as a result of the disruption of various aspects of the food web and the physical environment (Kimmins, 2008). These negative

Box 3.1 Unregistered fellings

Illegal logging and related trade refer to the harvesting, transport, processing, purchase or sale of timber in violation of national or subnational laws (Jonsson, 2015). A driver of illegal logging is the increased demand for timber products. Illegal logging damages forest ecosystems, costs forest managers billions in lost revenue, and is often associated with corruption and armed conflicts.

Removal statistics do not always fully account for all wood harvested; for example, they do not fully capture the quantity of wood harvested for local household consumption. Small quantities of fellings, which may, however, add up to significant volumes, are often not registered in official statistics. For example, 16 % of the overall forest wood consumption between 1987 and 2005 in Germany is assumed to have come from unregistered sources (Mantau et al., 2008, 2010).

Unregistered fellings are those that do not enter the (official) trade market but that come from small private owners and are for personal use. They are legal, if harvested in line with national environmental and forest management laws and practices, but may be subject to taxation.

([6]) http://www.eea.europa.eu/data-and-maps/indicators/land-take-2/assessment-2.

impacts of IAS alter ecosystem processes and reduce forest health and productivity. For example, the black cherry (*Prunus serotina*) out-shades ground vegetation and prevents the regeneration of native forest trees, which may have a long-lasting effects on forest succession. Therefore, IAS may ultimately lead to the loss of biodiversity. IAS are considered to be the second-most significant cause of biodiversity loss worldwide, after direct habitat loss and degradation (Shine et al., 2009).

Several European databases have inventoried IAS presence and distribution across all ecosystems in Europe. One of these databases, Delivering Alien Invasive Species in Europe (Daisie) (Daisie, 2011), has inventoried more than 12 000 IAS (see also Box 3.2). Terrestrial plants and invertebrates are, by far, the most common type of IAS, and they represent over 6 500 and 2 700 species in Europe, respectively. Among the problematic IAS, 33 are regularly found in European forest ecosystems or are dependent on trees. These problematic IAS comprise 8 species of mammals, 11 species of insects and other invertebrates, 12 species of vascular plants, including trees, and 2 species of fungi (EEA, 2012a). The number of IAS in forests may seem low compared with the numbers found in other ecosystems, especially given the extent of forests in Europe. However, the number of IAS and their damaging impacts are increasing and are expected to increase even further as a consequence of climate change, particularly in northern Europe (see Map 3.3).

IAS can spread in a variety of ways. Humans can intentionally or unintentionally introduce species into new areas or alter ecosystems in ways that promote invasions. Some IAS are important for farming, forestry, aquaculture, horticulture or recreational purposes (e.g. as pets or garden plants), or as biocontrol agents (e.g. Asian ladybirds). Other IAS have been introduced unintentionally as contaminants of other commodities (e.g. ragweed seeds in bird feed mixtures). Pathogens and insects that are introduced via imported wood or other forest products also present a threat (see Box 3.3). Invasive alien tree species are becoming established along forest edges.

The potential damage of harmful invasive organisms, and the costs associated with monitoring and combating them, can be tremendous. The incidence of invasive alien pests, such as the pinewood nematode (PWN) (see Box 3.4) and several species of fungi, is increasing in Europe. Currently, IAS cause damage estimated to cost approximately EUR 12.5 billion each year in the EU (EEA, 2012a).

Many introduced forest tree species are considered IAS. These are mainly broadleaved species. Ten countries (Austria, Croatia, Denmark, France, Hungary, Italy, Poland, Slovakia, Slovenia and Spain) have designated black locust (*Robinia pseudoacacia*) as an invasive alien tree species. Tree of heaven (*Ailanthus altissima*), originally introduced as an ornamental tree and for roadside planting, is now considered invasive in forests in France, Hungary, Italy, Slovakia and Spain. Another problematic tree is the sycamore (*Acer pseudoplatanus*), which was introduced to Norway as an ornamental tree about 250 years ago. The sycamore is now considered a problem as it has become invasive in the last 50 years, particularly in protected areas that were established to maintain Norwegian deciduous broadleaved forests. Conifer tree species are rarely considered as IAS.

The 2020 Biodiversity Strategy (EC, 2011a) highlights the significant pressures on biodiversity posed by IAS in the EU and acknowledges that these pressures are likely to increase unless action is taken to control the introduction and establishment of such species, and to address those that have already been introduced. The EU provides a legal basis for border control, with regard to the movement of plant material, in Council Directive 2000/29/EC of 8_May_2000 on 'protective

Box 3.2 IAS are listed in the Daisie database

IAS are defined as 'non-native species whose introduction and spread outside their natural past and present ecological range accidently or deliberately, with serious negative consequences for biodiversity, their new environment and economy' (COP 6, decision VI/23, http://www.eea.europa.eu/policy-documents/decision-vi-23-on-alien). An IAS will out-compete native organisms, spread throughout its new surroundings, increase in population density, and harm ecosystems and natural resources for generations (Scalera et al., 2012; EEA, 2012a). IAS can act as vectors for new diseases, alter ecosystem processes, change biodiversity, disrupt cultural landscapes, reduce the value of land and water for human activities, and cause other socio-economic consequences for humans.

Daisie is a comprehensive online European database of IAS that provides information on biological invasions. To date, 12 122 alien species are registered in this database, 15 % of which are considered to be invasive and to have negative ecological and economic effects. A list of the 100 IAS that present the greatest threats to biodiversity and ecosystems has been compiled (see http://www.europe-aliens.org/default.do).

measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community' (EC, 2000).

Climate change is likely to increase the presence and spread of IAS and their damaging impacts on agricultural, forest and natural resources.

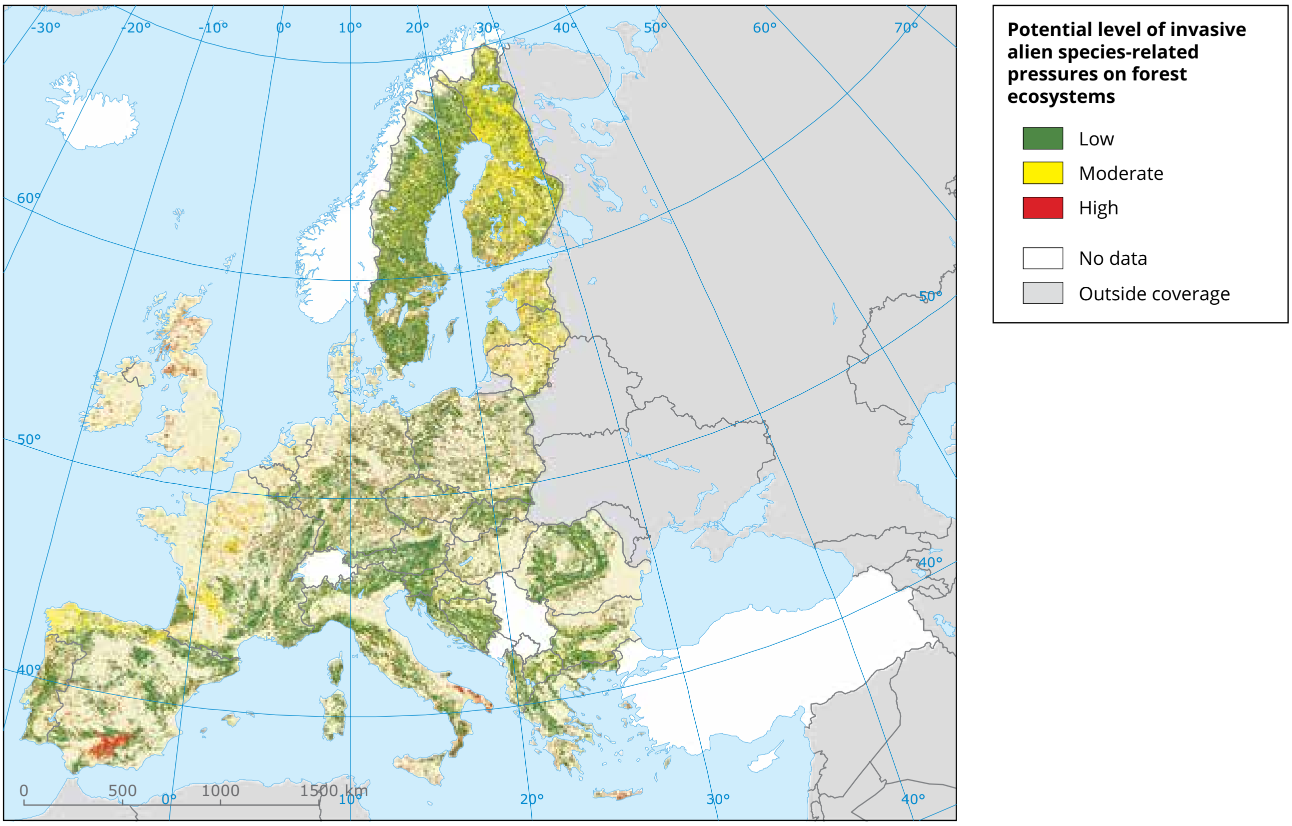
Box 3.3 Examples of dangerous IAS in Europe

The introduction and establishment of species beyond their native range can lead to high economic costs, and severe ecological and economic damages. For instance, insects that bore into the bark and wood of living trees may severely impact ecosystem structure and function because of the ability of some of these species to kill healthy trees. It has been estimated that 109 invasive alien insect pests of woody plants have been introduced to and established in Europe, 57 of these species are from North America and 52 are from Asia (Eyre et al., 2013). The Asian long-horned beetle (*Anoplophora glabripennis*) is an example of a dangerous animal that has been introduced as a consequence of increased intercontinental trade. This IAS is one of the most dangerous, as it kills deciduous trees. Since autumn 2011, the presence of this beetle has been documented at many sites (see http://www.bafu.admin.ch/wald/11015/11851/11852/index.html?lang=en).

The wide-spread Dutch elm disease has proved to be highly contagious and lethal to European elms; more than 25 million trees have died in the United Kingdom alone as a result of this disease (Daisie, 2011). The disease involves a virulent fungal pathogen, *Ophiostoma novo-ulmi*. This pathogen arrived in Europe in 1967 on ships made with elm logs from North America, and replaced a milder strain of the pathogen (*Ophiostoma ulmi*).

The chestnut blight fungus (*Cryphonectria parasitica*) is another example of a hazardous IAS. This fungus originated in Asia and has expanded, with regard to geographical area, at a slow, yet steady, rate since it was introduced to Italy in 1938 (Robin and Heiniger, 2001). It has devastated large plantations of sweet chestnut (*Castanea sativa*) in southern Europe.

Map 3.3 Potential level of invasive alien species-related pressures on forest ecosystems



Source: Malak et al., 2014.

Box 3.4 The example of the PWN (which has been detected in Portugal and Spain)

Recently, considerable attention has been given to a North American pest, the PWN (*Bursaphelenchus xylophilus*). In 1999, the PWN was detected close to Lisbon in Portugal (EPPO and CABI, 1990; Mota et al., 1999). Several new outbreaks have been identified since 2008 in other parts of Portugal, as well as in Spain. Scots pine (*Pinus sylvestris*) is at risk from this pest in northern and central Europe, whereas the European black pine (*Pinus nigra*) and the Maritime pine (*Pinus pinaster*) are threatened in central and southern regions of Europe.

In European countries, the authorities that are responsible for border control, with regard to imported wood and wood products, have long been aware of the risk of PWN introduction. PWN has been designated as a quarantine organism and strict measures on the trade of wood have been imposed to limit the invasion. These measures have added significantly to the costs already resulting from the destruction of pine forests.

Climate change is likely to affect populations of forest insect pests as a result of longer warm seasons, variations in precipitation patterns, modifications in food availability, and qualitative and quantitative changes in predator and parasite populations (Netherer and Schopf, 2010). There is evidence that these changes can affect the distribution and relative abundance of pest species in forest ecosystems, thus changing the frequency of pest outbreaks (Marini et al., 2012; Spathelf et al., 2014; Barredo et al., 2015). In Europe, higher temperatures are likely to promote distributional shifts of forest insect pests towards northern latitudes and higher elevations.

3.3 Pollutants and excessive nutrient loading

Atmospheric pollution, soil contamination and excessive nutrient loading affect exposed forest ecosystems. For instance, pollutants affect the CO_2 concentration in the atmosphere and the nutrient cycling in soils. Trees may become more susceptible to stress and acute events, such as drought, storms, diseases and pest infestation by, for example, the bark beetle (Paoletti et al., 2010; Southon et al., 2012; Erisman et al., 2013; Matyssek et al., 2013). This exposure may impact forest biodiversity and the capacity of forest ecosystems to provide valuable ecosystem services.

Pollutants have been a serious problem for forests in Europe, particularly in the 1980s and 1990s. Data on the concentration, deposition and impacts of pollutants are collected by countries in Europe under the Convention on Long-range Transboundary Air Pollution. Data directly related to ecosystem health have been used to assess damage to forests, crops, natural vegetation, soils, and surface and ground waters by determining the critical levels of pollutants and their loads with regard to the responses of these systems. The pollutant depositions and concentrations that exceed critical loads and levels are calculated and mapped in order to show the extent of air pollution impacts. An annual deposition of between 5 kg nitrogen per ha and 10 kg nitrogen per ha is estimated to be the general threshold for adverse effects; however, such adverse effects may occur at even lower levels over the long term (Clark and Tilman, 2008; Bobbink et al., 2010; Bobbink and Hicks, 2014). These assessments have successfully resulted in several emission reduction schemes, such as the 1994 Oslo Protocol on Further Reduction of Sulphur Emissions, the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone and, more recently, the EU National Emission Ceilings Directive (NECD) (EC, 2001).

The background concentrations of tropospheric ozone are increasing globally. Surface ozone concentrations during the summer growing season have fallen modestly in northern Europe, owing to emission controls on vehicles and industrial sources of ozone precursors. Additional sources of pollution are volatile organic compounds (VOCs), which are considered fuel for surface ozone production. They include a highly diverse group of chemical compounds with high vapour pressures, which contribute to the presence of nitrogen oxides, namely nitrogen monoxide (NO) and nitrogen dioxide (NO_2), and to photochemical ozone formation in the atmosphere. Related tree injuries include visible foliar injury and a decrease in biomass (Skärby et al., 1998; Mills et al., 2011; Holmes, 2014). Ground-level ozone may also have significant effects on biodiversity. One consequence could be, for instance, changes in species composition (Lindroth, 2010; Matyssek et al., 2010; Ainsworth et al., 2012).

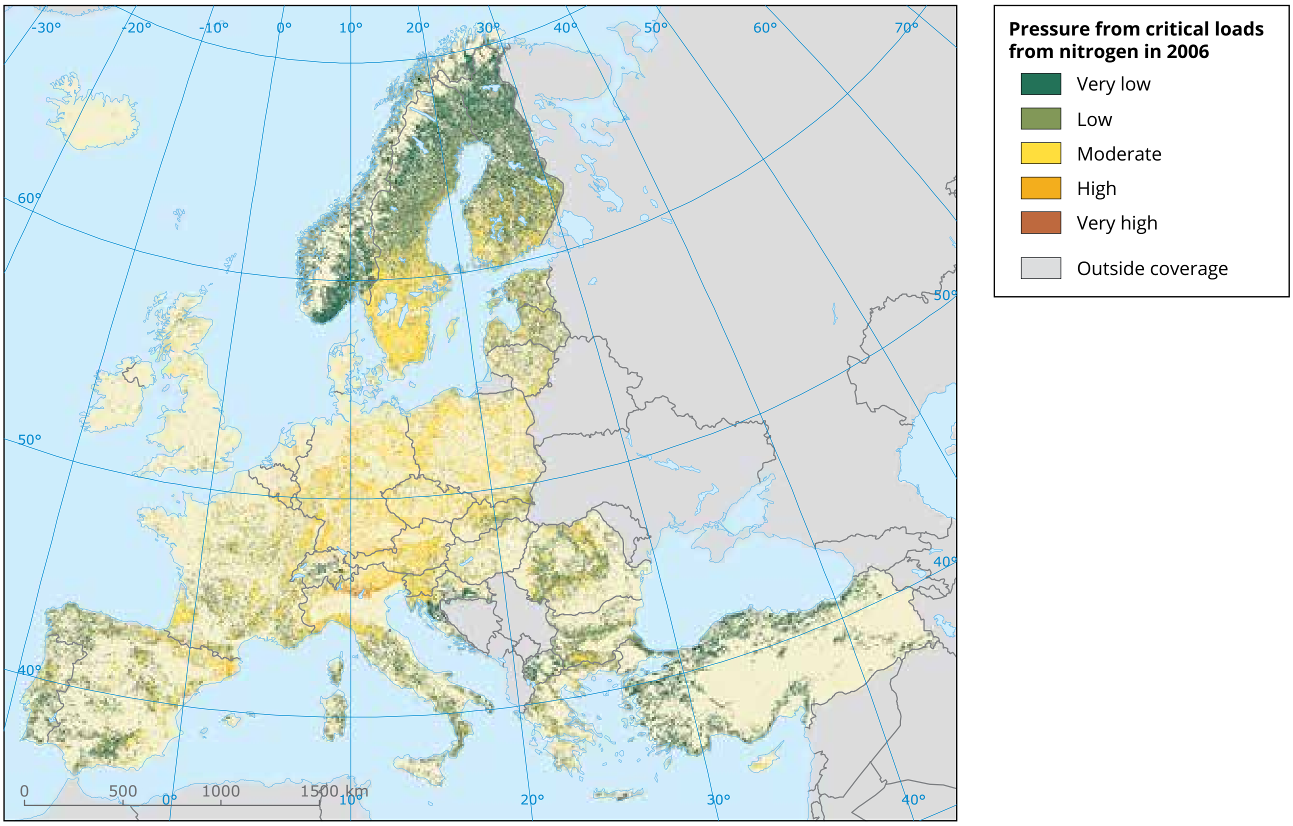
The nitrogen cycle has, to a large extent, been altered by human activities. Industrial and agricultural activities, as well as fossil fuel burning, emit nitrogen compounds to the atmosphere (Solberg et al., 2009). The atmospheric depositions of sulphate (SO_4^{2-}) and nitrogen compounds still exceed critical loads in many parts of Europe (see Map 3.4).

Among the European countries, northern central Europe has the highest inorganic nitrogen deposition levels. High deposition levels have been recorded in southern Germany, on the Swiss Plateau and further to the west in the north of France, the central United Kingdom and Ireland. Relatively high nitrogen deposition levels have also been recorded in regions bordering the Alps in the south, and some sites in Spain and southern France (Waldner et al., 2014).

This deposition contributes to the acidification and eutrophication of forest soils and freshwaters. Species limited by or adapted to nitrogenous or acidic environments are likely to thrive, whereas other species might be displaced. This is not desirable in protected ecosystems. An excess loading of nitrogen can lead to nutrient imbalances in trees and an increase in understory species, nonvascular plants (e.g. lichens) and mycorrhizal fungi, or changes in the composition of these species, which will, ultimately, increase the risk of degradation with regard to forest ecosystem health and vitality (Bobbink et al., 2010; Goodale et al., 2011; Thimonier et al., 2012). Nitrogen emissions are declining only slowly and, thus, acidification continues to impact terrestrial (including forest) and aquatic ecosystems (Hettelingh et al., 2013; de Vries et al., 2015).

Although a reduction in atmospheric emissions will not result in the immediate recovery of impacted forest ecosystems, there is clear evidence of recovery in some European forests and soils (see, for example, Vanguelova et al., 2010). However, there may be a legacy effect. Many effects of acid deposition are indirect and are associated with a decrease in soil pH values. For example, an increase in the solubility of toxic Al^{3+} ions is associated with a reduction in base cation concentrations. The leaching of base cations, especially magnesium, from soils has been linked to leaf chlorosis, a symptom that was commonly apparent on trees in some German forests in the 1980s; this yellowing was associated with forest decline (Katzensteiner and Glatzel, 1997; Eastaugh et al., 2011). Acid deposition can also lead to calcium leaching from conifer needles, e.g. in spruce, which become less able to withstand winter freezing/desiccation damage (Paoletti et al., 2010; Zetterberg et al., 2013).

Map 3.4 **Pressure on forests from critical loads from nitrogen in 2006**



Source: Malak et al., 2014.

3.4 The impacts of climate change

Climate change contributes to the rate, frequency, intensity and timing of these disturbances and its impact on forest ecosystems is expected to increase (Schelhaas et al., 2003; Seidl et al., 2010). Climate change and forests are closely connected through, for instance, air temperature, solar radiation and rainfall. The atmospheric concentration of CO_2 is a major driver of forest productivity and forest dynamics. Forests contribute to climate control through the large amounts of carbon they can remove from or release to the atmosphere, the absorption or reflection of solar radiation (albedo), cooling as a result of evapotranspiration, and the production of cloud-forming aerosols (Pan et al., 2011; Pielke, 2013). Changes in temperature and the availability of water can affect the health and productivity of different species in complex ways, by, for example, influencing species range and forest composition. The average atmospheric CO_2 concentration has now reached 400 ppm, mostly as a result of human activities. These increased concentrations of CO_2 and other GHGs contribute to global warming and increase the risk of abrupt, and possibly irreversible, changes that will affect the composition, structure, function and productivity of forest ecosystems. These shifts may have severe ecological and economic consequences (Hanewinkel et al., 2013). At the same time, forests mitigate climate change through the uptake of carbon. Therefore, the loss of forests through land-use conversion and forest degradation will increase CO_2 levels and contribute to climate change (IPCC, 2014a, 2014b). Climate change affects forest ecosystems as well as individual species. However, the assessment of the degree of impacts may not always be clear, as all forests are under management and the effects of forest management are difficult to separate from the effects of climate change. Nevertheless, forest biomass has grown over the past two decades, at an accelerating rate, as a consequence of a number of factors.

The distribution of several forest species is changing significantly. Trees migrate relatively slowly, primarily into newly suitable habitats at the latitudinal or altitudinal extremes of their ranges. The end edge of a tree population's distribution range is often the most southern part or the part with the lowest altitude. Because of climate change, these parts may become unsuitable for certain tree species as a result of direct effects, such as drought, or indirect effects, such as drought-induced pests or diseases. In France, the altitudinal distribution of 171 forest plant species at an elevation range of 0–2 600 m above sea level was studied using a 101-year data record that started in 1905. Climate warming has resulted in, on average, a significant increase, of 29 m per decade, in the optimum altitude for species; however, the change in optimum altitudes varied widely, from + 238 m per decade to – 171 m per decade, among species (Lenoir et al., 2010). Land-use changes are the most likely explanation for the observed significant decrease in optimum altitudes in some regions. In the Montseny mountains in north-east Spain, it was shown, using different data sources, that the altitude range for beech extended by approximately 70 m between the 1940s and 2001. A study comparing data from the 1990s and the 2000s for the Spanish Pyrenees and the Iberian System found a regular optimum altitudinal shift of 31 m per decade for five tree species, ranging from − 34 m to + 181 m per decade (Urli et al., 2014). Nevertheless, not all studies found a clear association with climate change (Rabasa et al., 2013), partly because there are time lags between changes to the climate and the migration response of tree species (Renwick and Rocca, 2015).

In addition to shifts in range, a change in the forest composition has also taken place. The composition of the tree species is a significant factor in the development of forest biodiversity. In north-east Spain, beech forests and heather heathlands have been replaced by holm oak forests at medium altitudes (i.e. 800–1 400 m), mainly because of a combination of higher average temperatures and land-use changes (Penuelas and Boada, 2003). Field-based observations, from a forest inventory that provides presence and absence information for 1880 to 2010 for a Mediterranean holm oak species (*Quercus ilex*), have been used to investigate migration speed. In four studied forests in France along the Atlantic coast, holm oak has colonised substantial new areas. The northwards movement of this species was at an unexpectedly low maximum rate of 22 to 57 meters per year (Delzon et al., 2013).

3.4.1 Climate change and forest conditions

It is difficult to distinguish the individual impacts of climate change from other drivers of ecosystem change, and often the impacts appear contradictory. However, regardless of the regional variations, there is a consensus that climate change already has and will continue to have direct and indirect impacts on the decline of forest health (EEA, 2016). Climate change is expected to have both positive and adverse impacts on forest structure, growth patterns, composition, productivity and functioning, depending on the location and type of forest (EEA, 2016). For instance, alpine forests are more susceptible to changes in the hydrological cycle, which affect precipitation, and to reduced snow and glacier cover due to increases in temperature. Temperatures in the Alps increased by, on average, approximately 2 °C between the late 19th and early 21st centuries (EEA, 2012b). Southern European countries are also affected, but by different factors. Soil degradation is already intense in parts of the Mediterranean and central-eastern Europe and, together with prolonged droughts and fires, soil degradation is already contributing to an increase in the risk of desertification (EEA, 2012b). In 2013, southern Europe recorded 36 000 forest fires and a burnt area of 291 000 ha (JRC and DG ENV, 2015).

Changes in the frequency and severity of pest and disease outbreaks are also more likely, and new forest conditions may cause introduced forest species to become invasive. Increases in the frequency and severity of summer droughts in southern European countries and extreme precipitation events in northern European countries will impact forest growth, phenology and species compositions, which, in turn, will alter the pattern of forest cover (Lindner et al., 2010).

Climate change is expected to alter habitat suitability for species. Changes in species composition and vegetation structure, for instance height, density and complexity, are likely to influence the whole forest ecosystem. These changes will affect forest processes, such as photosynthesis, respiration and decomposition, and threaten the survival of species at their warm and dry distribution limits. These effects will be more pronounced in regions in which the dominant tree species are outside their optimum ecological range, which is evident today for, for example, Norway spruce (*Picea abies*) in the relatively dry lowlands of central Europe (UNECE and FAO, 2011).

In Europe, it is likely that, overall, climate change will have a positive effect on wood production and wood supply. However, Mediterranean regions are likely to experience higher rates of tree mortality and forest fires, as temperatures and the frequency of droughts increase (Lindner et al., 2010; Hanewinkel et al., 2013; Lindner et al., 2014). Tree growth and productivity are expected to increase at relatively high latitudes and altitudes. In other regions, changes may be positive in the short term, but are likely to be negative in the mid to long term. Extreme events, including droughts, flooding, fire and devastating storms (see Box 3.5), are expected to become more frequent (Lindner et al., 2010) and cause adverse effects on food webs and regional tree die-off. For example, the defoliation of trees as a result of water deficits increased significantly in the Iberian Peninsula between 1990 and 2007. This

Box 3.5 Storms and storm damage to Europe's forests

Storms are serious threats to Europe's forests because they abruptly degrade and damage forests and forested landscapes. The systematic recording of observations on storms and storm damage to forests across Europe started in the mid-19th century. During recent decades, several European countries have experienced more incidents of substantial storm damage, which have resulted in the deforestation of entire landscapes. This trend may simply reflect improvements in reporting; however, the frequency and severity of high-intensity storms and the expansion of storm tracks over northern and central-eastern Europe do seem to be increasing (Gardiner et al., 2010). More than 130 storms have caused significant damage to Europe's forests since 1950. The causes of such heavy losses and the increase of their associated impacts are linked to changes in forest composition and structure, such as the increase in coniferous forest areas and growing stocks, and the increase in forested areas in some regions, such as the United Kingdom, rather than to an increase in storm frequency and severity (Lindner et al., 2008; Barredo, 2010).

The ability of forest ecosystems to resist strong wind gusts depends on the tree and stand characteristics (i.e. height, diameter, crown area, root depth, species composition and tree density) and the site conditions (e.g. soil type, moisture levels and frost duration) (Klaus et al., 2011). However, as for many other natural hazards, storms should be seen as a disturbance of the natural dynamic of these ecosystems. Therefore, their impacts, from an ecosystem perspective, could be positive: in many cases, storms increase the biodiversity of forest ecosystems by creating a mosaic of small forest patches at different stages, leading to uneven-aged forests that are, in general, more biodiversity rich and resilient than even-aged forests.

Nonetheless, storms affect ecosystem services, namely the protective effects of forests against natural hazards (e.g. rockfalls), the provision of drinking water and the function of forests as carbon sinks. With regard to their carbon-regulation function, forests can even become a source of CO_2 as a result of storm damage, because of the decay of unharvested timber and the additional CO_2 released from the organic layer of the soil after the removal of the forest canopy. While most of the effects on ecosystem services are probably negative from a human perspective, the exact impact on ecosystems is difficult to assess. A recent study showed no trend in normalised windstorm losses in Europe for the 1970–2008 period (Barredo, 2009). Therefore, it is likely that socio-economic factors and an increase in exposure have driven the increase in disaster-associated losses of recent years.

increase in defoliation is consistent with an increase in tree mortality rates in drier areas (Carnicer et al., 2011). Furthermore, droughts can lead to secondary impacts through pests and pathogens (Jactel et al., 2012).

Forest pests and diseases

Changes in environmental conditions can affect pest and pathogen species directly, by influencing their dispersal, reproduction, development and mortality, and indirectly, through altered plant nutritional quality, resistance and community interactions. The geographical ranges of forest insect and pathogen species are expanding at an alarming rate as a result of international trade.

In the southern Mediterranean region and some continental zones, an increase in temperatures and an increase in the frequency of droughts are likely to affect insects that are sensitive to heat and cause a northward or upward shift in their geographical ranges. Other heat-tolerant species, such as the pine processionary moth (*Thaumetopoea pityocampa*) and the oak processionary moth (*Thaumetopoea processionea*), will probably benefit from warmer conditions and, hence, expand their geographical ranges beyond the Mediterranean region and attack previously unaffected areas. However, temperature increases and drought could shrink the southern range of such species resulting, in some cases, in range contraction (Battisti et al., 2014; Netherer and Schopf, 2010).

Despite many uncertainties, it is generally accepted that there has been an increase in the incidence of pests and diseases in European forests (FAO, 2006; Desprez-Loustau et al., 2007) and a shift in the spatial and temporal ranges of insects, as a result of climate change (Netherer and Schopf, 2010; Bebber et al., 2014). Several changes have already been observed with regard to the occurrence of forest pests in Europe. In response to warmer and drier spring and summer periods in recent decades, the European spruce bark beetle (*Ips typographus*) has adapted a shorter development period and multiple generations (Baier et al., 2007). The spread of insect outbreak zones has been observed in regions that are reported to have experienced the most substantial warming in boreal forests (Volney and Fleming, 2000). In temperate continental forests, tree defoliation by the gypsy moth (*Lymantria dispar dispar*) and the incidence of other insect pests are among the factors responsible for the oak decline in central Europe (Balci and Halmschlager, 2003). Also, altitudinal shifts of this moth have been observed in Slovakia (Hlásny and Turčáni, 2009). In the Mediterranean region, an expansion of the altitudinal range of the pine processionary moth (*Thaumetopoea pityocampa*) has been observed in the mountainous regions of Sierra Nevada and Sierra de Baza in Spain (Hódar et al., 2003; Hódar and Zamora, 2004) and in mountainous regions of Italy (Battisti et al., 2005, 2006; Petrucco-Toffolo and Battisti, 2008). In addition, some species of fungi and pests benefit from milder winters in temperate forests, which facilitates the spread of pests formerly controlled by frost sensitivity (Settele et al., 2014), while others spread during drought periods to northern latitudes (Drenkhan et al., 2006; Hanso and Drenkhan, 2007).

Climate change drives shifts in the ranges of tree species and increases the effects of drought on forest dieback (Allen et al., 2010). Also, forests are increasingly challenged with human-related stressors that affect forest conditions, either directly, through logging and clearing, or indirectly, through air pollution and the introduction of invasive species (Trumbore et al., 2015). These processes, coupled with changes in climatic parameters, could facilitate the propagation and increase of forest insects and pathogens. Nevertheless, there are complex interactions at work and the mechanisms involved in each case are not fully understood. For instance, changes in host tree distribution and condition will have an effect on the populations and distribution of insects, but this should be evaluated by assessing the relationships of each pest species with the corresponding host tree species and the many environmental parameters that are changing as a consequence of climate change.

In addition, the interactions among different biotic and abiotic impact factors are only partly understood. What is known is that changing environmental conditions will produce ambiguous consequences for forest pests, involving positive, indifferent and negative responses (Netherer and Schopf, 2010).

3.4.2 Forest fires

Forest fires are an integral part of the dynamics of many forest ecosystems, as they are essential for forest renewal. They help control insect and disease damage, and they eliminate litter that has accumulated on forest floors. Most of the fires in the Mediterranean region are (either accidently or intentionally) of anthropogenic origin and only a few are started by lightning strikes. Weather conditions and the accumulation of fuel play dominant roles in affecting fire risks over time. Natural forest fires are also frequent in northern Europe, but these fires rarely reach large dimensions, as conditions that limit fire ignition and spread facilitate fire extinction. As a result of climate change, the weather is expected to get warmer and dryer, which will have an undeniable impact on forest fires in Europe. Because of an increase in the length of warm and dry seasons, fire-prone areas might expand to cover higher latitudes and altitudes, and, therefore, the frequency of extreme fire events will increase (Loepfe et al., 2010).

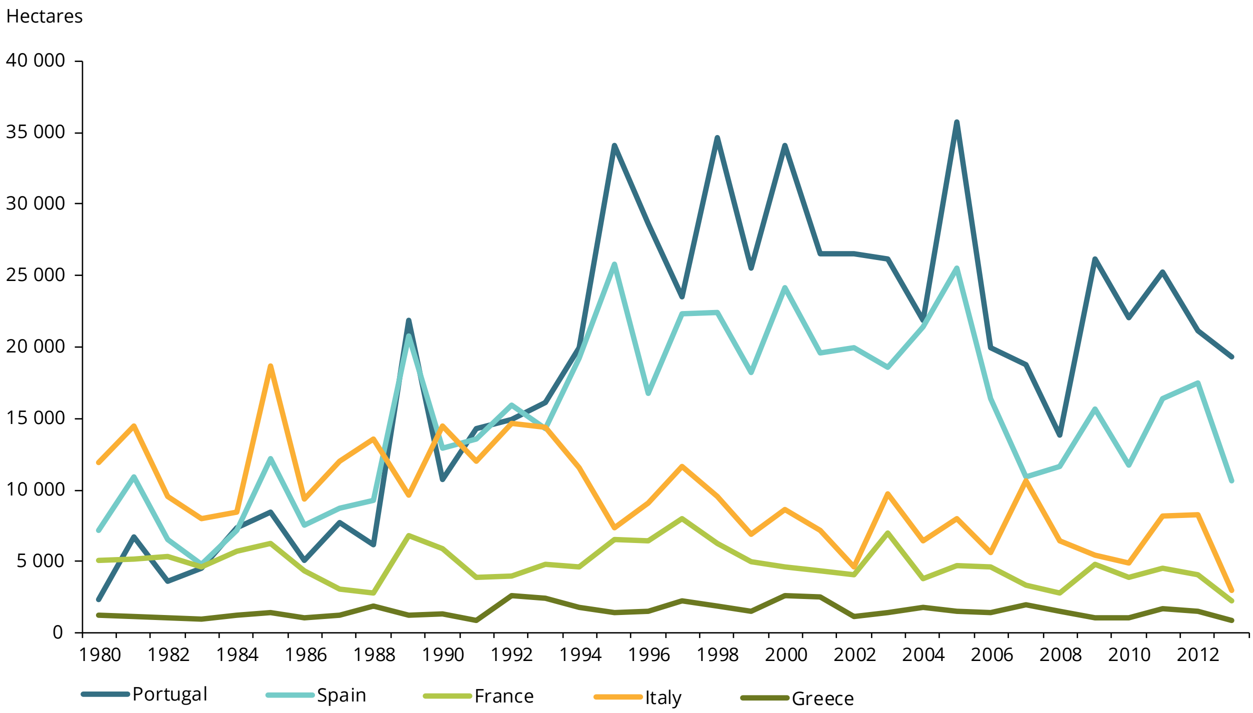
Forest fires attract the attention of the public. All over southern Europe, but also in the rest of Europe, forests are degraded by fires every year. Forest fires occur every year in Europe, causing damage to large forest areas.

Historical fire series are available for Europe and are regularly updated within the European Forest Fire Information System (EFFIS). However, the period covered is not the same for all countries and data covering more than 25 years are available for only a few case series. Long time series of forest fire data are available for five countries (i.e. France, Greece, Italy, Portugal, Spain) in southern Europe that are particularly affected by forest fires. The total area burnt per year since 1980 in these five southern Member States is shown in Figure 3.2. The size of the forest area burnt varies annually depending on forest stand conditions, weather conditions and fuel loading.

The statistics vary considerably from one year to the next, which clearly indicates that the size of the area burnt depends on seasonal meteorological conditions. Some multiannual periodicity in the area burnt can also be partially attributed to the dead biomass burning/accumulation cycle that is typical of fire-prone regions. However, the analysis of historical trends of the number of fires per year is controversial because fire frequency is strongly affected by any significant changes that may have occurred in previous years in the statistical reporting systems of the countries. Fire frequency in southern European countries increased in the 1990s, stabilised in the following decade and has slightly decreased in more recent years.

The total area burnt in 2014 was less than the average of the previous 15 years (JRC and DG ENV, 2015). The EFFIS (2016) reports that 83 809 ha of land was affected by forest fires in EU-28 and 14 188 ha was affected in other European countries in 2014, while the average annual area burnt for the previous 15 years was approximately 400 000 ha for EU-28, and, of this area, 85 % was in the Mediterranean region. The three worst years, in terms of areas burnt, were 2002, 2003 and 2012, with 812 184 ha, 783 223 ha and 607 304 ha of land burnt, respectively. Less than 3 % of the total number of fires have occurred over areas of more than 50 ha. Nevertheless, such fires were responsible for more than 75 % of the

Figure 3.2 Historical forest fire trends in southern Europe, expressed as the number of forest fires



Note: Burnt forest area (in ha) refers to five southern European countries from 1980 to 2013.

Source: EFFIS — data downloaded from http://forest.jrc.ec.europa.eu/effis/

total area burnt (San-Miguel-Ayanz and Camia, 2009). The number, size and severity of fires in Europe have increased and this is linked to recent climatic changes. Large fire (> 400 ha) frequency and total area burnt have increased markedly since the mid-1980s, and this is strongly associated with increases in spring and summer temperatures.

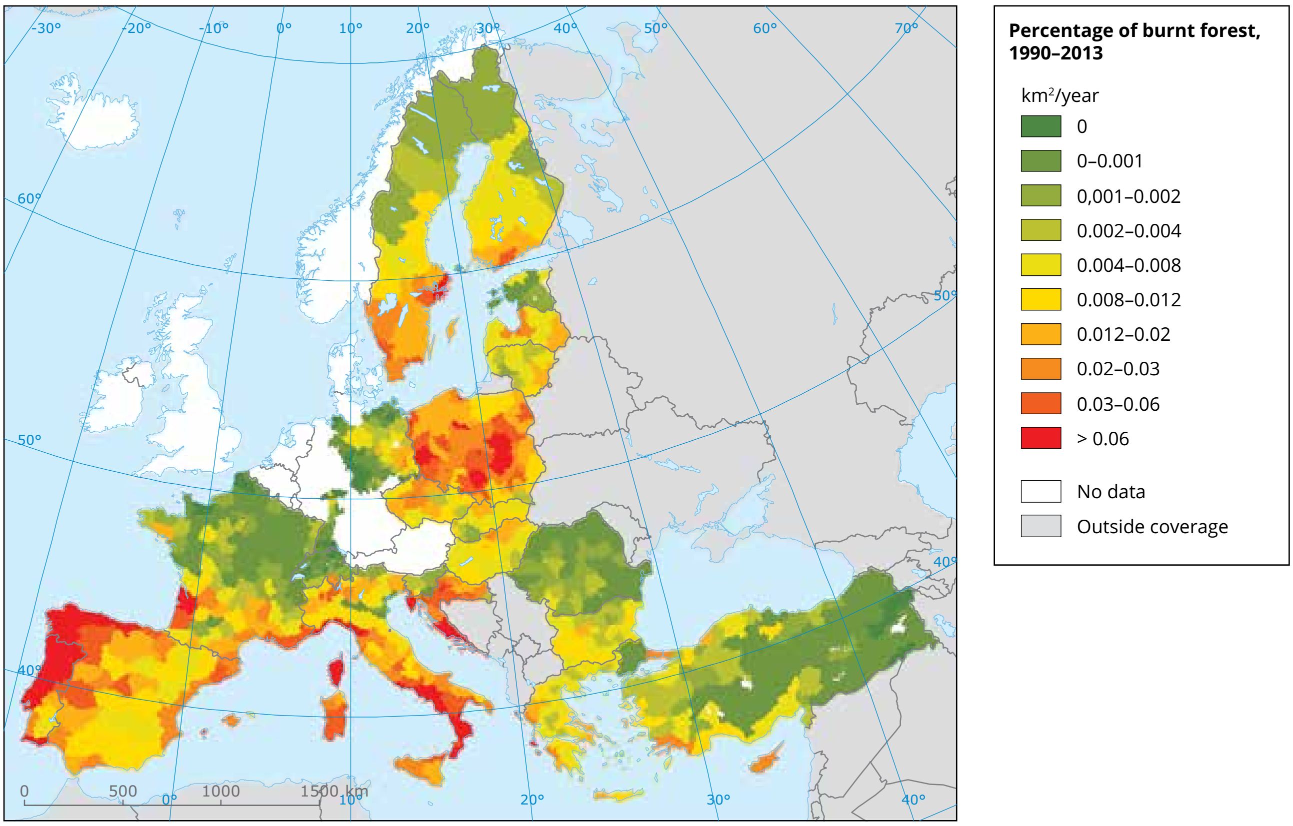
Forest fires are an important disturbance agent in many forested landscapes. Fire risk depends on many factors, such as weather, vegetation (e.g. fuel load and condition), topography, forest management practices and socio-economic contexts. Each year, enormous resources are mobilised to fight forest fires in Europe and worldwide (Map 3.5). Fire suppression is crucial, but it is not sufficient. Fires are symptoms of socio-economic and land-use problems, such as destabilised rural areas that result from rural depopulation, an increase in pressures from tourism and the inadequate management of forests. Forest managers should invest more in understanding the dynamics and consequences of fire regimes, rather than simply trying to control them. Even so, budgets are still mostly allocated to the suppression of forest fires rather than to prevention measures. It is, thus, essential that both Mediterranean and non-Mediterranean countries integrate forest management activities with their fire prevention strategies.

3.5 Other sector activities

Pressures on Europe's forests can also arise from activities outside the forest sector. Many disturbances are side-effects of other land uses, such as agriculture, industry, settlement, traffic and tourism. They have an influence on forest structure, composition and functioning, and are the main cause of the increased fragmentation of forested landscapes in Europe (see also Section 3.1.2).

Forests and agriculture are entangled and impact on each other as well as on the environment. Agricultural land use impacts on the main components of the biosphere and environment, including soil, air, water, biodiversity, CO_2 levels and renewable energy. In areas

Map 3.5 The pressure on forest ecosystems from forest fires, expressed as the percentage of burnt forest per km² per year for the period 1990–2013



Source: EFFIS — data downloaded from http://forest.jrc.ec.europa.eu/effis/ and processed by the European Topic Centre on Spatial Information and Analysis (ETC-SIA) (Malak et al., 2014).

with intensively cultivated cropland, forest edges and hedgerows that are surrounded by farmlands are likely to be affected by the use of herbicides and fertilisers. However, very few studies describe these impacts, which, at the local and even regional levels, may be critical for forest biodiversity. The agriculture sector plays a substantial part in reducing the use of chemicals that cause the acidification and eutrophication of fresh waters.

Likewise, the transport sector has an impact through infrastructure development (e.g. the construction of roads), which leads to increased landscape fragmentation. There are also direct environmental impacts of infrastructure development, in the form of increases in the concentration and deposition of pollutants and particles, and noise levels. The development of transport infrastructure is also associated with an increase in the number of animal deaths.

The presence of industries and mining activities in or close to forests may affect them through atmospheric emissions. There are several examples documented in the literature of pollution from the mining industry, smelters or other industrial emissions at the local level, from a particular activity, as well as at the regional level, associated with the long-range transport pollutants, that affect forests (see Chapter 5).

Around 25 % of all European rivers flow through forested areas (i.e. 870 000 km of 3.5 million km of rivers) and almost 33 % of 71 000 lakes, with a total area of 92 000 km^2, are located in forested parts of Europe. Watershed development must be more aware of its impacts on the range of services provided by forest ecosystems. The quality of water in these discharges is likely to influence forest ecosystems.

The sustainable management and use of forests are influenced by the other types of land use and the activities of other sectors. Each of these activities is usually considered and managed individually, despite the potential interactions among them. The situation is the same with regard to the multiple pressures that influence forest ecosystems. The assessment of the potential for cumulative impacts of multiple pressures and activities on forest ecosystems may produce a picture that is very different from those based on single pressures or sectors. Such impacts are rarely assessed and documented. More integrated assessments of the impacts of the multiple pressures and sectors on forest ecosystems are needed for better planning and the sustainable management of resources at the landscape level. Is it then at all feasible to assess the impact of these multiple and combined pressures on forest ecosystems?

3.6 Are Europe's forests under pressure?

Table 3.1 gives an overview of the impact (indicated by the colour of the box) of each pressure on forest biodiversity to date, and the projected future trend for the pressure (indicated by the direction of the arrow). Habitat change and pollution/nutrient enrichment are estimated to have caused the greatest overall impact on forest ecosystems until now, but climate change pressures are projected to increase significantly in the future. These findings correspond well with the global Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005), although there are some differences. The intensity of past pressures is greater in Europe, as a result of the history of industrialisation and intensive agriculture, but the pressure of 'pollution and nutrient enrichment' is predicted to decrease because of improved policies and legislation. Indeed, all but three pressures (namely habitat change in forest ecosystems, pollution of freshwater ecosystems and pollution of wetland ecosystems) are estimated to be stable or increase in the future. This will make fulfilling the biodiversity policy objectives challenging.

However, it is important to recognise that these pressures may interact with each other. The interactions are complex and are not necessarily the sum of different pressures. Multiple pressures, such as logging, pollution, IAS and climate change, among

Table 3.1 The impacts of the major drivers and their trends with regard to biodiversity in Europe in recent decades

Pressure	Forest ecosystems
Habitat change	↘ (red)
Climate change	↑ (yellow)
Land-use changes and management	→ (orange)
Invasive species	→ (orange)
Nutrient enrichment and pollution	↗ (orange)

Note:

Projected future trends in pressure			
↘	→	↗	↑
Decreasing	Continuing	Increasing	Very rapid increase

Observed impact on biodiversity to date			
(yellow)	(orange)	(red)	(red)
Low	Moderate	High	Very high

Source: Modified from EEA, 2016.

others, may have varying degrees of impact on species and habitats, and they may act cumulatively with other stressors, such as pollutants or/and climate change. Multiple factors can impact upon forest ecosystems at the same time. A combination of cumulated impacts of natural and human-induced drivers may lead to further degradation of ecosystem functions and services (Carpenter et al., 2009). An example of cumulative effects is provided by the interacting disturbances that can increase fire risk. Drought often reduces tree vigour, which can increase vulnerability to insect infestations and diseases. Insect infestations and diseases can lead to an increase in the fuel available and, therefore, increase the opportunity for forest fires, which, in turn, can support future infestations by weakening tree defence systems (Lombardero and Ayres, 2011; Santolamazza-Carbone et al., 2011; Lausch et al., 2013).

There is little knowledge about the impact of multiple pressures on forests, that is which activities cause which stressors; what intensity, frequency and spatial scale the activities occur at; what direct and indirect cumulative effects affect the forest; and how the different components of the ecosystem react (from individuals to whole ecosystems). Nevertheless, this lack of knowledge should not hinder the implementation of a solution, such as adaptive or EBM, that could reduce the harmful effects on ecosystem functioning, or the application of a precautionary approach. The understanding and prediction of the responses of forest ecosystems to multiple pressures are paramount to the successful implementation of EBM.

Europe's forests are human-dominated ecosystems, as almost all forests are under some form of management. The majority of Europe's forests are available for wood supply and, as such, are managed for the provision of timber and other services. Nevertheless, the area of forest continues to increase. This increase is largely as a result of active afforestation policies and the abandonment of agricultural land or land with low fertility in remote rural areas. Overall, the continued use of land for forests is guaranteed in most countries, as national laws require replanting and regrowth after logging. However, it takes around 10 to 20 years for a stand to recover after such a disturbance.

There has been a reduction in the intensity of forest land use over the past several decades, and an increase in the focus on the sustainable management of forests and the protection of forests and their biodiversity. New demands, such as the increase in demand for woody biomass for bioenergy, may, however, change this focus. Tensions can arise between the management of forests to protect ecosystem services and genetic resources, and the management for commercial production or the conversion of land for food production. These tensions are likely to increase in the future because of the size of forest-related carbon pools and fluxes, and their importance in the mitigation of GHG emissions.

Substantial changes in land use and climate are expected to result in an increase in pressures on the supply of ecosystem services, including those from forest ecosystems. Many changes will lead to an increase in vulnerability, as a result of a decrease in the supply of ecosystem services, such as water availability and soil fertility, and an increase in the risk of forest fires, especially in Mediterranean and mountainous regions. Some changes might be positive, such as an increase in forest area and productivity, or could offer opportunities for more land for extensive agriculture or bioenergy production.

Pressures from other sectors also contribute to the pressure on forests ecosystems. Human-driven activities, such as agriculture, transport, urban sprawl, mining and tourism, can create further pressures for Europe's forested landscapes. Increases in trade and transportation, and especially the increase in the import of wood and wood products, are critical drivers of the introduction and spread of IAS in Europe. Formerly isolated ecosystems have become accessible to IAS, which may threaten native species as competitors or predators, or as vectors for disease, thereby modifying ecosystems, their habitats and their species.

Deforestation in Europe occurs mostly to allow urban expansion and infrastructure development. Such processes lead to the fragmented forest landscapes that currently dominate western, central and southern Europe. Fragmentation itself puts high pressure on forest resources and forest biodiversity.

Ecosystems may rapidly change state if certain thresholds and tipping points are exceeded. However, the identification and quantification of such thresholds may be challenging (Hüttl et al., 2014), and the changes may be abrupt or slow. Many shifts seem to occur slowly over long periods after a tipping point is reached (Lenton, 2011; Adams, 2013; Brook et al., 2013; Reyer et al., 2015). Several examples demonstrate that transitions in ecosystem properties are directly linked to losses of ecosystem functions and services and, hence, to the degradation of existing ecosystems (Hüttl et al., 2014b; Spangenberg et al., 2014; Millar and Stephenson, 2015).

4 Conditions of forest ecosystems in Europe

Healthy forests are at the heart of resilient ecosystems. Healthy forest ecosystems help to prevent, reduce and adapt to risks. They support biodiversity, provide ecosystem services to society and contribute to human well-being. Biodiversity is a key component of SFM and is an integrated part of forest-related policies and practices.

Biodiversity (see Box 4.1) embraces the composition of species and their genetics, and the functional roles that species play within forest ecosystems. Biodiversity maintains multiple types of ecosystem functions and processes, and their dynamics (Figure 4.1). Communities with more species tend to provide more, high-quality ecosystem functions (Maestre et al., 2012) and services (Gamfeldt et al., 2013) than communities with fewer species. Changes in the species richness, abundance and composition of forest ecosystems may lead to parallel changes in the amount and quality of the forest ecosystem services. Biodiversity is increasingly being recognised as a foundation for ecosystem health and stability, and for the services and benefits that human societies receive from forests (Costanza et al., 2007; Balvanera et al., 2006, 2014; EC et al., 2014).

Terrestrial ecosystems account for 80 % of all species. About 10 million known species ([8]) of plants and animals have been identified in the world. There are estimated to be between 25 000 and 400 000 plant species. More than 1 million plant names (The Plant List, 2016) in 642 plant families have been assigned, of which one-third are accepted species names, 44 % are synonyms and 23 % are unresolved.

The natural vegetation of Europe comprises mainly mixed forests. Recent estimates of European biodiversity indicate that there are 20 000–25 000 vascular plant taxa (Euro+Med PlantBase, 2016; Bilz et al., 2007), more than 100 000 species of invertebrates (Fauna Europaea, 2016) , 489 species of birds (IUCN and Natural Resources, 2016), 260 species of mammals (Temple and Terry, 2007; Temple and Cox, 2009), 151 species of reptiles, 85 species of amphibians and 546 species of freshwater fish (Kottelat and Freyhof, 2007).

Forests are repositories of nearly 90 % of the world's terrestrial biodiversity. They host a multiplicity of trees and other plants, animals and microorganisms, most of which are forest dependent. Nevertheless, the precise number of existing forest species in Europe is unknown. Worldwide, the number of tree species is estimated to be 8 000, for which genetic-level information is available for 500 to 600 species (Commission on Genetic Resources for Food and Agriculture, 2014).

Forests with high levels of biodiversity usually have complex structures and functions that arise from myriads of interrelations among living organisms and abiotic factors. Organisms adapt to continually changing environmental conditions and maintain ecosystem functions. The capacity of a forest ecosystem to absorb disturbances and recover its structure and functions is termed 'ecological resilience'. Ecological resilience is a feature of a healthy forest and is a prerequisite for providing services and determining the levels of services that benefit human well-being (Palmer and Febria, 2012).

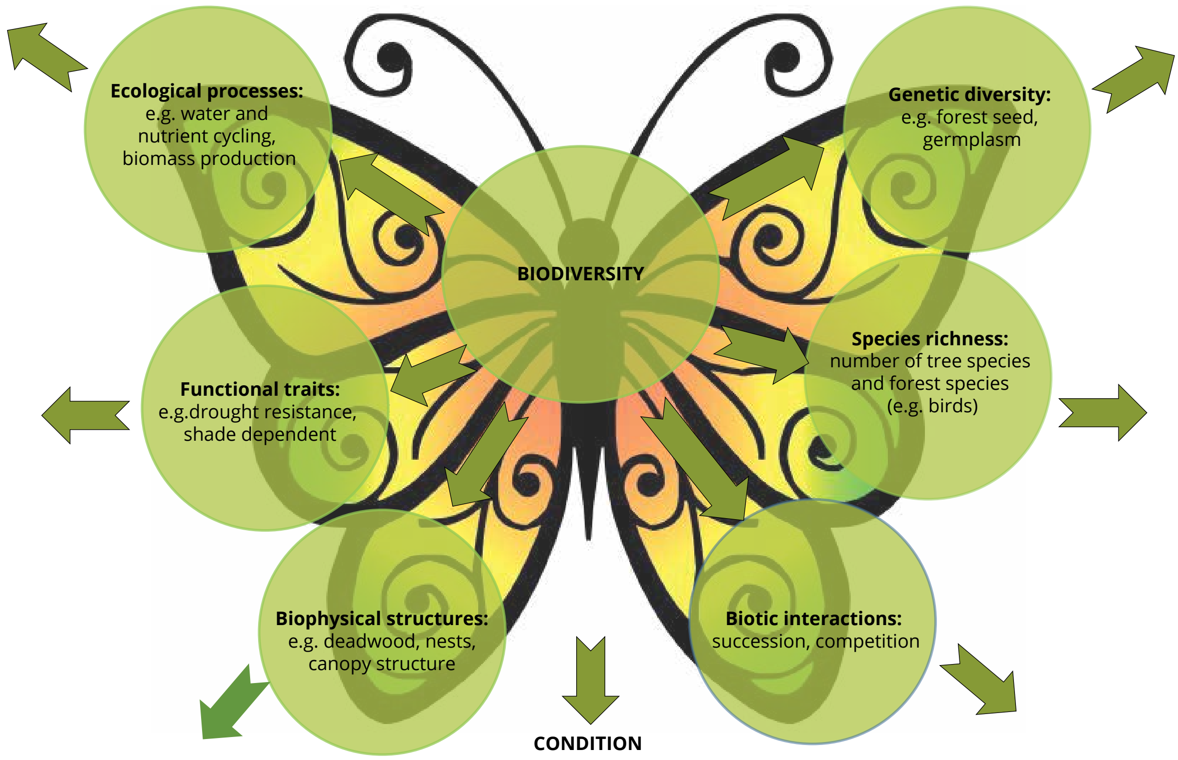
Box 4.1 Definition of biodiversity

Biodiversity refers to the variability of living organisms from all sources, including plants and animals, and the ecosystems of which they are a part; this includes genetic biodiversity within species, the species themselves and the ecosystems they are part of.

Source: Modified from the CBD (http://www.cbd.int/convention/articles/default.shtml?a=cbd-02).

([8]) From Catalogue of Life (http://www.catalogueoflife.org/col/details/database/id/9) accessed 28 September 2015.

Figure 4.1 **The many ways in which biodiversity supports the delivery of forest ecosystem services and its importance for the condition of ecosystems**



Source: Adapted from EC, 2013b.

In 2015, Forest Europe, the UNECE and the FAO gathered information on threatened forest-occurring species from the IUCN Red List (Forest Europe et al., 2015). The European Red List of Threatened Species is a valuable tool that complements information on the status of species in EU-28 (see Table 4.1); however, the data set is not complete for all countries. The number of threatened taxa is alarmingly high: at least 2–7 % of the species listed are extinct; around 15 %, most of which are fungi, are critically endangered; and, typically, more than 40 %, especially birds, vascular plants and trees, are endangered.

The IUCN has estimated that, in the EU, 27 % of mammals and saproxylic beetles, 10 % of reptiles and 8 % of amphibians are threatened by extinction in the EU (EEA, 2010).

Table 4.1 **The number of threatened forest species — trees, birds, mammals, other vertebrates, other invertebrates, vascular plants and fungi — in 2010**

Species group	Forest habitats	Extinct	Critically endangered	Endangered	Vulnerable
Trees	110	3	20	54	33
Birds	548	21	66	323	138
Mammals	198	12	21	76	89
Other vertebrates	200	3	29	84	84
Other invertebrates	2 380	145	274	700	1 261
Vascular plants	2 882	48	442	1 456	936
Fungi	4 584	300	905	2 003	1 376
Total	**10 902**	**532**	**1 757**	**4 696**	**3 917**

Source: Forest Europe/UNECE/FAO, 2011.

The protection and maintenance of biodiversity are crucial to the sustainable management of forests. Concerns over decreasing biological diversity and the loss of ecosystems have given rise to key questions for natural resource managers, forest managers and stakeholders. Managing forests for a narrow set of ecosystem services may lead to significant changes in the structure of forest ecosystems. For instance, management for the purpose of producing timber shortens forest stand development to only 10–40 % of its potential lifespan. Other ecosystem services may be overlooked and undervalued. Favouring some services over others may lead to losses of system integrity, functioning and resilience (Richter et al., 2015).

The state and development of forest biodiversity are monitored at national and international levels, although this is challenging as biodiversity is complex and difficult to quantify. The reporting processes of both the FAO and Forest Europe include important aspects on forest biodiversity. FRA reporting considers areas of primary forest, areas designated for biodiversity conservation, forests in protected areas and the species composition of forests (UNECE and FAO, 2000). Forest Europe assessments include additional information on regeneration, naturalness, deadwood and genetic resources, landscape patterns, threatened forest species and SFM (MCPFE et al., 2007; Forest Europe et al., 2011, 2015). The overall state of biodiversity in forest ecosystems is presented in the following sections.

4.1 Diverse European forest types

A comprehensive assessment of forest biodiversity is not feasible, as forests include vast numbers of species and habitats. A frequently applied approach for assessing forest biodiversity is to characterise biodiversity by three components: (1) **forest composition**, which relates to the identity and variety of species, habitats and ecosystems; (2) **forest structure**, which relates to the physical organisation of forest ecosystem components; and (3) **forest functions**, which relate to ecological and evolutionary processes (Noss, 2010).

4.1.1 Forest composition

According to the FAO (2014), approximately 80 000 to 100 000 tree species have been described (Oldfield et al., 1998; Turok and Geburek, 2000). At the global level, trees and large woody shrubs are likely to represent about half of all vascular plant species.

There is no comprehensive overview of the current forest-associated species in Europe, nor of the exact number of forest species in European forests. Information from international reporting processes on forest tree species distribution in Europe remains sparse. The 2010 Temperate and Boreal Forest Resource Assessment (TBFRA) reported that the

Photo 4.1 Boreal forest landscape, Finland

10 most common trees represent more than 90 % of the total growing stock in many European countries (UNECE and FAO, 2000). In temperate forests that are not particularly diverse with regard to tree species, the role of trees in promoting biodiversity is likely to be mainly associated with and attributable to the level of intraspecies genetic variation (see, for example, Whitham et al., 2006).

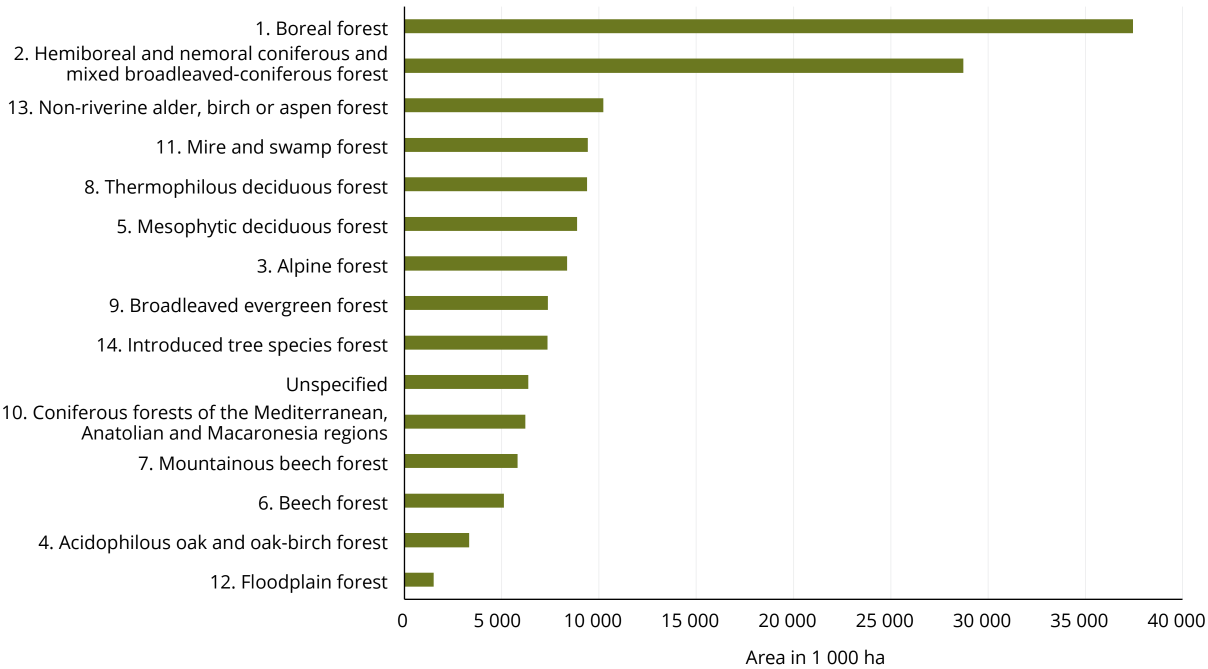
The diversity of forests in Europe is reflected by a number of forest type classifications. The European Vegetation Database (EVD) includes 156 forest alliances. These have been assigned to the 36 forest habitat types of the European Nature Information System (EUNIS). The EVD has revealed that at least 3 500 vascular plant species are associated with EUNIS forest habitats (Rodwell et al., 2002; Chytrý et al., 2014). Annex I of the Habitats Directive lists 81 forest habitats (see Annex 2 of the present report).

A number of experts from many European countries developed a forest typology that can be used for European-level assessments of forest condition and policy actions. The European Forest Type (EFT) classification was prepared by the EEA (EEA, 2006a) and used for the 2011 Forest Europe assessment. The EFT classification aggregates 79 forest habitat types into 14 categories (EEA, 2008; Barbati et al., 2014). These categories reflect the variation in the main factors that determine European forest biodiversity.

Figure 4.2 shows the extent of the EFTs, reflects the variation in the main factors that influence forest biodiversity in Europe, and reveals that there are substantial variations in forest coverage across Europe. It also reveals that two EFTs, namely the boreal and hemiboreal–nemoral EFTs, are dominant and cover more than 40 % of the forested area of Europe. This classification system is used as a framework for assessing the state of forest biodiversity and how the main threats vary in different parts of Europe. Its strength is that it can differentiate forest types within the usual, much broader, classification of coniferous, broadleaved or mixed. For instance, the state of biodiversity can be more accurately assessed for plantations of conifers and protected areas of Scots pine by using the EFT classification system than by pooling these two very different forest types in one assessment.

Europe's animals are also profoundly affected by the presence and activities of humans. The IUCN has included all terrestrial mammals in its latest European Red List (Temple and Terry, 2007). Nearly 15 % of Europe's mammalian species are threatened and a further 9 % are close to being threatened. Many organisms at the top of the food chain, such as large carnivores and birds of prey, exist in relatively small numbers, while some animals, such as game, thrive in a developed continent free from natural predators. Other European animals have become extinct or are

Figure 4.2 The areas covered by the 14 different EFTs



Source: Barbati et al., 2011, 2014.

under substantial threat. The changes that forests have undergone in recent centuries have brought a great number of species to the edge of extinction. Other than Fennoscandia, there are currently very few areas of untouched wilderness in Europe.

4.1.2 Forest structure

The vast majority (i.e. 80–90 %) of forests in Europe are characterised by closed forest stands with a canopy cover of more than 40 % (FAO, 1998). This reflects the age structure of Europe's forests. Information on forest age structure in Europe is sparse. Nevertheless, a study by Vilén et al. (2012) analysed the changes in age structure in Europe's forests between 1950 and 2010. The results indicate that the mean forest age in Europe decreased by 7 years between 1950 and 2010, and that there is a large variation in forest age across countries. In some countries, a decrease in mean forest age is related to increased afforestation. In other countries, it is explained by changes in forest management practices, for instance a shift from the selective felling of timber-sized trees to clear-cut systems. The proportions of middle aged forests (41–80 years) and mature forests (81–100 years) have increased since 1980. In some countries, forests have aged by up to 19 years. The share of old forests (> 100 years) has decreased substantially in some countries in northern and western Europe, and, in fact, only 17 % of forests in these regions are more than 80 years old. The majority (60 %) of Europe's forests are even-aged. However, the share of uneven-aged and old forests (> 80 years) in Europe has increased slightly since 1990, especially in central-west and south-west Europe (Forest Europe et al., 2015).

Forest stands that are more than 100 years of age fall into the old-forest category (only 5 % of forests in Europe have trees older than 140 years; see Box 4.2). Old and natural forests are mostly heterogeneous uneven-aged forest stands that have richer structural components, such as a high variability in tree sizes and deadwood, than intensively managed forests (Bauhus et al., 2009).

Box 4.2 Old forests in Europe

The importance of old trees for biodiversity is well recognised (Barbati et al., 2012). Old forests are vital for forest biota, particularly many rare and threatened species. For instance, the old forests of Romania are home to up to 13 000 species (Steinke, 2013). Ancient forests also have a higher volume of deadwood, which forms microhabitats for many species including fungi, lichens, ferns and invertebrates, as well as woodpeckers and beetles. In the Białowieża Primeval Forest, half of the 12 000 species found there are dependent on decaying logs (Bobiec et al., 2000). Old forests are also important for their aesthetic, cultural and nature conservation values.

Old forests can be defined in many different ways as there is no agreed reference definition. The terms 'old forests' and 'old trees' may be used to refer to the stage of maturity of the trees (i.e. the stage at which growth processes become slower than they were during earlier developmental stages). They can also be used refer to the continuity of the forest cover. From a functional point of view, old forests refer to productive ecosystems that capture large amounts of energy from the sun through their leaves. They are stable with regard to biomass production and they stock large amounts of carbon. Old forests also retain large quantities of nutrients in both living and dead organic material. Furthermore, the levels of soil erosion are low in old forests. Many compositional and functional characteristics of old forests reflect their structural features. Old forests usually exhibit complexity and high structural diversity, including a wide range of tree diameters, heights and layers, a wide range of tree cover densities, and large amounts of standing and lying deadwood. Only a few old forests exist in Europe and these cover a total area of approximately 3 million ha (i.e. less than 2 % of the total forest area). Most of these forests are located in Finland and Sweden, and in the mountains of central and eastern Europe. For instance, the Carpathian Mountains still harbour around 300 000 ha of old forests.

Photo 4.2 Glengariff Woods, Ireland

4.1.3 Forest functions

The characteristic exchanges that occur within a forest ecosystem are called 'functions' and in addition to energy, water and nutrient exchanges. Examples of forest ecosystem functions include the fixation of carbon by trees and plants, the formation and maintenance of soils for tree and vegetation growth, the provision of habitats for flora and fauna, nutrient cycling and watershed protection, and the decomposition and production of biomass (Figure 4.3).

A large body of evidence indicates that biodiversity can increase if a forest ecosystem incorporates more components. For instance, biodiversity increases if more nutrients, deadwood and species accumulate in a forest. This leads to an increase in the complexity of the forest ecosystem and, in turn, to more ecosystem functions. Forest functions are, thus, considered to be the basis of ecosystem services and, in particular, are connected to the supporting services of an ecosystem. Forest functions have the potential to provide, regulate and maintain ecosystem services and cultural values.

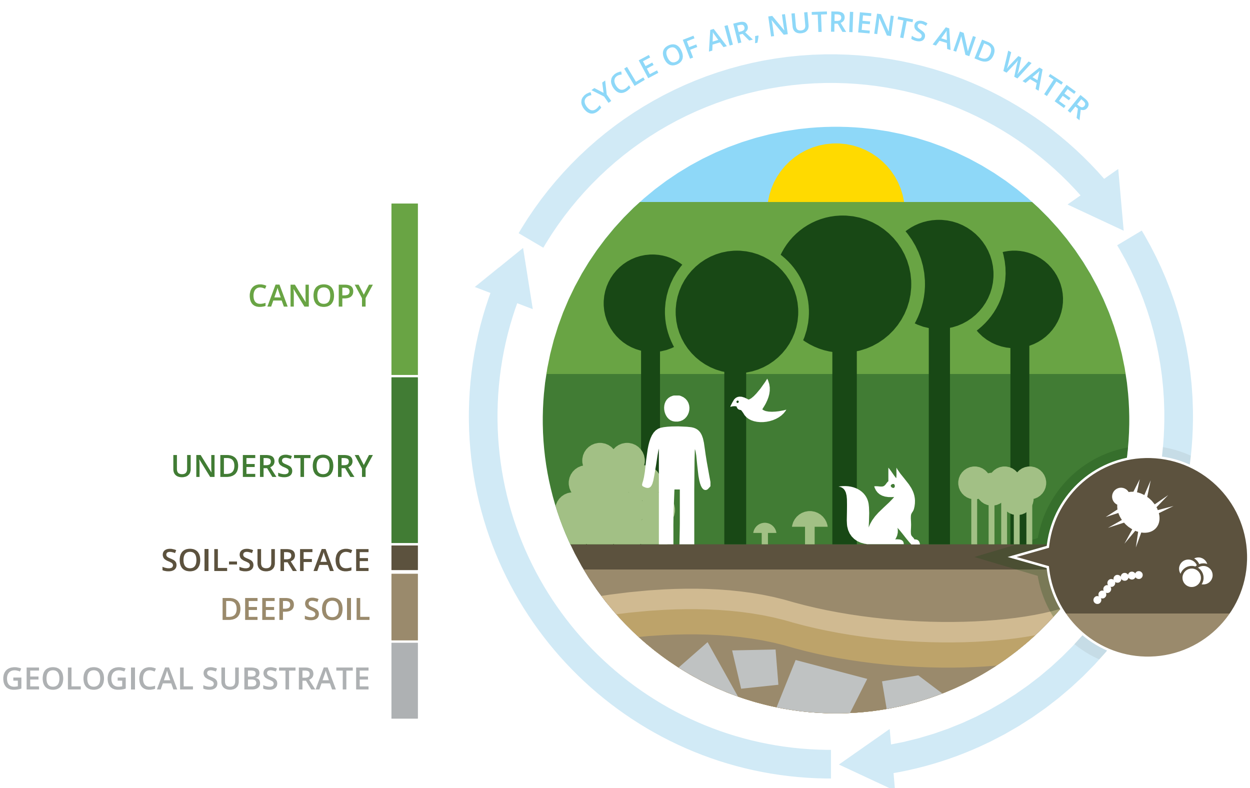
The provision of deadwood is another example of an important forest function; the occurrence of deadwood is a supporting function for other ecosystem services.

Deadwood

Deadwood, that is, dead standing and fallen trees, stumps and coarse woody debris, plays a vital ecological role. It creates a basis for nutrient and carbon cycling and storage, and it contributes to soil formation. Deadwood provides habitats, shelter and food sources for forest-dwelling species, including birds, bats and other mammals. Furthermore, deadwood plays a fundamental role in sustaining productivity and ecosystem services, including the stabilisation of forests and carbon storage (Bobiec et al., 2005; Vanderwel et al., 2006; Bradshaw et al., 2015;). Preserving and, if appropriate, enhancing the amount of deadwood in European forests is thus considered an important feature of SFM (MCPFE, 1998; EEA, 2008).

In general, information on the volume of deadwood in Europe's forests is sparse. The volumes of deadwood depend on the degree and type of forest management, and are also affected by natural disturbances. The volume of deadwood in European forests is, on average, lower than would be expected in more natural forests. However, this might reflect management issues, such as fire prevention strategies, and the age structure of European forests. The volumes of deadwood usually increase to very high levels after

Figure 4.3 Forest ecosystem functions and supporting services



a catastrophic event, such as a storm. The average volumes vary between a few m³/ha to 20 m³/ha. However, values can be significantly higher than this in mature forests. For example, an average volume of deadwood in old-growth beech forests was estimated to be 136 m³/ha (Barbati et al., 2011). In boreal forests, deadwood volumes were estimated to be approximately 9 m³/ha on average (SLU, 2011), but up to 120 m³/ha in protected boreal forests (Siitonen, 2001).

In the hemiboreal and nemoral coniferous, and mixed broadleaved coniferous forests, the average volumes of deadwood vary from 5 m³/ha to 28 m³/ha. There is little information available on the volumes of deadwood from other regions of Europe. Barbati et al. (2011) have documented high levels of deadwood per hectare in mountainous regions; this can be explained by poor accessibility and the low intensity of harvesting. The volumes of deadwood are low in southern European forests, partly because deadwood is actively removed from these forests to control forest fires (EEA, 2008).

In conclusion, the generally low relative amounts of deadwood in these forests supports the EEA's recommendations to manage forests in a way that will increase the amounts of deadwood, particularly given the present situation of the growing demand for biomass for energy, which may lead to further losses of deadwood. However, the amount and volumes of deadwood have slightly increased in Europe over the last 20 years (Forest Europe et al., 2015).

4.1.4 Biodiversity and naturalness

The capacity of forests to maintain and protect forest biodiversity may be measured by their coverage and naturalness. Forest naturalness is related to how similar a forest is to the natural (original) state of the forest; naturalness is used as a reference for assessments of the degree of degradation of forest ecosystems (Winter, 2012). However, almost no forests in Europe can be defined as natural, as all forests have, to some degree, been affected by humans. Temperate forests are considered most influenced by human activities (Schmitt et al., 2009).

Forest statistics provide information on the level of forest naturalness, based on a simplified nomenclature system with three classes: (1) plantations that are intensively managed, often with introduced tree species; (2) other naturally regenerated forests or semi-natural forests; and (3) primary forests or forests that have been undisturbed by human activities (see Table 4.2).

Table 4.2 Three categories of forest naturalness, as reported by different sources, and their relationships to forest naturalness and high nature value (HNV) forests

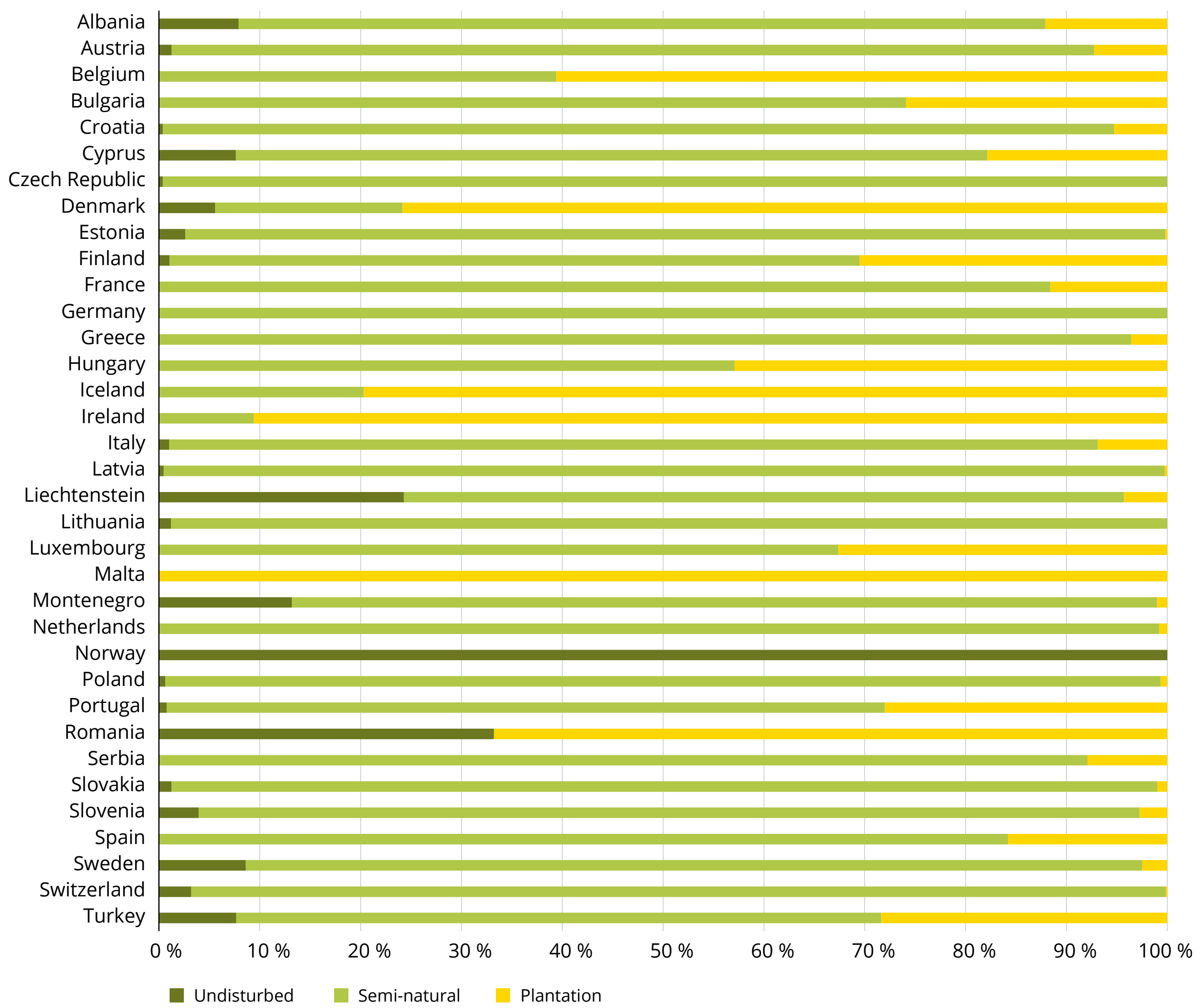
European Commission (2009)		Forest Europe (2015)	FAO FRA (2015)	Naturalness	HNV forest
Plantations	Forest stands established by planting and/or seeding in the process of afforestation or reforestation; intensively managed stands of introduced or native species, even-aged, regular spacing of trees in stand, 1 to 2 tree species. Excluded are established plantations with no forest operations for a significant period of time (considered to be semi-natural forests).	Plantations	Planted forests		No
Semi-natural	Forest stands which have natural structure, composition and function but have been modified through forest operations. Most forests with a long and active management history.	Semi-natural	Other naturally regenerated forests		Some of them
Naturally dynamics	Forests where natural structure, composition and function have been shaped by natural forest dynamics with no or little human interventions over long time period allowing for re-establishment of natural species composition and processes.	Undisturbed by man	Primary forests		Yes

Source: Adapted from EC, 2009b.

Forests with a high degree of naturalness are forests that have been undisturbed for a long period, usually for more than 100 years, and that have been affected by human activity to only a limited extent (EEA, 2014a). Because of the history of forests in Europe, very few forests, if any, are regarded as untouched by human activities, and, likewise, the area of old forest that remains in Europe is small. Old forests, defined as areas that have a long continuity of forest cover, are vital genetic reserves and have characteristics essential for forest flora, fauna and habitats. The area of undisturbed forests is estimated to be approximately 8 million ha in the EEA-38 (< 5 %); half of this undisturbed forest area is located in Finland, Sweden, and central and eastern Europe (Figure 4.4). The assessment of forest areas with a high degree of naturalness is complex, mainly because of a lack of clear and commonly agreed definitions. The area of undisturbed forest is often estimated using a suite of indicator species or microhabitats that are likely to be present in natural forests (see Box 4.3).

Confusion may arise between the concepts associated with naturalness and those associated with biodiversity. In general, forest ecosystems with high levels naturalness harbour a large amount of biodiversity. However, this is not always the case. For instance, ancient beech forests (which have a very high level of naturalness) are frequently characterised by almost pure stands and, therefore, have relatively low levels of biodiversity, while an artificial plantation (with a low level of naturalness) could comprise a mixture

Figure 4.4 The classification of forests, per country, according to their degree of naturalness in 2015

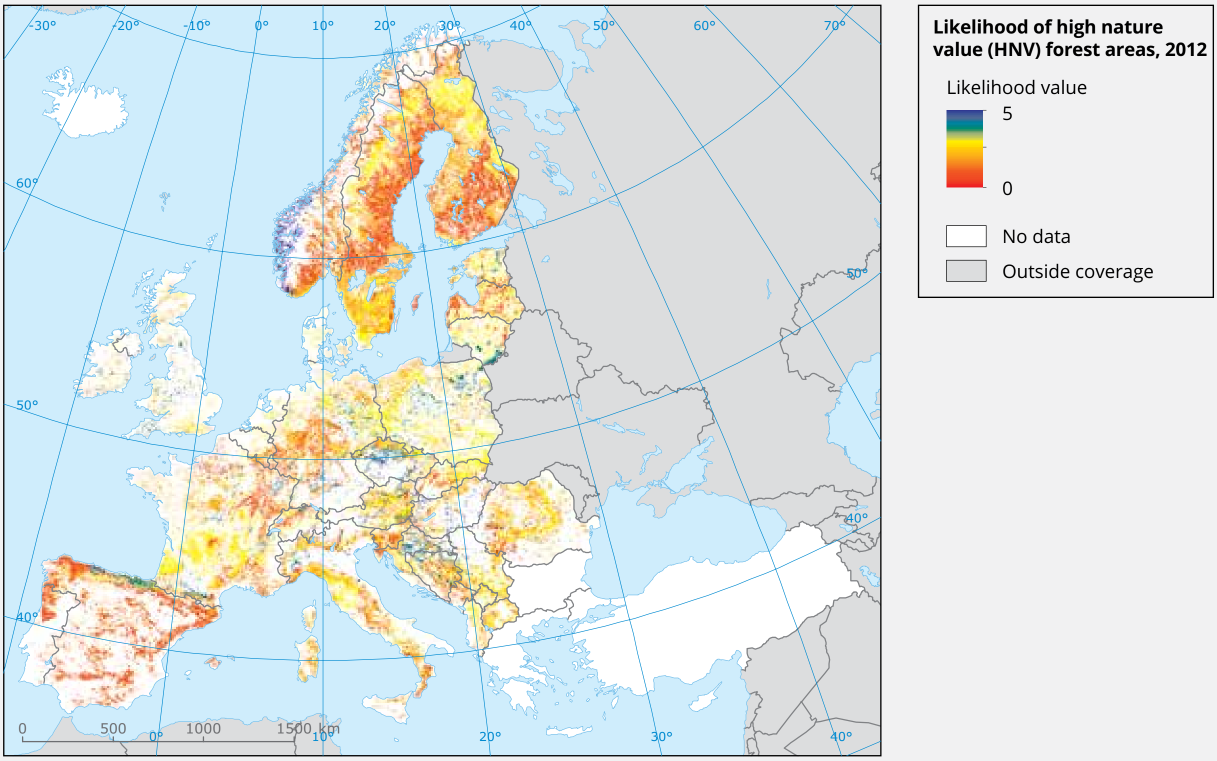


Source: Forest Europe et al., 2015.

Box 4.3 The assessment of the likelihood of forest naturalness in EU-28

A recent study by the EEA (EEA, 2014a) identified some areas of natural and semi-natural forest in EU-28 that approximate to naturalness. The study was based on the spatially explicit multicriteria analysis of the available pan-European data sets. Model results were compared with data from ancient beech forest sites. The highest possible accuracy of results was achieved on the basis of three variables: (1) the naturalness of tree species composition, (2) the level of hemeroby and (3) the connectivity (see also http://www.eea.europa.eu/publications/developing-a-forest-naturalness-indicator).

Map 4.1 Likelihood of high nature value (HNV) forest areas, 2012



Source: EEA, 2014.

of several tree species. Therefore, naturalness and biodiversity are not necessarily correlated in all forest ecosystems. Naturalness relates not only to species richness, but also to the structure and functions of the forest ecosystem, its resilience to change, the extent to which it has been fragmented and the processes by which it regenerates itself (Brumelis et al., 2011; Ikauniece et al., 2012).

4.1.5 Semi-natural forests are the dominant forest type in Europe

Currently, most forests (68 %) in Europe regenerate naturally and by natural expansion. The majority of forests are semi-natural, meaning that they are influenced by man but have kept, to some extent, the characteristics of natural forest ecosystems with regard to their structures and functions (see Table 4.2 and Figure 4.4). Semi-natural forests are the dominant forest type in Europe, covering about 87 % of the total forest area. These forests include a broad range of ecosystems, most of which have been influenced by human intervention. Semi-natural forests are managed in order to produce a wide range of ecosystem services, mostly related to wood, recreation, soil and watershed protection, infrastructure, and the protection of nature and biodiversity (FAO, 2006, 2010, 2015a). There has been a slight decrease in the area of semi-natural forests in recent years, because of the increase in the area of plantations and forests undisturbed by humans.

The distinction between semi-natural forests and plantations in Europe is not always clear. For instance, the planting of indigenous species on clear-cut forests can make classifying a forest as a plantation, when the forest reaches maturity, difficult. In slow-growing forests, planted and natural stands are virtually impossible to distinguish after several decades (Evans, 1992). Furthermore, the definition of plantation forests is interpreted differently in different countries. The area of planted forests in Europe is approximately 49 million ha, that is, 26 % of the total forest area (FAO, 2010, 2015a; Forest Europe et al., 2015).

Forest statistics suggest that there are approximately 17 million ha of plantations in the EEA region, that is, about 9 % of the total forest area is covered by plantations, of which 8.6 million ha (i.e. 4.5 %) comprise introduced species (FAO, 2015a). Single-species plantations have the largest share of introduced tree species. Vast areas of Portugal and northern Spain, as well as south-western France, are intensively used for plantation forests, which have replaced abandoned agricultural lands, see also Box 4.4. Afforestation efforts, principally involving introduced species, such as spruce in Iceland and mainly Sitka spruce and lodgepole pine in Ireland, have contributed to the increase in forest areas in these countries. This trend is expected to continue in the Mediterranean region, as satisfying economic returns on tree planting have been realised in some locations, especially in France, Portugal and Spain.

4.2 Genetic biodiversity

Forest genetic resources refer to the genetic variability of trees and species within forests. They are key to the conservation and sustainable management of forests. The conservation of native forest genetic resources impacts the growth and development of planted forests, and has paramount importance in the protection of biodiversity. The genetic composition of

Box 4.4 Ecosystem services from plantations

The establishment of plantations may involve the introduction of non-native species. Some introduced conifer species have high economic values and are important for forestry purposes. The most important conifer species include Sitka spruce (*Picea sitchensis*), lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*) and Australian eucalypts (*Eucalyptus* spp.). Some commonly introduced broadleaved tree species are the black locust, and the northern red oak and poplar species. Eucalyptus species have been planted for forestry in vast areas of Portugal, Spain and, to some extent, Turkey. Plantations often have single tree species and, therefore, have much lower levels of biodiversity than natural forests (Brockerhoff et al., 2008). Intrinsically, plantations represent the opposite of naturalness (see Table 4.2).

The main objective of plantation management is to provide timber and to achieve high economic returns from the high-quality and efficient production of wood (e.g. industrial roundwood) (Bauhus et al., 2010). In addition, plantations have also been established over time in Europe for a broad range of other purposes, including for protective functions (e.g. erosion control). Plantations that have been established on former agricultural lands may provide more environmental benefits than would have been provided by using the land for agriculture. For instance, plantation forests contribute to climate regulation, by sequestering and stocking carbon, to the regulation of water run-off and even to the alleviation of pressures related to harvesting wood from natural forests (Lindenmayer, 2009). Some studies document how to integrate strategies to promote biodiversity with the design and management of plantations, and suggest that a balance can be achieved between protection and the production of wood and other ecosystem services (Kanowski et al., 2005).

At stand level, the degree of biodiversity depends on the choice of species (native or exotic), the structure (mixed or monoculture), and the frequency and intensity of silvicultural practices (i.e. the removal of deadwood, stumps and understorey vegetation). At the landscape level, the distance to patches of native vegetation is decisive with regard to the degree of biodiversity, with relatively short distances allowing an increase in species richness in the plantation and the possible migration of populations to and from the plantation (Hartley, 2002; Lindenmayer and Hobbs, 2004). The diversity of fauna is higher within plantations if there is native vegetation close to their borders (Elton, 2000; Lindenmayer and Franklin, 2002; Bieringer and Zulka, 2003).

Photo 4.3 Beech plantation at Jægersborg Hegn, Denmark

species and the variation of this genetic composition are fundamental to healthy and productive forest ecosystems. A high level of variety of genetic material safeguards the potential for forest ecosystems to regenerate, and facilitates their adaptation to environmental changes, as well as improving their resilience and productivity. These capacities of forest ecosystems depend on the in situ genetic variation within each population of a species (Bradshaw and McNeilly, 1991).

The degree of genetic diversity governs the tolerance ranges of a species, as well as interspecific competitive interactions, which, together with dispersal mechanisms, constitute the fundamental determinants of how a species responds to change. However, this capacity for adaptation and resilience is at risk because of human-made changes in landscapes and gene pools. The fragmentation of a population may adversely affect its genetic and reproductive status.

Studies have documented the genetic characteristics of less than 1 % of tree species (FAO, 2014). Temperate conifers are among the best-described tree species, along with many poplar, acacia and eucalyptus species. A 2014 FAO report (FAO, 2014) compiled information from 86 countries, representing over 85 % of the global forest cover. This knowledge base is required for the improvement of the integration of forest genetic resource management into relevant cross-cutting sectoral policies, and for supporting the sustainable management of forest ecosystems. One of the main messages of this FAO report is that half of the forest species reported by these countries are threatened or subject to genetic erosion as a result of land-use conversion, the unsustainable use of forests or the effects of climate change.

Europe has approximately 2 100 tree species, of which approximately 25 % are subject to management related to forest products and ecosystem services (FAO, 2014). A quarter of the reported species and subspecies are classified as threatened. This information on the genetic resources of forests is crucial for conservation, sustainable management and the integration of cross-cutting policies. Information on the loss of ecosystems and tree species, as well as the loss of intraspecific diversity, is needed. The loss of intraspecific diversity may lead to lower quality or less desirable phenotypes. The consequences for natural as well as managed forests may include a decrease in the opportunities for reproduction and regeneration.

The European forest genetic resources programme (Euforgen) has developed 34 species distribution maps that include population-level information. This information is enormously helpful for monitoring the dynamics of species' genetic resources. Since 2007, the European Forest Genetics Information System (Eufgis, 2016) has provided georeferenced online information about the genetic conservation status of 106 tree species across more than 3 000 sites in Europe. This information is used for pan-European reporting processes, such as those of Forest Europe. In 2010, the total areas of forests in the EEA region (33 countries) managed for in situ and ex situ gene conservation were 410 000 ha and 60 000 ha, respectively. More than 840 000 ha was managed for seed production (Forest Europe et al., 2011, 2015). The tendency for an increase in the area of forest managed for in situ gene conservation underlines the increased awareness of the importance of the long-term conservation of forest genetic diversity, in order to conserve biodiversity, and the sustainable management of forest ecosystems.

More efforts are needed to improve conservation, sustainable management and the use of forest genetic resources. The genetic resources of all types of forests (i.e. natural and managed) will be vital for adaptation and resilience in an uncertain future. The option of new services and the maintenance of intraspecific diversity are important for managed forests, in order to allow the establishment of improved and adapted germ plasm that can meet new demands and growing conditions.

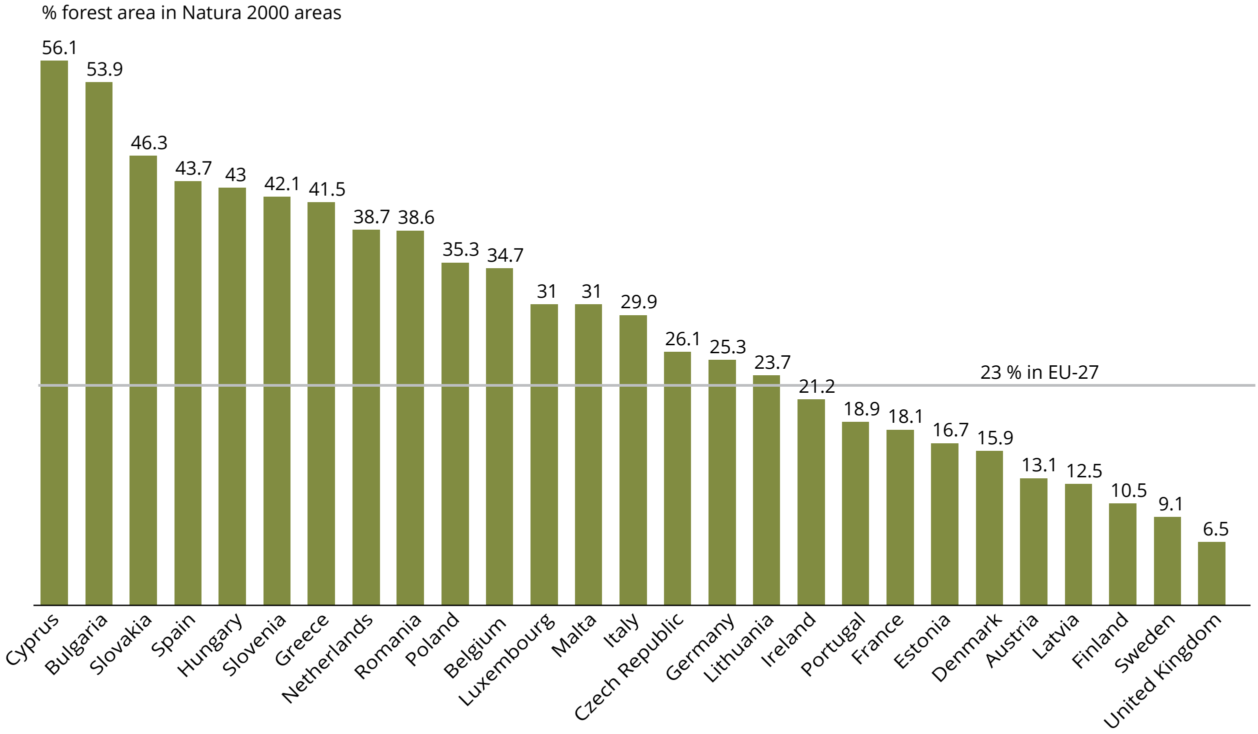
The protection of forest biodiversity and forest genetic resources is essential for sustaining healthy and productive forests and, thereby, for maintaining their protective environmental roles.

4.3 The protection of forests in Europe

Protected areas constitute an important element of forest protection strategies. Around 44 % of the EU territory is under Natura 2000 protection (EC and DG AGRI, 2014). More than 27 000 sites are designated as Natura 2000 sites. The aim is to protect Europe's most valuable and threatened habitats and species. The management of natural resources is carried out to varied extents in these Natura 2000 sites.

Forests make up almost half of the area of Natura 2000 sites (i.e. 37.5 million ha) and 23 % of all forests in Europe are within Natura 2000 sites (see Figure 4.4). The share of forests in the Natura 2000 network varies significantly across the EU Member States (see Figure 4.5). The Member States with the largest proportion of Natura 2000 forests are Spain (8 million ha), Poland (3 million ha) and France (3 million ha). In 2012, 18 of the 27 EU Member States

Figure 4.5 Percentage of forest areas within Natura 2000 sites in the 27 EU Member States in 2012



Note: The percentages of forest areas within Natura 2000 sites were estimated using Corine land cover classes. Not all forest areas coincide with the habitat types defined in Annex I of the Habitats Directive.

Source: EC and DG-AGRI, 2014.

had more than 20 % of their forest areas within Natura 2000 sites, and more than 40 % of the land in Bulgaria, Cyprus, Greece, Hungary, Slovakia, Slovenia and Spain was covered by the Natura 2000 network.

Forest ecosystems also constitute the largest proportion of nationally designated areas in the EEA region (according to the Common Database on Designated Areas (CDDA)), accounting for almost one-third of the land cover (EEA, 2012c). The largest undisturbed forests are located in Bulgaria, Estonia, Finland, Romania, Slovenia, Sweden and Turkey (Forest Europe et al., 2011). Białowieża Forest is the only remaining part of the immense forest that once spread across the European Plain.

Other protected areas in the EEA region include World Heritage Sites, biosphere reserves, the Emerald Network, established as part of the Bern Convention, and areas protected by the Alpine and Carpathian Conventions, as well as other regional networks of protected areas.

The high share of forests in the Natura 2000 network reflects the importance of forests for biodiversity in Europe.

4.4 The state of nature conservation in Europe's forests

The Birds and Habitats Directives are the legal foundations of nature and biodiversity policy in the EU. They provide information on the state of conservation of nature and aim to safeguard the conservation of rare, threatened and endemic species in EU-28. Forests play an important role in the conservation of biodiversity as they constitute half of all Natura 2000 sites and host a significant proportion of Europe's biodiversity.

Some information on Europe's forest habitats and species can be extracted from data reported under the Habitats Directive. The Member States regularly monitor and report data and information on the conservation status of forest habitats and species (Council of Europe, 1979; EC, 1992). Birds are listed in the Birds Directive (EC, 2009b). The latest assessment of the conservation status of forest habitats and species of Community interest covers the 2007–2012 period.

Forest habitats

Annex I of the Habitats Directive covers 85 forest habitat types. In 2012, 229 individual assessments were provided by Member States. The 10 most common Annex I forest habitat types and their areas reported by the Member States are listed in Table 4.3. The total area covered by these habitat types is estimated to be 57.2 million ha. They cover almost 75 % of the Annex I forest habitat areas, which corresponds to 35.5 % of the total forest area of EU-28. Atlantic acidophilous beech forests are the most dominant forest habitat type (22 million ha), followed by Galicio-Portuguese oak woods (approximately 10 million ha).

Despite the increase in forest areas in Europe and the increase in the area of forests within protected sites, the conservation status of the Annex I forest habitats was reported to be 'unfavourable to bad' by the EU Member States. Only 15 % were estimated to have a 'favourable' status and 54 % were estimated to be 'unfavourable to inadequate'. 'Unfavourable to bad' assessments also made up a relatively high share (26 %) of evaluations. As regards trends in conservation status, both 'unfavourable to stable' (40 %) and 'unfavourable to declining' (28 %) were reported by a significant proportion of assessments, while 'unfavourable to improving' was reported by a mere 3 % of assessments (see Figure 4.6).

Forest species

The Habitats Directive covers about 2 000 species, as listed in Annex II of this directive. The number of forest-related species is 249, of which 43 are plants, 44 are invertebrates, 23 are mammals, 11 are amphibians and 63 are birds.

The highest numbers of forest species are found in the Mediterranean and Alpine regions. Of 642 assessments of the conservation status of non-bird forest species, most were 'unfavourable': 44 % were 'unfavourable to inadequate' and 16 % were 'unfavourable to bad'. However, more than a quarter of assessments were favourable (26 %). As regards trends in conservation status, nearly a quarter (22 %) of the assessments were 'unfavourable to stable', while only 6 % were assessed as 'unfavourable to improving'. Moreover, a significant number (17 %) of the remaining assessments were 'unfavourable to declining'. Therefore, the overall picture is mixed, with a relatively high share of favourable assessments, but also a large proportion of unfavourable assessments with little sign of improvement. It is estimated that less than 35 % of forest species are associated with a favourable conservation status (see Figure 4.7).

Birds

Birds are considered to be good proxies for measuring the diversity and integrity of ecosystems, as they tend to be near the top of the food chain, have large ranges and have the ability to move elsewhere if their environment becomes unsuitable; they are, therefore, highly responsive to changes in their habitats (Eurostat, 2015). Birds play an essential role in forest landscapes by, for instance, attracting birdwatchers and other people who are especially fascinated by particular types of birds, such as eagles, storks or cranes (Buchanan et al., 2011; Belaire et al., 2015). The Birds Directive covers about 500 wild bird species, of which 168 forest bird species are associated with forest ecosystems in the EU.

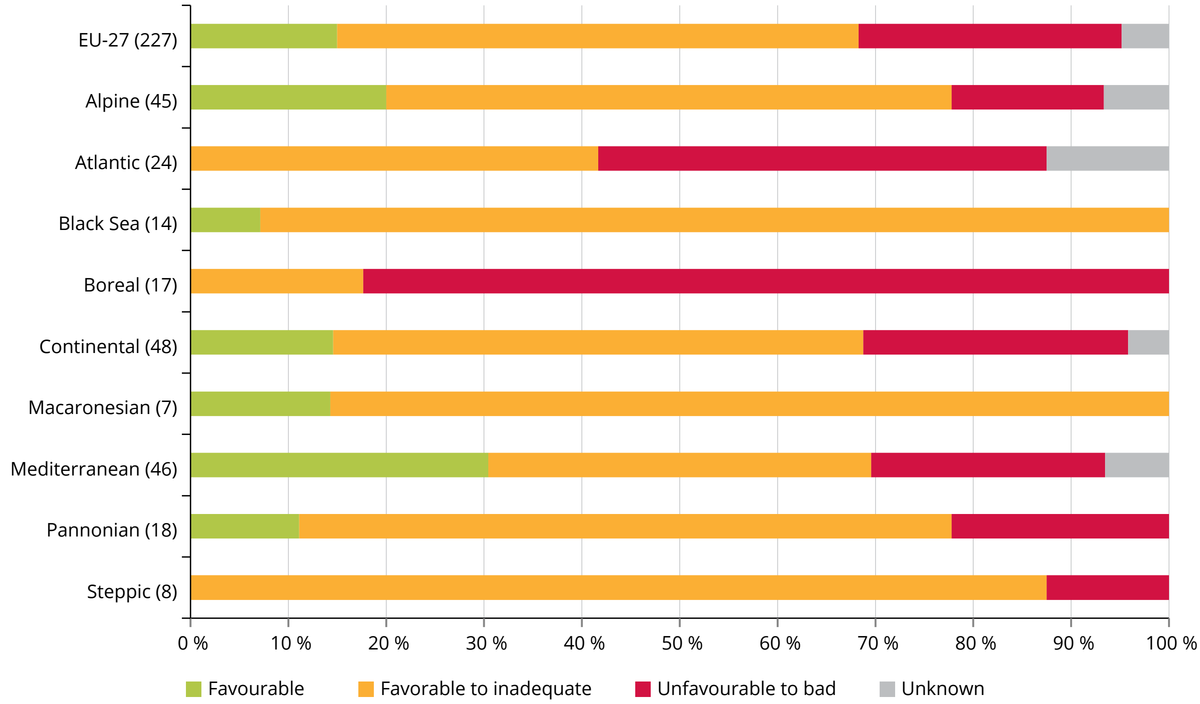
The overall average changes in the population levels of common bird species reflect the health and functioning of the ecosystems they inhabit. The common bird index (Eurostat, 2015) is an aggregated index of bird populations that comprises farmland and forest

Table 4.3 The 10 most common forest habitats, as defined in Annex I of the EU Habitats Directive

Rank	Code	Habitat	Surface area (km²)
1	9120	Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercinion robori-petraeae* or *Ilici-Fagenion*)	220 866
2	9230	Galicio-Portuguese oak woods with *Quercus robur* and *Quercus pyrenaica*	98 399
3	91D0	Bog woodland	44 469
4	9340	*Quercus ilex* and *Quercus rotundifolia* forests	43 819
5	9010	Western Taïga	35 112
6	9130	*Asperulo-Fagetum* beech forests	33 120
7	91M0	Pannonian-Balkanic turkey oak — sessile oak forests	33 028
8	9110	*Luzulo-Fagetum* beech forests	25 069
9	9040	Nordic subalpine/subarctic forests with *Betula pubescens* ssp. *Czerepanovii*	19 420
10	9160	Sub-Atlantic and medio-European oak or oak hornbeam forests of the *Carpinion betuli*	18 248

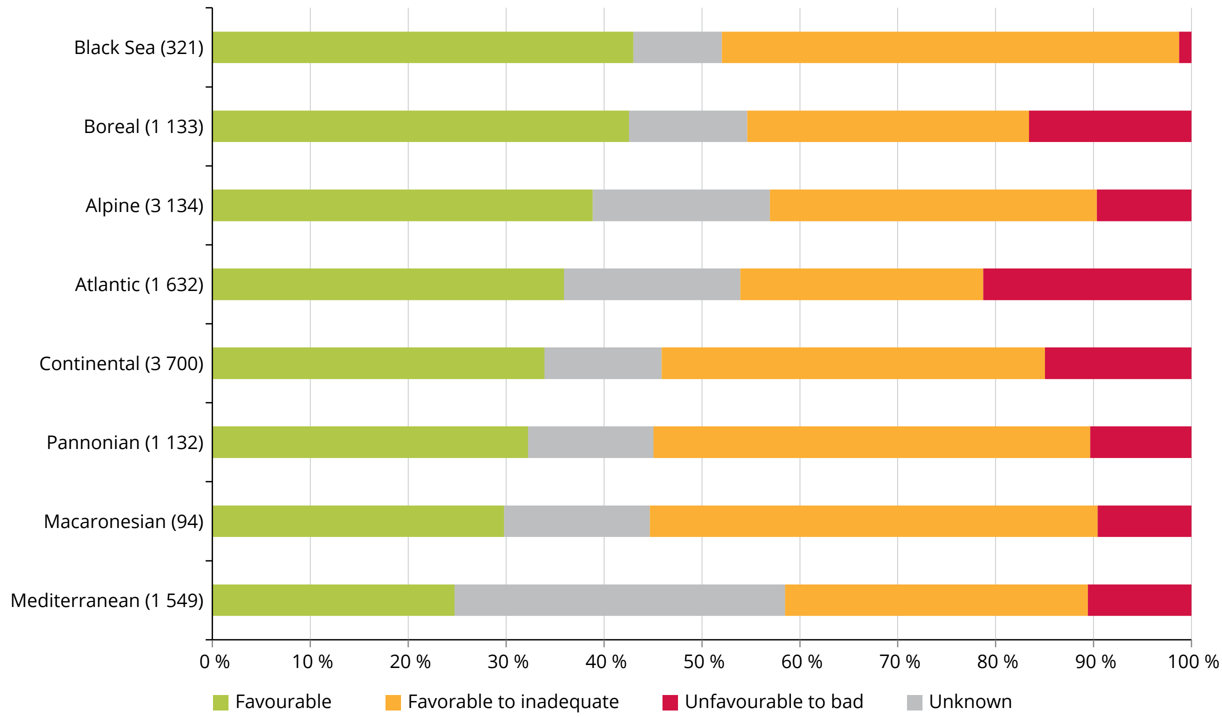
Source: EEA, 2015b.

Figure 4.6 Conservation status of forest habitat types by biogeographical region, 2007–2012



Note: The habitats referred to are the forest habitat types defined in Annex I of the Habitats Directive.

Figure 4.7 The state of forest species, including mammals, plants, amphibians, reptiles and invertebrates, 2007–2012



Note: The species referred to are those covered by Annex II of the Habitats Directive.

species, together with other common generalist species, that is, species that can occur in many different habitats or are particularly adapted to life in cities. The common bird index covers 163 different species of birds across the EU (39 of which are common farmland species and 33 of which are common forest bird species). As shown in Figure 4.8, there was a decrease, of approximately 11 %, in common bird populations between 1990 and 2012. The forest bird index represents bird species that are highly dependent on agricultural or forest habitats during their nesting seasons and for feeding. Both indexes include year-round and migratory species. The forest bird index suggests that, between 2000 and 2012, there was some recovery (an overall increase of 16 %) of forest bird populations.

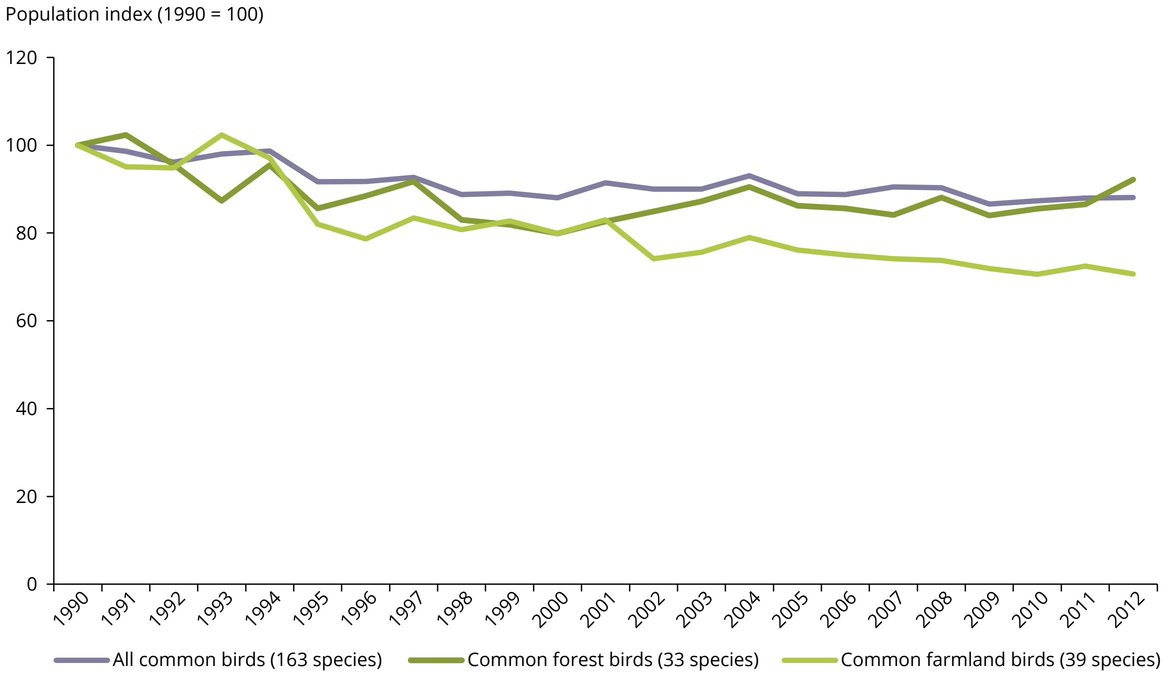
4.5 Forest health and ecosystem services

The expression 'forest health' means different things to different people, depending on the interests that lie in the forest. A forest manager will consider a healthy forest to be one that has optimal growth and that provides the range of expected products, particularly wood products of a given quality for placement on relevant markets. From an ecological point of view, a healthy ecosystem is one that is able to exist, reproduce and perpetuate in a given environment by maintaining a perennial structure (i.e. growth, organisation and biodiversity), and that can implement processes of resistance against adverse external threats, such as plant and animal pests, and climatic effects, in order to quickly repair eventual damages and reproduce itself (Mery, 2010).

The capacity to deliver and the quality of ecosystem services depends on the general condition of a forest, as well as the functioning of forest processes, such as nutrient and water cycling, and photosynthesis. The outputs of these interactions are the functions of the forest ecosystem (primary production) and thus provide the potential to deliver provisioning, regulating and maintaining ecosystem services, and cultural values. Forest health also influences the capacity of a forest to resist a series of threats and pressures due to natural and human factors, respectively, including storms, droughts, floods, pests, insects and air pollution.

The *Inclusive wealth report 2014* has increased the awareness of the large extent to which economies and social welfare depend on healthy and resilient ecosystems (UNU-IHDP and UNEP, 2014). Worldwide, the wealth generated from forests is estimated to be more than USD 273 trillion. The degradation and loss

Figure 4.8 Common bird and forest bird population indexes for Europe



Note: For each EU Member State, the base year (i.e. 1990 or the year that the Member State entered the scheme) has a value of 100 %.

Source: Bird Life, 2013.

of ecosystem services can have many consequences, including the disruption of supply chains, an increase in the costs of raw materials, as they become increasingly scarce, and a decrease in water availability. Ultimately, our society depends on healthy ecosystems, which underpin biodiversity and deliver essential ecosystem services. Healthy, well-functioning ecosystems deliver the range of ecosystem services that are required to meet societal demands. One of the key challenges for forest management is the maintenance of healthy and resilient forest ecosystems in the face of various pressures, while maintaining ecosystem functions and providing ecosystem services.

Forest condition, health and vitality are assessed by international and national mechanisms. Such comprehensive assessments include indicators, such as defoliation, the presence of pests and insects, IAS, tree species diversity, vascular plant diversity, the volumes of deadwood, and the degree of naturalness, regeneration and management.

Over the last century, forest health in Europe has been affected by air pollution. In the 1980s, the focus was on acid rain, and the associated threats to trees and water quality. Defoliation was monitored at approximately 6 000 sites across Europe and this showed that the canopy condition has fluctuated over the past three decades. The latest data collection on defoliation suggest that there has not been any major deterioration in forest health (Michel and Seidling, 2014).

Recently, the main threats to forest health and productivity have been from insect attacks and fungi infestations. Forest insects and pathogens are biotic disturbance agents that are detrimental to forests. Insect outbreaks can lead to damaging levels of defoliation or mortality under suitable climatic and site conditions. Widespread forest decline can threaten the provision of ecosystem services, such as timber, amenities and nature conservation. Damages are also caused by forest fires, storms, wind and snow.

Climate change is likely to further increase the frequency and severity of these impacts on forest health and forest ecosystem functioning, and the delivery of ecosystems services. Overall, the emerging picture is one of negative impacts, from a wide variety of causes, linked to climate alterations. Nevertheless, the precise impact of climate change on forest health, growth and biodiversity is difficult to assess.

The loss of species and habitats decreases the resilience of forest ecosystems and makes forests more vulnerable to pressures related to human activities, which exacerbates their effects and may cause a corresponding loss of ecosystem services. Although there is a need for a better understanding of how biodiversity loss might affect the dynamics and functioning of ecosystems and, consequently, their services, hardly any data are available that allow the assessment of the resilience and sensitivity of forest ecosystem services to change (Bentz et al., 2010; Mooney, 2010; Pereira et al., 2010; Sturrock et al., 2011). Knowledge about the effects of biodiversity changes on ecosystem functioning has improved in recent decades. However, the links between indicators of biodiversity, such as species diversity, functional diversity and ecosystem services, and human well-being are still patchy. The protection and maintenance of forest biodiversity is thus a prerequisite for the multifunctionality and long-term provision of forest ecosystem services, including security with regard to long-term livelihood, as this will reduce vulnerability and improve resilience. The next chapter addresses the individual pressures that affect the state of biodiversity and the drivers of these pressures.

5 Forests and their ecosystem services

Forests provide a huge range of products and services that are of vital importance to the functioning of the biosphere. They provide the basis for the delivery of tangible and intangible benefits to society and human well-being. These help to meet the basic needs of people in Europe by providing employment and contributing to the economy and wealth. The demand for ecosystem services is projected to grow, and, likewise, the need for more raw materials and services is expected to increase.

The concept of ecosystem services is currently in an implementation phase, and many international and national initiatives have been launched to translate the concept into practice. The EU Biodiversity Strategy 2020 proposes concrete actions in order to improve knowledge on ecosystems and their services. Under Target 2 and Action 5, the EU Member States are requested to map and assess the ecosystems and their services within their national territory (EC, 2011a). A working group, consisting of representatives from Member States, European Commission services and the EEA, was set up to implement the Mapping and Assessment of Ecosystems and their Services (MAES) framework for six main ecosystems. Such studies, as well as accounts of natural capital, are expected to increase our knowledge and understanding of the dependency of ecosystem services on biodiversity, and increase the focus on protecting ecosystems in order to also protect biodiversity.

The MAES work produced a conceptual framework for ecosystem assessment, and typologies for ecosystems and ecosystem services (EC, 2013a, 2014). The ecosystem services approach is based on the fact that humans depend on nature and, therefore, the flow of ecosystem services is linked to the supply of services that are used by humans. The MAES initiative adopted the Common International Classification of Ecosystem Services (CICES) framework to classify ecosystem services that depend on biodiversity (http://www.cices.eu; Haines-Young and Potschin, 2013). The CICES framework facilitates cross-references between ecosystem services and environmental accounting initiatives.

Forest ecosystems are one of the six pilot ecosystem types. Forest ecosystem services can be split into three categories (TEEB, 2010) based on supporting services, such as primary production and biodiversity, a resource that is increasingly being recognised as important with regard to sustaining many of the goods and services that humans enjoy from ecosystems. These provide a basis for three higher level categories of services:

- provisioning services, which include products such as food (e.g. game, roots, seeds, nuts and other fruit, spices and fodder), fibre (e.g. wood, water and cellulose) and medicinal products (e.g. aromatic plants and pigments);
- regulating services, which are of paramount importance for human society and include services for (1) carbon sequestration; (2) climate and water regulation; (3) protection from natural hazards, such as floods, avalanches, rock-fall and erosion; (4) water and air purification; and (5) disease and pest regulation;
- cultural services, which satisfy the spiritual and aesthetic appreciation of ecosystems and their components.

These categories are considered as references for ecosystem assessments in Europe, and are already applied in order to support the maintenance and restoration of forest ecosystems in Europe.

Forest ecosystems also support services that are not included in the proposed categories, despite being essential. These are the ecosystem function processes themselves, such as photosynthesis, NPP, water and nutrients, which are indispensable for the maintenance of forest ecosystem functioning. Table 5.1 presents examples of ecosystem services from forests in Europe ([9]).

([9]) See http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm.

Table 5.1 Ecosystem services from forest ecosystems and examples

	Examples of ecosystem services from forests in Europe	Links to human well-being
Provisioning services		
Crop, livestock and fisheries	Non-wood forest products for commercial and local use (e.g. honey, berries, fungi, cork, resin and medicinal plants) and meat (e.g. from reindeer and Iberian pigs). Products from agroforestry (e.g. cork ecosystems and silvopastoralism (*))	Food, medicine and health
Trees for timber	Raw timber materials for roundwood and further processing and manufacturing of wood (e.g. chips for paper board and pulp for paper); alternative construction material substituting steel and concrete to reduce the use of fossil fuels and enhance building standards	Shelter, materials, furniture and nappies
Trees for wood fuel	Wood of all kinds from residues after harvest, stumps, roots, recycled for local firewood and heat as well as power plants	Heating
Water supply	Upland forested catchments providing water downstream for, for instance, urban areas	Drinking water
Regulating services		
Climate	Regulation of climatic stress, lowering extreme temperature, heavy rainfall, water retention, and protecting soils, humans and animals; carbon stock and carbon sequestration by forests and soils; stock of carbon in wood products	Access to clean air and water
Water	Water conservation, run-off regulation, and water retention and storage	
Hazards	Soil erosion control; reduced chemical and pesticide exposure; flood regulation; air pollution reduction	Security from disasters
Disease and pests	Regulation of incidence and spread of insects, pathogens and diseases	Safety
Detoxification and purification	Water, soil, air quality and noise reduction	Clean air, water and soils, and tranquillity and health
Pollination	Habitat for wild pollinators	
Cultural services		
Wild species diversity	Habitat for flora, fauna and microorganisms; genetic reserves	
Environmental settings	Education and research, recreation and health, social activities, and spiritual and cultural values	Well-being, health, strength and social cohesion
Supporting services		
Soil formation, and nutrient and water cycles	Forests support soil formation and other biogeochemical processes essential to life	
Biodiversity	Protection of unique and native species, genetic biodiversity and ancient forests	

Note: (*) Silvopastoralism refers to the use of extensive livestock (for grazing) in management practices to maintain a balance between the forest and grasslands.

Source: Adapted from CICES, 2016, and EC, 2014.

The MAES framework was applied to Europe (EEA, 2016). The valuation of forest ecosystem services is ongoing as the second step of the MAES work. This work supports the analysis of interdependencies and possible trade-offs among different forest ecosystem services, and the assessment of the potential of forest ecosystems to deliver multiple services. This assessment is the basis for the valuation of the multifunctionality of forest ecosystems for human well-being.

A detailed description of the work carried out as part of the MAES initiative, undertaken by the European Commission and its Member States, is presented in various reports on ecosystems and their services (EC, 2013a, 2014; Maes et al., 2016).

5.1 Supporting services from forests

The importance of supporting ecosystem services on human well-being may not be as clear as it is for the other ecosystem services, but supporting ecosystem services are the basis for the continued production of the other ecosystem services. Supporting services are closely linked with biodiversity and ecosystem functions (see Section 4.1.3, Figure 4.3 and Boxes 5.1 and 5.2).

Forests are habitats for hundreds of species and, as such, they provide conditions that are essential for the life cycles of plants and animals living within and around them. Each species has its own role and importance. Many species are needed to provide multiple forest functions, as each species promotes different functions (Gamfeldt et al., 2008; Isbell et al., 2011; Maestre et al., 2012). Furthermore, according to the precautionary principle, all species should be conserved because which species actually provide ecosystem services is unknown (Ehrlich and Ehrlich, 1982).

Another example of supporting services from forests relates, for instance, to the role of forest flora and fauna in the development of soils (see Box 5.2). Forests provide deadwood and other inputs that contribute to the base of the food chain. Supporting services are those which are essential for the production of all ecosystem services. These are all strongly interrelated and, in many cases, are underpinned by a vast array of physical, chemical and biological interactions.

5.2 Provisioning forest ecosystem services

The wood component of forest ecosystems is the basis for many economic activities and has a clear market value. Forestry includes the management, production and removal of timber from forests as roundwood. Roundwood can be further broken down into industrial roundwood and fuelwood. Industrial roundwood includes all uses of roundwood except for fuel.

Box 5.1 Protective functions of forests in mountain areas

Worldwide, mountain forests are important for various ecosystem goods and services, and they are particularly sensitive to climatic and anthropogenic changes. Mountain forests protect against avalanches; for instance, tree canopies reduce the amount of snow that can reach the ground, which prevents the formation of unstable snow layers.

Other natural hazards, such as flooding and landslides, represent serious risks to the people and infrastructures of mountain valleys. They are usually triggered by extreme rainfall events of short duration and high frequency.

The management of forests in mountain areas is challenging. Forest measures must consider the protection of people and infrastructures against natural hazards, while, at the same time, ensuring the sustainable use of wood and the other ecosystem services provided by forests. Furthermore, forest management needs to adapt to the continually changing environment. The integrated risk management of forest, water and land processes is essential for the reduction of the impacts of extreme disturbances.

Photo 5.1 Avalanche protection in mountain forests of Engelberg, Switzerland

Photo 5.2 Flood protection in mountain forests of Engelberg, Switzerland

Box 5.2 Forest and soil interactions

Forests and forest soils are inherently entangled and have huge impacts on each other and the environment. Trees rely on soil for anchorage, nutrients and water. Furthermore, forest–soil interactions support key ecosystem services, such as the capturing and storage of carbon (approximately 50 % each).

Soil protection depends on the protection of trees and forests. Sustainably managed forests protect soils from erosion, which prevents landslides and, in this way, allow the provision and maintenance of clean water supplies and a balanced water cycle. After unsustainable logging and clearing of tree vegetation, productive land may be lost and the soil may be exposed to rain and wind erosion, which, in turn, may lead to land degradation.

Furthermore, trees, as well as other plants, play an important role in the creation of new soil, through the rotting and decomposition of leaves and other vegetation. Soil formation is an example of how supporting services may be long term in nature. Soil formation involves changes in the physical, chemical and biological properties of the soil over decades, centuries and even millennia. The impacts on human well-being are indirect, occurring through effects on regulating and provisioning services.

5.2.1 Industrial roundwood

Most harvested timber (approximately 80 %) is converted into a variety of wood products, such as paper, packaging, construction materials and furniture, textiles, medicines and pharmaceutical supplies, which, again, contribute to human welfare, literacy, education, culture and hygiene. Wood product manufacturing industries, or woodworking industries, produce, for example, sawnwood, wood-based panels and other wooden products such as joinery and carpentry materials, containers, and other packaging and articles.

Photo 5.3 Productive functions of forests

Wood is the most commonly used material for housing and furniture in northern parts of Europe and in mountainous areas. With regard to lifestyle and design, wood has many advantages over other materials, because it is renewable, reusable and recyclable (and so its use has the potential to contribute to the achievement of the EU's 2050 goals), and it is increasingly being recognised as such. Approximately 90 % of the woodworking industry's raw material comes from sustainable EU forests, while the rest is imported. The latest statistics suggest that there has been an increase in roundwood production throughout the world, which reflects the increase in the demand for wood, especially from broadleaved trees (Eurostat, 2015) (see Figure 5.1).

The use and demand for wood can be expressed as the development of harvested wood. Wood supply in EU-28 was estimated to be approximately 432 million m³ in 2013 (FAO, 2015a). However, some of the peaks in wood supply can be attributed to the logging of forests between 2000 and 2007 after severe storms. There is no information available on the value of this production. The amount of traded roundwood equated in 2013 to approximately 25 % of total roundwood production.

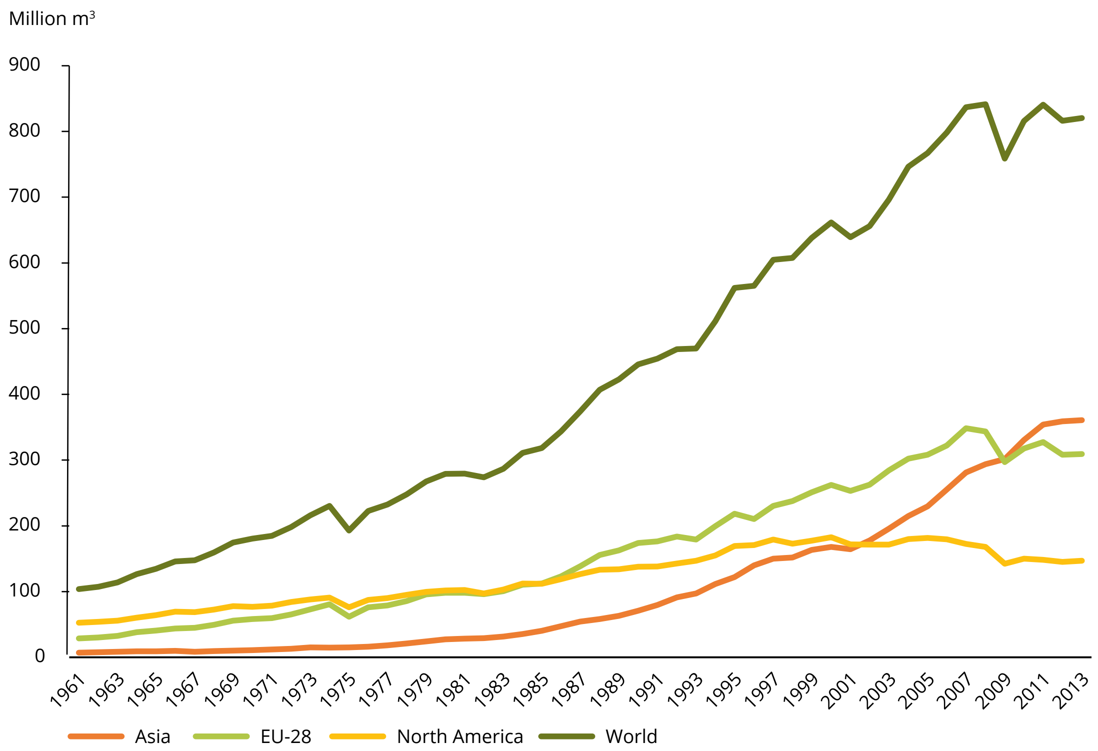
5.2.2 Fuelwood and bioenergy production

With a few exceptions in some regions of Europe, only residues from forest harvesting, as well as by-products and waste from processing industries, are used for fuelwood. Fuelwood is currently the most important feedstock for renewable energy, both in the EU and at the global level (IEA, 2012).

In 2013, around 98 million m³ of wood were extracted from forests for fuel, which is equivalent to 22 % of the total wood supply in EU-28 (Eurostat, 2015). In many European countries, fuelwood accounted for 5 % of the total energy usage in 2012 and, in some countries (i.e. the Baltic countries, Finland, Hungary and Poland), fuelwood accounted for 75 % of all renewable energy. The EU is the largest consumer of wood pellets; in 2013, approximately 20 million tonnes of wood pellets were consumed, of which one-third was imported from non-EU countries, mainly Canada and the USA (Figure 5.2).

The growing demand for and consumption of wood for bioenergy are related to an increase in the security and diversity of energy supplies, as well as to the relatively low and stable cost of fuelwood compared with fossil fuel energy sources. Another argument, which is still

Figure 5.1 Roundwood production throughout the world as a whole, and in Asia, North America and EU-28

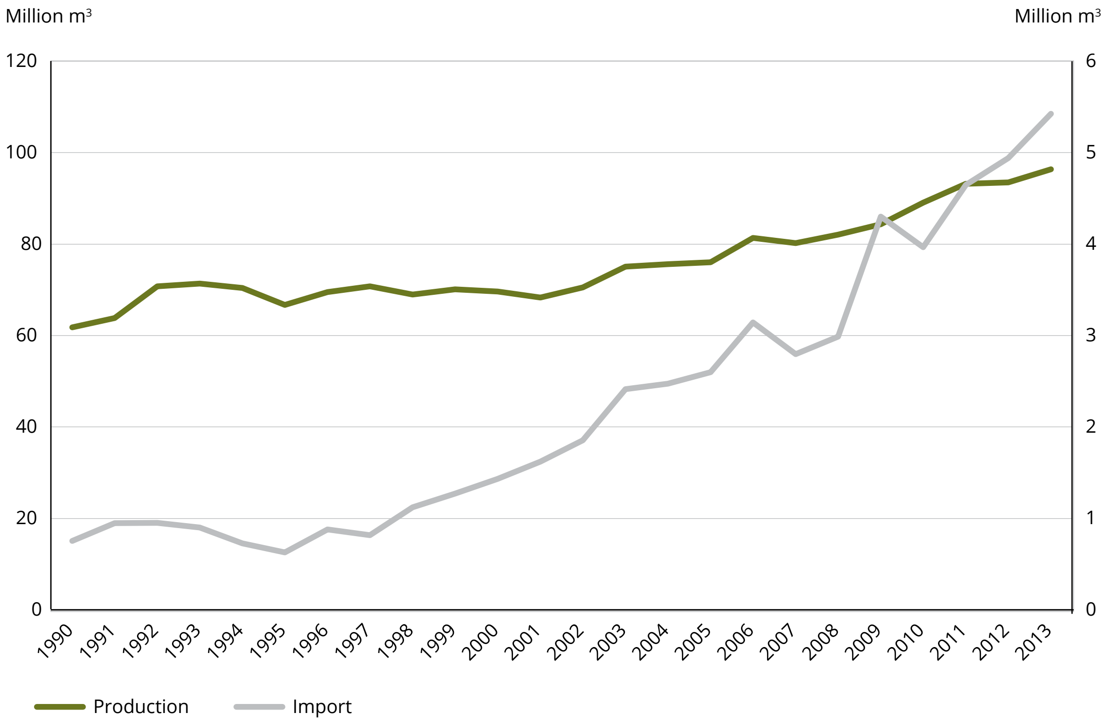


Source: FAO, 2015.

Photo 5.4 Wood residues for fuelwood

under debate, is that efforts to mitigate climate change are linked to forests and the role that forests play in the supply of biomass, and the securing of a carbon-neutral energy supply. Renewable energy sources are expected to play a fundamental role in the achievement of the EU energy sector's 2050 decarbonisation targets. The EU has set the ambitious target of reducing GHG emissions by at least 80 %, compared with 1990 levels, by 2050, in order to halt global climatic warming (EEA, 2014b; EC, 2011a). The availability of timber for bioenergy depends on the other uses of forest biomass and forest functions, such as for wood for industry, biodiversity protection, carbon stock, recreation, and landscape and social sustainability. Future supplies may depend on the potential synergies between wood products and bioenergy production. The decline in production by the paper industry is likely to reduce the demand for pulp and pulpwood as a whole. This will have an impact on the supply of wood for sustainable bioenergy (see also Box 5.3).

Figure 5.2 The production and import of fuelwood between 1990 and 2013



Source: FAO, 2015.

Box 5.3 Impacts and trade-offs from the extraction of biomass from forests

Biomass from wood and wood residuals provides the highest proportion of energy from organic, non-fossil materials, and accounted for almost half of the gross inland renewable energy consumption in the EU in 2012 (Eurostat, 2015). It has been estimated that the availability of wood from forests and other sources for energy production could be increased from nearly 350 million m^3 to approximately 750 million m^3 in the EU between 2010 and 2030 (Mantau et al., 2010).

Overall, fellings are below the net annual increment in Europe (see also Figure 6.2). The increased use of woody biomass is likely to substantially affect forest biodiversity and forest ecosystem services. A recent study of 24 European countries indicates that an increase in wood and residue removal to its maximum potential would reduce the average amount of deadwood by 5.5 % by 2030, compared with 2005 (Verkerk et al., 2011). Consequently, adverse effects are expected on deadwood-dependent species, which constitute an important component of biodiversity in European forests (Jonsell et al., 2007; Hjältén et al., 2010). The extraction of fuelwood as a substitute for fossil fuels may lead to additional revenues for forest owners (Tilman et al., 2009; Walmsley and Godbold, 2010), and it is also recognised as a way of balancing anthropogenic nitrogen deposition in forests (EEA, 2008). Other studies suggest negative impacts, such as an increase in soil erosion and compaction, a depletion of soil nutrient stocks and changes in nutrient cycling, and an increase in non-forest vegetation, of the extraction of biomass from forests (Walmsley and Goldbold, 2010). However, the potential impacts, whether positive or negative, on other services provided by forests will need to be considered, alongside impacts on biodiversity, in order to better understand the possible trade-offs, see Table 5.2. Understanding trade-offs and developing optimised management strategies are critical issues for future forest management in Europe.

Table 5.2 The connections between management measures and the different services provided by forests

Forest ecosystem services	Impacts of management
Provisioning services (e.g. non-wood forest products)	For instance, the presence/abundance of berries and mushrooms are affected by age structure, density and forest species composition (Ihalainen and Pukkala, 2001; Bonet et al., 2008)
Regulating services (e.g. climate change mitigation)	The amount of wood extracted from a forest determines the rate at which biomass accumulates and, therefore, the amount of carbon stored in forest biomass and soil (Eggers et al., 2008)
Cultural services (e.g. recreation)	Forest characteristics, including openness and density, species composition, age and size of trees or stands, type of fellings and thinning, affect the appreciation of forests by visitors (Ribe, 1989; Gundersen and Frivold, 2011)

Source: Adapted from Verkerk et al., 2011.

5.2.3 Non-wood forest products

In addition to wood products, non-wood forest products (NWFPs) are increasingly appreciated by society. NWFPs comprise food, such as mushrooms, berries, herbs, nuts, honey, game and fodder, as well as resin, bark, ornamentals, cork, Christmas trees and medicinal plants, and are important sources of income. NWFPs contribute to the economy, and their contribution to the total economic value (TEV) of forests is increasing (Forest Europe et al., 2011, 2015). However, information on NWFPs is sparse. Recent estimates (FAO, 2010, 2015) indicate that the value of NWFPs in Europe is less than EUR 4.3 billion. However, this value is likely to be an underestimate, because of the lack of relevant data and information.

The contribution of NWFPs to income is significant in some countries. A total value of almost EUR 3 billion was reported; most of this (80 %) value can be attributed to marketed plant products (mainly Christmas trees, berries, nuts and cork) and 20 % can be attributed to marketed animal products. In 2010, the value of marketed NWFPs is estimated to have been approximately 14 % of the roundwood value (Forest Europe et al., 2011, 2015). However, this value is considered to be a substantial underestimate given the wide ranging contributions made by NWFPs listed above. The real importance of NWFPs is difficult to assess, because of scant and inconsistent statistics. Therefore, their contribution to incomes is not fully recognised, and, therefore, neither is their contribution to wealth and economies.

The provision of clean drinking water is an example of an important NWFP, which contributes extensively to society and human welfare. Increased attention is now being given to the externalities related to the use of forests. Externalities are consequences of human activities that are experienced by people that are not involved in the decisions that led to such activities. For example, logging in the forests upland of a watershed may cause water run-off and inflict damage on farmers downstream; if the farmers affected are not compensated, such damages would be considered externalities.

One primary reason for this focus is that private property rights to natural capital are frequently impossible to define or enforce. Non-specified or unprotected property rights can prevent markets from forming, or can make markets function badly if they do form. The components of ecosystems, and the services they deliver, such as drinking water from forested uplands, do not always have boundaries. Furthermore, forests contribute to the economy of other sectors, such as health, tourism, water and agriculture, which are also not included.

5.2.4 Hunting and game management

Hunting represents an important socio-economic activity, especially in rural areas. Hunting is also an important source of recreation, and a vital social and cultural activity for the 7 million hunters of the EEA region.

Wild animals are an important and natural part of forest ecosystems. Productive populations of herbivore game species have considerable economic and social value. Game meat is an important NWFP and hunting is linked with strong cultural traditions. Wild animals are also a resource related to the development of nature-based tourism.

A certain degree of grazing damage by herbivores to the forest is natural and unavoidable. However, high levels of hoofed game, such as deer, roe deer, moose and wild boar, which feed on (young) trees, can pose a problem to forests and biodiversity. High levels of hoofed game can lead to a reduction in forest growth, as a result of regenerating tree loss. Deer prefer certain tree, and other plant, species, so large populations of deer can lead to a decrease in plant diversity, which has negative impacts on the biodiversity of the whole ecosystem. A low diversity of tree species in a forest leads to fewer options for future actions and, thus, creates more risks for forest owners, especially in light of climate change.

Large hoofed game populations hinder the natural regeneration of forests, and make any afforestation virtually impossible; this, in turn, leads to high costs for planting and tree-protecting activities, and thus severely complicates measures for adaptation to climate change. In winter, some deer species feed on tree bark, which can permanently decrease the quality of timber. Also, high levels of game can have adverse impacts on the protective functions of mountain forests.

In 2011, Forest Europe et al. reported that, on average, 2.2 % of forest areas were being damaged annually by grazing in EU-27. However, at the local level, the share of damaged forest areas can be considerably higher; for instance, Sweden reported damages to 6.2 % of its forest area. Considering that grazing mainly affects young forests, which covered, on average, 11 % of the total forest area in EU-27 in 2011, forest regeneration is substantially affected. In Germany, game levels have increased considerably since the Second World War and have reached unprecedented levels. For approximately 50 % of the forest area in Rhineland-Palatinate, the fulfilment of forest management goals is unlikely because of the high hoofed game population levels. On average, in Germany, one-fifth of saplings are damaged by grazing, and at least EUR 90 million is spent each year on fences (Ammer, 1996).

Possible options for protecting forests from high levels of grazing include fences or other protective measures, or more intensive hunting and/or the re-introduction of carnivore predators. Fences are not an optimal solution: they are expensive and can increase herbivore levels in unfenced areas. Such protection measures should be used only in places in which game population levels cannot be reduced by other means. There is a conflict of interest between hunters, who prefer high game levels, and forest owners/managers, who have to deal with the resulting damages. Sustainable hunting management is critical for the achievement of an ecological balance between game species and forests.

5.2.5 Husbandry

Husbandry in forests is an extensive and unique traditional land use that is increasingly carried out across Europe. It combines livestock and forestry for multiple benefits in the same management unit. Such silvopastoral practices enhance biodiversity, including biodiversity at the landscape level, and maintain traditional management systems. Silvopastoralism has three components: trees, pasture and animals.

Reindeer husbandry in northern Europe is an example of silvopastoralism. Reindeers feed on grasses in forests and on lichens from, for instance, felled trees. Husbandry is economically and culturally important in several regions of Europe. In Sweden, for example, the herding area for reindeer husbandry covers more than 22 million ha and includes more than half of the productive forest land of this country (KSLA, 2015). There are approximately 250 000 reindeers and 4 600 reindeer owners in Sweden.

5.3 Regulating forest ecosystem services

In addition to wood and non-wood products, Europe's forests provide a broad range of essential ecosystem services such as water filtration, carbon storage, wildlife habitats, recreational opportunities and scenic beauty. The forest area of Europe is still expanding. However, the protection and maintenance of healthy, diverse and productive forest ecosystems is essential in order to provide essential ecosystem services that support human health, mitigate climate change, regulate watershed disruption, ensure clean drinking water and halt the loss of biodiversity. An ongoing European project, 'Future-oriented integrated management of European forest landscapes' (Integral), has examined which ecosystem services are important throughout Europe (Biber et al., 2015). Following wood provision, socio-economic functions and biodiversity protection were identified as the most common forest ecosystem services. Within protective functions, services related to water protection were considered most prominent. Other protective services and non-wood provisions, including the protection from fires and coastal protection, were more regionally important.

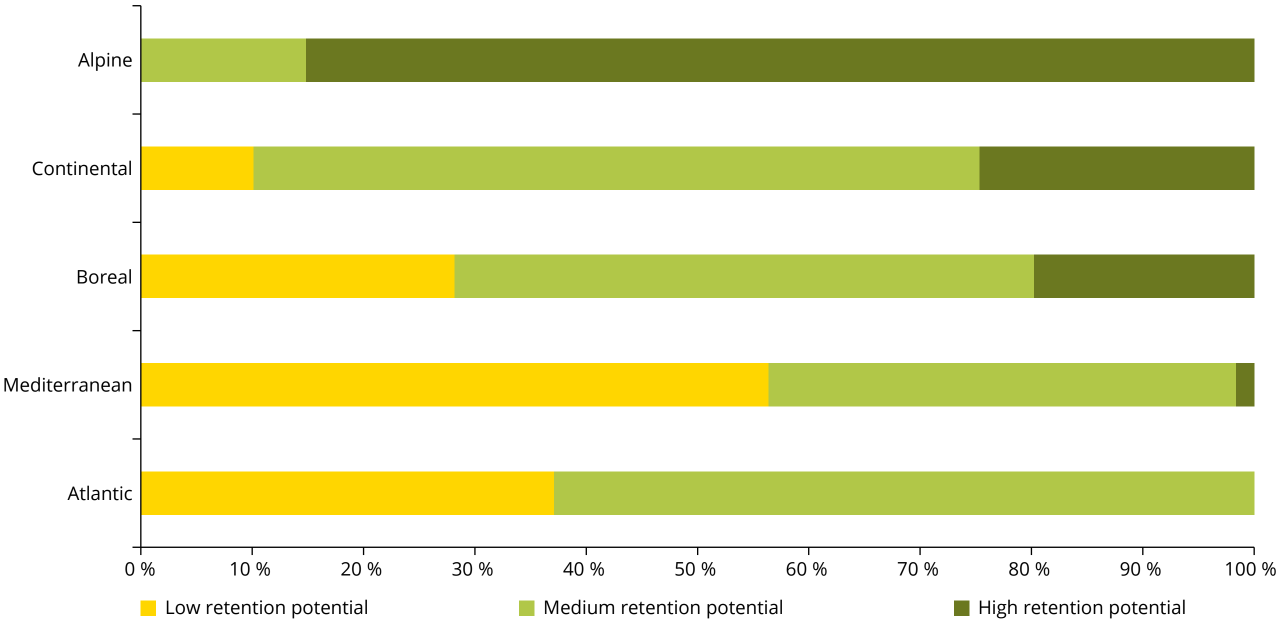
5.3.1 Water retention from forests

A recent EEA report quantified the role of forests in water retention (EEA, 2015a). Water retention is one of the major regulating ecosystem services and it helps to prevent floods, provide clean water and mitigate droughts. Forest ecosystems absorb water by retaining excess rainwater, and preventing run-off and damage from flooding. Forests also provide clean water and mitigate the effects of droughts. This knowledge is essential for the development of better policies to handle the consequences of climate change and extreme weather events. Based on the water account database developed by the EEA, 287 sub-basins, hosting more than 65 000 catchments, were selected in order to assess the role of forest cover and type, and the management of water retention.

Forested water basins with a forest cover of more than 30 % retain 25 % more water than basins with lower forest coverage. For basins in which the forest cover is 70 %, water retention is 50 % greater than in basins in which the forest cover is only 10 %. One of the other main findings relates to the influence of forest types on the degree of water retention. Coniferous forests retain 10 % more water than broadleaved or mixed forests. In general, forests in Alpine and Continental regions have the highest water retention potentials, while Atlantic and Mediterranean regions have lower water retention potentials (Figure 5.3). In Mediterranean regions, forest cover actually prevents water retention; in this region, the lower the level of forest cover, the higher the water retention potential. This suggests that a one-size-fits-all solution cannot be applied to forest cover and water retention in Europe. These findings are highly relevant to the implementation of ecosystem services, as identified in the EU Biodiversity Strategy to 2020.

Photo 5.5 The role of forests for water retention and clean drinking water

Figure 5.3 Potential water retention from forests by biogeographical regions



Source: EEA, 2015.

5.3.2 Climate regulation

Both temperate and boreal forests play critical roles in modifying and controlling climate, and their roles should not be underestimated. These types of forest exert a strong influence on surface climate in mid- and high-latitude regions, and also on climatic events in the tropics (Douville et al., 2002). Thus, significant climate change could be caused merely by the redistribution of terrestrial ecosystems. Such redistribution could be caused by intensive logging, as already observed for boreal forests; it could also be induced by an increase in the atmospheric concentration of CO_2 and other GHGs. Furthermore, the variability of the climatic, soil and vegetation characteristics of a region, as well as the representation of land surface processes in the applied climate model, also have an influence on simulated vegetation–atmosphere interactions.

Past deforestation in temperate regions has resulted in cooler temperatures via changes in albedo (Betts et al., 2008): forests with relatively low albedos were replaced by crops with higher albedos, which, therefore, absorb less incoming solar radiation. In addition, this cooling was further enhanced via the sea–ice–albedo feedback described by Bonan et al. (1992) and Sanderson et al. (2012). Without this feedback, other effects of deforestation would be likely to cause overall warming as described in Box 5.4. Lee et al. (2011) examined differences in the measured temperatures between adjacent forested and non-forested areas. This study found that temperature differences are partly dependent on latitude, that is, with increasing latitude, forested areas become progressively warmer than adjacent open areas. However, this dependence was not apparent at latitudes south of 35 °N.

Afforestation in temperate regions would still act to mitigate global warming through CO_2 uptake, but the warming effect of decreased surface albedo would partly offset the cooling effect of sequestering CO_2, especially in snowy landscapes. In some parts of boreal forests, the warming effect of decreased surface albedo may outweigh the cooling effect of CO_2 sequestration (Betts et al., 2008).

Furthermore, forests help to mitigate climate change — over a single year, a mature tree will take up approximately 22 kg of CO_2 from the atmosphere, and, in exchange, release oxygen. Each year, 1.3 million trees are estimated to remove more than 2 500 tonnes of pollutants from the air.

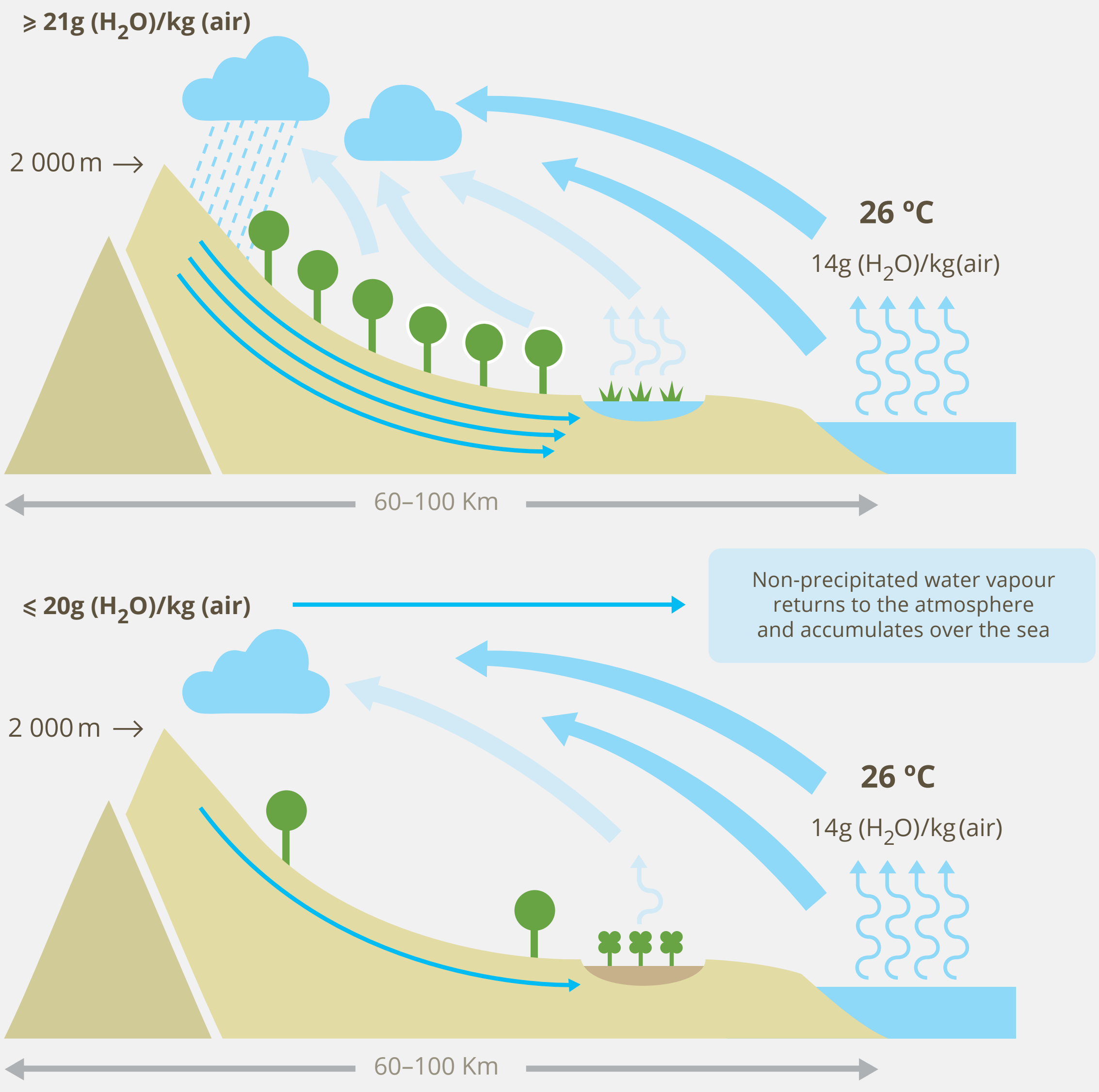
Carbon storage

Both forests and forest soils play a vital role in climate change mitigation strategies. In recent decades, European forests, including forest soils, have absorbed large amounts of CO_2 from the atmosphere. The annual sequestration of carbon is estimated to be 0.72 Pg in the EEA region and 0.4 Pg in EU-28, corresponding to 9 % of the annual European human-made carbon

Box 5.4 A Mediterranean case study

The impact of deforestation in Mediterranean regions, and how this can potentially change regional precipitation patterns, has been explored in the Valencia watershed. Precipitation in Mediterranean regions is fed mainly by evaporation from the Mediterranean Sea. However, without coastal forests, no rain would fall in the mountains within 80 km of the coastline. Rain from summer storms and the Mediterranean cyclogenesis, which involves evaporation from the Mediterranean Sea, account for more than 75 % of the total precipitation in the Valencia Region and neighbouring areas of Spain. In a complex sea-breeze system, evaporated water is carried inland, where it may or may not precipitate against the mountains at the head of the watershed, 60 km to 100 km inland (Millán et al., 2005). Whether or not precipitation occurs depends on the amount of evaporation along the path of the sea breeze, that is, on evaporation from coastal plains. With extra moisture from evaporation, precipitation will take place before reaching the mountains. Without additional evaporation, but instead more dry heat, the lifting condensation level (LCL) will rise to altitudes above the mountains and, as a result, precipitation will not be possible. Instead, the water vapour will return to the sea by the return-flow of the sea breeze (see Figure 5.4).

Figure 5.4 Precipitation-generating processes in Mediterranean coastal mountains



Note: The amount of evaporation from coastal plains that is necessary to produce rain in the watershed is estimated to be about 3 mm/day on average, over an 80 km distance. Afforestation in this area, combined with irrigation and marsh conservation near the coast, could, in principle, provide these levels of evaporation.

Source: Río et al., 2011.

emissions (Forest Europe et al., 2015). Forest soils are the largest pool of carbon (more than 50 %), whereas biomass above the ground (i.e. trees) absorbs almost 30 % of carbon.

Forests and wood also store carbon. During its life-cycle and recycling phase, wood can be used for construction and to replace materials such as plastic, steel and concrete. At the end of these cycles, wood can be used as a substitute for fossil fuels (i.e. to produce energy and heat). This cycle is referred to as the 'cascading use of harvested wood' and has been recommended as an alternative to using wood directly for energy purposes.

5.3.3 Adaptation to climate change

The potential for forests to mitigate climate change has been widely studied, because it could provide a means to circumvent the issue of reducing the use of fossil fuels (Dixon et al., 1994; Niles et al., 2002; Canadell and Raupach, 2008; Canadell and Schulze, 2014; Lundmark et al., 2014; Keith et al., 2015). Few studies have addressed issues related to adaptation, even though the risks of pests and disease are likely to increase in coming years and forests, in general, will need to adapt to the altered growing conditions due to climate change. One of the major challenges for forest owners and stakeholders is managing the uncertainty caused by climate change. Forest management strategies and practices are likely to adapt to changes in growth rates, shifting species and provenance suitabilities, and increasing risks of disturbance. Since these changes will probably occur at a faster rate than the rate at which ecosystems are able to adapt autonomously (UNECE and FAO, 2011), forest management needs to support adaptation with targeted and planned measures. Research has identified many adaptive management measures, including modifications in the choice of species, rotations, thinning schedules, harvesting operations, drainage and other activities, that can support responses to the changing climate (Kolström et al., 2011).

Such management measures need to be adapted in accordance with the local conditions: European forests are considerably diverse, and the expected climate-related changes and disturbances vary regionally. There are very few examples of implemented forest management strategies that apply adaptation to future uncertainties and risks (EEA, 2012b). The challenge is to find out how and, in particular, when management changes should be implemented (UNECE and FAO, 2011). As precise forecasts of future climate conditions are not expected, it is crucial to incorporate better uncertainty and risk factors into adaptive forest management.

5.4 Cultural services

5.4.1 Recreation and tourism

Tourism plays a key role in the EU because of its importance for economies and employment, as well as its social and environmental implications. Forests attract a large number of visitors who appreciate nature, biodiversity and peaceful surroundings. Many recreational activities, such as hiking, bird watching and wildlife viewing, are pursued in forests. Recreational activities and tourism in forested areas are essential elements of forest use throughout Europe and clearly contribute to rural development.

Ecotourism is one example for which income depends on the health of the ecosystem visited. Some ecotourism enterprises gain from on-site biodiversity without contributing to its conservation. At the other end of the spectrum, landowners and managers may actively enhance biodiversity in order to profit from tourist-related activities, and thus, in such cases, tourism and biodiversity are interlinked. Some examples of ecotourism-related facilities and activities include nature-based hotels; camping facilities; tour operators; sporting activities, such as cycling, trekking and rambling; organic restaurants and cafés; educational courses; and holidays.

However, in some areas, a significant increase in tourism may result in negative environmental and socio-cultural impacts. Waste generation, as a result of visitor activities, and the negative visual impressions it creates, may have a serious impact locally, but, to date, these effects have not been considered problematic (Bori-Sanz and Niskanen, 2002).

There are hardly any statistics on tourism in forested areas. However, several case studies demonstrate an increased interest, see Box 5.5. The example in Box 5.6 shows how a small enterprise can provide direct biodiversity benefits through the development of tourism services and facilities.

Box 5.5 The assessment of the recreational values of Danish forests in order to guide national plans for afforestation

The competition among different land uses (e.g. for agriculture, industry and urban development) in Denmark is high and, therefore, assessing the benefits associated with forests can help to inform decision-makers with regard to the (socio-economically) most optimal location of new forests.

The assessment focused on the recreational values (i.e. cultural and recreational ecosystem services) that forests in the North Zealand region, Denmark, provide to the public. These included, for example, 12 005 visits to forests for leisure activities (e.g. walking, jogging, cycling, picnicking, camping and hunting) and the aesthetic values of forests. The assessment estimated which type of forests people prefer to visit, and the total recreational value that different types of forests provide to the public (e.g. how many visits are made to different forest sites on an annual basis).

Photo 5.6 A walk in the forest

Recreational value was estimated using the 'welfare economic value' of visiting a given forest site. This welfare economic value provides an indication of the value that people attach to visiting forests for recreational purposes, and it was modelled based on the observed trade-offs between minimising the cost of travel and the recreational experience, in line with the preferences of the individual, provided by visiting a forest. Consequently, the recreational value in this assessment was not estimated as the actual amount of money that people spend on visiting forests (e.g. travel costs). This information, combined with information on the frequency of visits, obtained from a Danish household survey, resulted in the estimate of a total number of visits.

The assessment of recreational values and preferences in North Zeeland found that the value of recreational services varied significantly among different forests. In the region investigated, the recreational value provided by the different forests ranged from EUR 5 200 to 14 850/ha per year for forests with the highest per hectare value, while forests with the lowest per hectare value ranged from EUR 200 to 320/ha per year (2005 values). The assessment also found that the preferences towards the different recreational characteristics of forests varied across the population. According to the study, the main elements that determine the demand and preferences for recreational services include the level of accessibility to the sites (i.e. distance from home to site); the characteristics of the forest sites (e.g. size, level of broadleaf species available, age of tree stands, presence of water, degree of open land, nature quality of surrounding areas, slope, distance to coast and species diversity); and visitor characteristics (i.e. age, ownership of car and income). The assessment found that, in general, the people of North Zealand have the same preferences with regard to the structural features of forests.

Source: Zandersen and Termansen, 2013.

Box 5.6 Case study: Wnukowo ecotourism in the Puszcza Piska Natura 2000 site

Wnukowo, a small enterprise, offers a range of products and activities to tourists, all of which seek to minimise the impact of tourism on the Masurian Landscape Park in the Puszcza Piska Natura 2000 site. The enterprise offers lakeside bed and breakfast and camping facilities, sells local products and foodstuffs, and charters out kayaks, canoes and motorised yachts. In this way, the Wnukowo campsite benefits biodiversity by ensuring that tourists are educated to a high standard with regard to nature conservation, through the products and activities that it sells. For example, the piped water, showers, WC and sewage meet the strict standards and requirements of the Masurian Landscape Park. The enterprise also benefits biodiversity indirectly by attracting backpackers and, therefore, reducing illegal camping in neighbouring nature reserves. The operations and services provided by such companies in the region are crucial for the protection of water biodiversity at the lakeshore and in the wider ecosystem.

Source: RSPB, 2009.

5.4.2 Forests and cities

More people now live in cities and towns than live in rural areas, with around 75 % of the European population living in urban areas. The proportion of urban dwellers is set to increase to 80 % by 2020 (EEA, 2011a). Continuing urban expansion and sprawl poses many challenges, with regard to, for example, the pressures on forests and other natural areas.

Moreover, as most Europeans now live in cities, there is more focus on ensuring health and well-being in urban settings. In cities, high volumes of traffic, noise and atmospheric pollution, and a high density of built-up areas contribute to a lower quality of life (EEA, 2011a). Forests and nature can help. Urban forests offer numerous benefits to people with regard to their well-being, in addition to a number of ecological services. Access to green environments in cities and around cities makes people happier and healthier, and studies have demonstrated the positive effects of urban forests on physical and mental well-being.

Climate change projections foresee an increase in mean annual temperatures of 2 to 5 °C by 2100 in Europe. The greatest warming is expected to occur in eastern and northern Europe in winter and southern Europe in summer. Heat waves pose particular risks to the elderly and people who suffer from respiratory and cardiovascular diseases. During the severe heat wave of 2003, more than 70 000 extra deaths were reported in 12 European countries. Air quality often deteriorates during heat waves and thus aggravates health problems.

The elderly are particularly vulnerable to the health-related impacts of climate change. In Europe, the proportion of the population aged 65 years and above increased from 10 % to 16 % between 1960 and 2010, and is projected to rise to 30 % by 2060 (Eurostat, 2011). In this increasingly ageing and urbanising society, forests and green spaces in urban areas could help to protect people from the health-related impacts of climate change.

Trees and shrubs cool surrounding areas by several mechanisms. Their leaves reflect light and heat upwards and provide shade, while transpiration releases water into the air, which results in a decrease in the temperature in their vicinity. These natural processes can, thus, partly reduce the negative impacts of heat waves in urban areas. Modelling studies of urban temperatures over the next 70 years project that, in urban areas in which the green cover is reduced by 10 %, urban temperatures could increase by 8.2 °C above current levels. On the other hand, an increase in the urban green cover by 10 % could restrict this temperature increase to only 1 °C.

In addition, the projected increase in the proportion of people aged 65 years and above in Europe will result in different patterns with regard to the use of leisure and recreation time: older retired people will take part in recreation, but the types of activities that they will participate in will depend on their physical abilities. Furthermore, as developed countries increase in prosperity and average incomes increase, more will be spent on leisure and recreational activities. Tourism is rapidly increasing; however, the nature-related tourism sector is growing at a rate six-fold higher than the rate of tourism growth overall. Forests are also closely associated with cultural, intellectual and spiritual inspiration for many people.

Scientific evidence suggests that time spent in forests not only has a positive psychological effect on people, but also influences physiological processes (Nilsson et al., 2011) (see Section 5.4.3 on wellness). The economic value, related to a decrease in the rate of illness and a reduction in the need for medical interventions, of these health benefits has not yet been properly evaluated and deserves more attention (Nilsson et al., 2011). Factors related to human health issues should also be considered and better integrated into forest management strategies.

As the European population ages and becomes more urbanised, the 'public health' benefits from forests are also likely to increase. In practical terms, this means that many cities will need to extend their forests and green spaces, and make them safer and more accessible. Consequently, the planting of trees and afforestation should be an integral part of local and regional spatial planning. The management of urban forests in and around city centres will need to take both environmental factors, such as climate change adaptation, and human-related factors, such as the ageing of the population, into consideration.

5.4.3 Wellness — the wider health benefits of urban forests

Giving urban residents the opportunity and the possibility to enjoy greater access to safe green spaces and to reconnect with nature has multiple benefits for mental and physical health. For example, a study of the whole population of England showed that those who lived close to green environments had 25 % lower all-cause death rates than those who lived further away from green environments, even after adjustments were made for the wider health impacts of poverty (Mitchell and Popham, 2008; van den Berg et al., 2015)

Another study concluded that every 10 % increase in green space is associated with a reduction in the rate of disease equivalent to an increase in life expectancy of five years. In addition, readily available and safe urban forests and green spaces are associated with the following health benefits, many of which are especially important for older people:

- an increase in physical activity and a reduction in obesity;
- a reduction in stress levels and improvements in mental health;
- reductions in noise levels, which can improve mental and physical health;
- improvements in hospital recovery times;
- lower levels of violence and crime, and increased social interactions which can help to improve overall well-being.

5.5 Payments for ecosystem services

In general, payment for ecosystem services (PES) schemes are understood to involve an agreement whereby users of an ecosystem service pay providers for that service. However, many forest ecosystem services are not tangible, as they do not have a market or a price. Some non-market forest ecosystem services are unlimited and free, meaning that the forest owner or manager may not be compensated for their provision. If there is no market on which to trade forest ecosystem services, there is little incentive for landowners to consider their value when making land-use decisions.

Efficient land-use decisions must take into account the TEV, including market and non-market, and use and non-use values, of each land-use option. If the TEV of forested land, including the value associated with timber production and the other ecosystem services it provides, is compared with the TEV of alternative land uses, it is likely that more land would remain for forest production, which would ensure the sustainable flow of essential forest ecosystem services. However, this problem cannot be addressed without knowing the TEV of forested land, including the value of all non-market forest ecosystem services.

An estimation of the economic value of important ecosystem services would allow the inclusion of environmental concerns in economic decision-making, and an evaluation of synergies and trade-offs between the different ecosystem services (Notaro et al., 2008). However, externalities are often enjoyed by people living outside the forests and who are not directly responsible for forest management and protection. The evaluations of externalities and the revenues for forest owners are, thus, difficult to assess (Siry et al., 2005, 2015; Kula, 2012;). One main reason for this is that private property rights may be impossible to define or enforce. Non-specified property rights prevent markets from forming, or make markets function badly if they do form. The components of an ecosystem and the services they deliver do not always have boundaries: the example of drinking water from forested uplands is a case in point (see Boxes 5.7 and 5.8).

An externality could be eliminated by, for instance, taxing the company that fells the forest upland of a watershed. The company would be the polluter and the farmers would be the ones impacted by the pollution. Markets for externalities have attracted considerable attention under the label 'PES' (Schomers and Matzdorf, 2013; Wunder, 2015). PES is attractive for biodiversity and habitat protection, and conservation (Daniels et al., 2014). Such protection may require the engagement of the forest owners. With regard to the value for recreation or ecotourism, a tax could be claimed from visitors or tourists, the revenue of which could be paid to local owners. An important first step, with regard to forest natural capital, is to determine how to quantify externalities. Many of these are supplied free of charge, as externalities often benefit people living outside the forests and who are not directly responsible for forest management and conservation. Hence, it is difficult to assign a value to these externalities and recognise revenue for forest owners. Compensation packages could be relevant to at least four areas: (1) biodiversity and habitat protection, and conservation; (2) carbon sequestration and storage; (3) hydrological services; and (4) forest-based tourism. The fact that money would go directly to the providers would help to ensure that these services would continue to be supplied.

Little information is available on income from PES with regard to the informal production of wood and NWFPs. A valuable regulating service provided by forests, agro-ecosystems, semi-natural areas and heathlands/ shrub land is pollination (see Box 5.9). The importance of pollination for agriculture is well documented. Several studies highlight the effects of remnant forests on crop

Box 5.7 A typical example of a watershed and the ecosystem services it provides

A typical watershed comprises commercial timber, farmland, recreational opportunities, and both market and non-market products, such as resins, honey, fibres, drinking water, timber and wood for fuel. Watershed forests clean the water and protect downstream farmers from floods, droughts and sediments. Such forests also shelter biodiversity and stock large amounts of carbon from the atmosphere. Some of the watershed products, such as timber, and related activities, such as ecotourism, are sources of revenue for the forest owner, while other benefits are not. Many of the non-market services from forests can be attributed to other sectors of the economy or are omitted. Forest services that are provided as intermediate inputs to other sectors, such as livestock grazing or tourism, are attributed to the sector that uses the services, rather than to forestry, which can, therefore, lead to the underestimation of the economic value of forests. Some ecosystem services, such as carbon storage, are not represented at all in estimates of the economic value of forests.

Source: Brauman et al., 2007; Gómez-Baggethun and Barton, 2013; Wollheim et al., 2015.

Box 5.8 Public schemes — payments for drinking water from forested catchments of the Canton of Basel-Stadt, Switzerland

Forests cover 12 % of the Canton of Basel-Stadt and are dominated by broadleaved stands (429 ha), of which 90 ha are the property of 330 private forest owners. About half of the drinking water for this canton is supplied by the Langen Erlen catchment area. In this area, water from the Rhine is purified in a natural and sustainable way by the forests. Among other good practices, this has required changes to the species composition; for example, poplars, which were damaging the soil quality, were replaced with willows and *Prunus avium* (cherry trees).

Water consumers pay for the sustainable management of these forests through extra charges on their water bills.

For more information see http://www.waldwissen.net/wald/boden/wsl_wald_wasser/index_DE.

Box 5.9 Pollination: an important ecosystem service

Pollination is delivered by a range of insects, including wild and native honeybees, bumblebees, many other wild bee species and other insects. Pollinators support crops, accounting for 35 % of global agricultural production volumes. Of the main crops grown for human consumption in Europe, 84 % (e.g. many types of fruit, vegetables and nuts) require insect pollination to enhance product quality and yields.

Bees are essential for both wild ecosystems and agriculture. This service is often not appreciated because of a lack of data. A realistic estimate of the annual value has been calculated; this has helped to increase public interest as it allows comparisons with other ecosystem outputs using trade-off analysis between different services. In 2009, the annual economic value of the pollination of crops by bees in EU-27 was estimated to be EUR 22 billion (Gallai et al., 2009). The assessed value of this pollination service across several ecosystems is of the same magnitude as the total value of marketed and non-marketed roundwood in EU-27 (approximately EUR 16 billion) in 2010.

pollination (Garibaldi et al., 2013). Agri-environmental practices that maintain the natural forest ecosystems around agricultural fields have a positive impact on biodiversity, especially on functionally important species, such as bees and spiders, that provide crop pollination and pest control services (Whittingham, 2011). More species of native pollinators and natural enemies of agricultural pests move from forests into agricultural fields than vice versa.

Some forest owners may receive an income from PES, in addition to the revenues from the sale of marketed products. PES should be developed; the systems in place today are too simple and possibly inefficient (Forest Europe et al., 2011, 2015). Options for PES that acknowledge the economic value of forests have been discussed at pan-European and EU level (UNECE and FAO, 2014). However, the data on income are sparse, and, so far, the reported data suggest that PES contribute a minor amount to income. Another crucial aspect that involves forest owners and managers relates to deciding who is responsible for paying for the management costs of delivering ecosystem services. Currently, payments are not made to the owners of forests that provide supporting or regulating services (Slee, 2009, 2012; Quine et al., 2013). At most, forest owners and managers receive revenue from the sale of goods and, occasionally, for recreational services. In some cases, these may offset or exceed management costs.

Further challenges involve the scope for realising new benefits by redefining property rights and the attempt to optimise the multifunctional outputs of forests, especially the trade-offs with regard to global, national and local benefits.

6 Healthy and productive forests in Europe

Can forests be managed in a sustainable way that permits ecosystem processes to continue, while at the same time allowing timber production and other services? Recently, the understanding of traditional practices and how the use of forest resources can be made consistent with biodiversity and landscape conservation has increased. Several international assessments, such as the Millenium Ecosystem Assessment (MEA) and the Economics of Ecosystems and Biodiversity (TEEB) initiative, have helped to increase the understanding of the importance of the range of ecosystem services that forests provide. These efforts aim to promote the integration of SFM with human well-being and the recognition that healthy, multifunctional, resilient and productive forests constitute the basis of SFM.

6.1 Are forests in Europe healthy?

As already mentioned in Section 4.5, the expression 'forest health' can be interpreted differently depending on the particular interests that lie in the forest: from a forest manager's perspective, a healthy forest is one that has optimal levels of growth and that provides the range of expected products, mainly wood products of a given quality, for placement on relevant markets, whereas, from an ecological perspective, a healthy ecosystem is one that is able to maintain biodiversity and ensure the long-term capacity of forest ecosystems to resist and respond to human-induced changes, and restore ecosystem resilience now and for the future.

Forest condition, health and vitality are assessed as part of international and national reporting strategies. Such comprehensive assessments include indicators, such as defoliation, the presence of pests and insects, IAS, tree species diversity, vascular plant diversity, the volumes of deadwood, the degree of naturalness, regeneration and management. Forest health in Europe has been affected by air pollution in the last century. In the 1980s, the focus was on acid rain and its impact on tree and water quality.

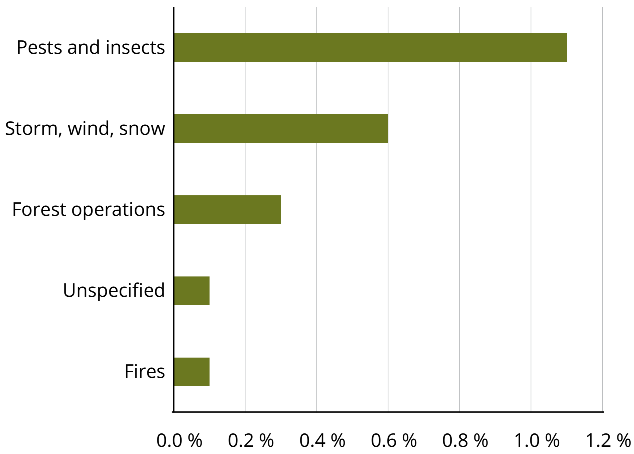
Forest health and productivity are affected by a range of disturbances, such as insect attacks and fungi infestations. For instance, insects and pathogens are biotic disturbance agents that are detrimental to forests. Insect outbreaks can lead to harmful levels of defoliation or increased rates of mortality under certain climatic and site conditions. Defoliation has been monitored at approximately 6 000 points across Europe. This suggests that the canopy condition has fluctuated over the past three decades as a response to diverse abiotic and biotic disturbances. However, the latest data collection on defoliation shows that there has been no major deterioration in forest health (Michel and Seidling, 2014).

Widespread forest decline may threaten the provision of ecosystem services, such as timber, amenities and nature conservation. The sources of disturbances can be natural (e.g. climatic factors, abiotic site conditions, fire and pest organisms), semi-natural (e.g. climate change) or human-made (i.e. due to interferences from the socio-economic environment or forestry) (Führer, 2000).

The relative importance of such disturbances within forest ecosystems has been reported by various countries (Forest Europe et al., 2015). Figure 6.1 shows the relative importance of disturbances ([10]) such as pests, diseases and hazards on forest ecosystems, compared with human-related activities and forest fires. About 3 % of Europe's forest area is affected by damage, and the dominant causes are biological agents, such as insects, diseases, wildlife and grazing (which, according to the latest Forest Europe report (Forest Europe et al., 2015), affects approximately 1.5 % of forests). Damages are also caused by forest fires, storms, wind and snow. Forest operations cause less than 0.5 % of the damages to Europe's forest area. The frequency and severity of these impacts on forest health, forest ecosystem functioning and the delivery of ecosystems services is likely to further increase as a result of climate change. The emerging picture, overall, suggests that adverse effects result from a wide variety

([10]) This information is based on the reporting of only 19 countries.

Figure 6.1 Relative areas of forest affected by different types of disturbance



Source: Forest Europe et al., 2015.

of causes linked to climate change. Nevertheless, the precise impact of climate change on forest health, growth and biodiversity is difficult to assess.

In general, forest ecosystems in Europe are in a better condition than other ecosystems, such as grasslands and wetlands. Most forests in Europe (68 %) regenerate naturally or by natural expansion. Almost 90 % of forests are semi-natural forests that are used and influenced by man, but still display characteristics of natural forest ecosystems in terms of their structures and functions. The *State of Europe's forests 2015* report indicates that 65 % of European forests are core forests, meaning that they are not fragmented and that the forest area has increased by natural expansion and afforestation over the last decades (Forest Europe et al., 2015). The internationally recognised proxy indicators that are used to assess forest biodiversity suggest that Europe's forests are diverse and overall healthy semi-natural ecosystems. However, these results are not supported by the reporting of the state of nature conservation in Europe by Member States. The latest reporting, in accordance with the Article 17 of the Habitats Directive, by Member States covered the period 2007–2012 and suggests that only 15 % of the forest habitats listed in Annex I of this directive have 'favourable conservation status', whereas 76 % have 'unfavourable conservation status' and 5 % are categorised as 'unknown'. Forest species did better, as 26 % were estimated to have 'favourable conservation status'. However, 60 % have 'unfavourable conservation status' and a further 14 % were reported as 'unknown'. The majority of forest habitats listed in Annex I and forest species listed in Annex II cover about half of Europe's forests and are reported as having an unfavourable nature conservation status. This supports the fact that forests in Europe are highly human-modified ecosystems that are far from their natural state. All forests in Europe have been influenced by human use and management over the centuries. This has had a major impact on their natural biodiversity (i.e. species and genetic compositions, and structures and functions).

Despite this reportedly unfavourable nature conservation state of forests, forests do play a significant role in maintaining biodiversity in Europe as they provide habitats for a large number of species.

6.2 Are European forests productive?

Forests are an integral part of the land-resource base and rural development. Forests contribute directly to the economy by providing significant employment and income in rural areas in which unemployment is rising, both in the formal and informal sectors. Forests in Europe provide numerous valuable resources, many of which are monetised, but some of which are hidden. For instance, forests and the forest sector supply ecosystem services which meet basic needs and provide raw materials for manufacturing opportunities. In general, forest productivity, resilience and the capacity to deliver natural capital are directly related to the level of biodiversity (Carpenter et al., 2009; Haines-Young and Potschin, 2010; Ring et al., 2010; Xu et al., 2015). All activities are dependent on the maintenance of healthy forest ecosystems for production.

The wood component of forest ecosystems is the basis for many economic activities and has a clear market value. Table 6.1 compiles some of the main contributions made by forests in the EEA region (FAO, 2015b). Total activities contribute at least EUR 135 billion to the annual gross value added (GVA). GVA is the sum of all revenues from the forest sector minus the costs of purchases from other sectors and paid to owners for labour, land and capital. It is, as such, a good indicator of the income generated by forest activities. Pulp and paper currently account for approximately 42 % of revenue from the forest sector, whereas the production of roundwood and solid wood products together accounts for almost 60 %. Overall, the GVA from forest activities reached almost EUR 200 billion in the 2010–2011 period.

The overall contribution of Europe's forests to gross domestic product (GDP) is usually reported to be approximately 1 % on average. Nevertheless, the forest sector is often considered to be less important than other sectors (because of, for example, the modest contributions made by forest-based industries' to GDP in some EU Member States).

Photo 6.1 Wood out of the forest, Finland

Approximately 5 million people (full-time equivalents) are employed in formal forest sector activities. Most of these workers are in the forestry (36 %) and wood industries (37 %), and the remaining 27 % are in the pulp and paper sector (FAO, 2014). Many downstream economic activities, such as contributions to the housing and construction industry and manufacturing, and those related to the numerous emerging products that are used for textiles, pharmaceutics, composite products, etc., are not included or are estimated only very approximately. In the USA, the economic contribution of the informal forestry sector was estimated to be 10-fold higher than the contribution made by the formal sector. In addition, many full-time and part-time jobs in microenterprises are not included in official European statistics (Eurostat, available online: http://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_in_figures_-_Eurostat_yearbook).

Forests are still relevant to local and national economies, particularly in the northern and eastern parts of Europe. Forests are particularly important for the national economies of some countries, including Finland and Sweden (in which forestry contributes 3.9 % and 2.1 %, respectively, to the total GVA) and, to a lesser extent, Austria, the Czech Republic, Estonia and Slovakia (in which forest-related activities contribute approximately 1 % to total GVA). A wide range of products and activities, including construction, packaging, bioenergy and tourism, are derived from the forest value chain beyond the boundaries of the forest sector (Pülzl, 2013). Forests are also important for the economies of other regions (see Box 6.1 on the contribution of forests to the economy in Mediterranean regions). However, documentation is sparse.

Europe's forests are considered productive today and are very likely to be increasingly acknowledged for their products and services. An increase in activities within the forest sector is expected, which would lead to a stable and, eventually, an increase in forest extent and downstream activities. However, future productivity will be completely dependent on the maintenance of biodiversity in forests and the sustainable management of forest resources and natural capital.

This entails a balanced approach to economic, social and environmentally sustainable development. The broad picture is that forests in Europe are managed in an environmentally sustainable way and that there seems to be no evidence of a systematic imbalance at

Table 6.1 Human activities related to forest ecosystems in Europe and their estimated economic value (GVA and turnover), associated employment and expected future trends, dependency and impact on natural capital — statistics for 2010–2011

Human activities and forest ecosystems		GVA in billion EUR	Turnover in billion EUR	Employment (million)	Expected trend	Dependency on forest natural capital	Pressures on forest capital
Production of living resources	Forestry and logging (ISIC NACE 02)	21.1	10.2 (*)	0.7	Increased	Yes	++
Extraction of living resources (NWFPs)	Plant based	2.6			Increased	Yes	+++
	Animal based	0.6					
Forest industries	Manufacture of wood and articles in wood (ISIC NACE 20)	31.2	122	1.1	Increased	Yes	
	Manufacture of paper and paper products (ISIC NACE 21)	42	180	0.7	Down	Yes	
	Manufacture of furniture	29	96	1		Yes	
	Printing and services related to printing	33	88	0.8		Yes	
Tourism and recreation	Recreation				Increased		+
Man-made structures	Sawmills				Down		
Energy production (renewable)	Wood fuel				Increased		++
Research and surveys	Forest research	-			Down		
	Forest inventories and monitoring	-			Unchanged		
Military	Dumped munitions	-			Down		++
Total		**170.3**	**496.2**	**4.3**			

Note: (*) Norway, Sweden, Finland and Denmark. + low pressure; ++ moderate pressure; +++ high pressure.

Source: Hetemäki et al., 2014; FAO, 2014; Eurostat (sbs_na_ind_r2); estimates (in italics) provided by the Directorate-General (DG) for Enterprise and Industry.

European level. Overall, Europe demonstrates stable or increasing forest cover and resources. Forest area and growing stocks are expanding. Overall, policies and instruments for SFM are in place. For instance, most national forest acts ensure that the forest extent is permanent. Replanting or nature regeneration must occur after the logging of any forest area to ensure continuity in forest land use.

Forests in Europe are considered to be one of the ecosystems in which biodiversity is best conserved, despite extensive human activities and multiple combined pressures. In most European countries, the major objective of forest management is to sustainably manage forest ecosystems rather than to sustainably produce raw materials (Moldan et al., 2012; Sikkema et al., 2014). The sustainable management and use of forests can be expressed as the ratio of fellings to the net annual increment. Box 6.2 indicates that forests in Europe are, overall, used in a way that forest growth, expressed as the annual increment, balances the fellings from forests. Only a few countries exceed this ratio.

Box 6.1 The total economic value of forests in the Mediterranean region (Croitoru, 2007)

Mediterranean forests provide a wide array of ecosystem services. However, most of the benefits are poorly recognised and valued. The use of forests varies a lot across the region. For instance, in Portugal, 93 % of the total wood forest products are used for timber production, whereas in southern and eastern parts of the region, 100 % of the wood produced is used for fuel. Only a few attempts have been made to assign a value to the NWFPs in the Mediterranean region. The importance of NWFPs as a source of livelihood and sustainable development is widely recognised. The main NWFPs of the Mediterranean region are cork, mushrooms and honey. The value of NWFPs varies a lot. Ecosystem services, such watershed protection, carbon sequestration, biodiversity conservation, pharmaceutical inputs, hunting and options for recreation, account for a many of the services provided by forests in the region.

Various studies have attempted to quantify the total economic value (TEV) of Mediterranean forests. The TEV is the sum of direct-use, indirect-use and non-use values. The study estimated that the TEV of Mediterranean forests in the European region was about EUR 173/ha. This value varies in the region depending on the forest type, climate, soil and human activities.

Photo 6.2 Mediterranean forest, Var, France

The social aspects of the sustainability of Europe's forests include opportunities for public access and use of forests. Forests are greatly appreciated for their recreational and cultural services. The majority of forests in Europe are open for public access.

The economic aspect of sustainability relates to the ability to reconcile increasing resource demands and economic growth, on the one hand, with ecosystem resilience and human well-being, on the other. Forests influence job availability and income in Europe's rural areas.

Forests, as major ecosystems and renewable resources in Europe, are part of the roadmaps that have been devised in order to achieve existing objectives and targets by 2020/2030; for instance, they contribute to the 2020 climate and energy package, the Europe 2020 Strategy, resource efficiency and the EU Forest Strategy. The 7EAP expresses the increasing complexity of defining, analysing and responding to environmental problems.

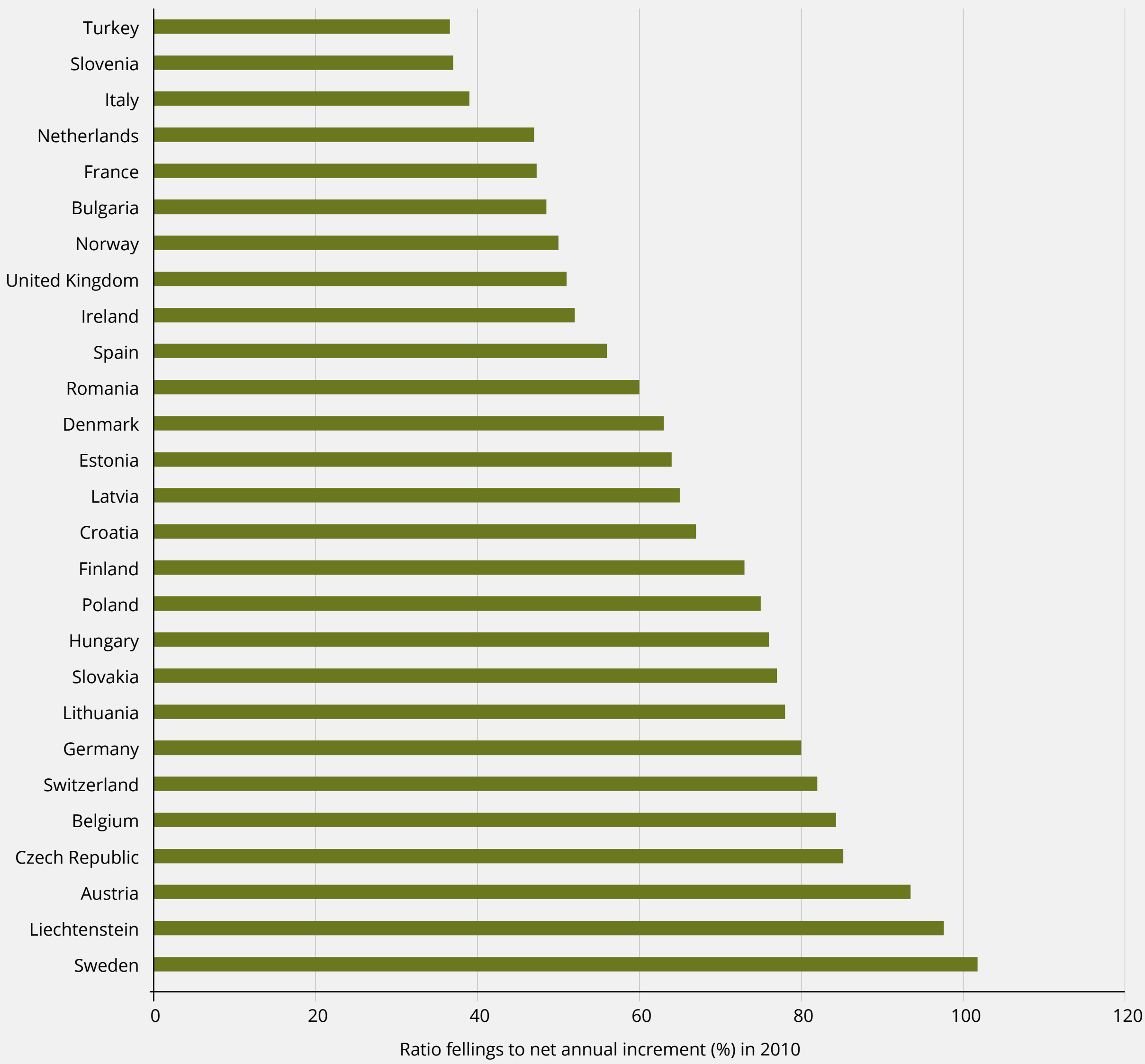
Wood production in Europe is basically at its carrying capacity. Based on current estimations of the sustainability of forests, expressed as the ratio of fellings to annual increments, most countries in Europe could deliver 30–40 % more wood. However, a felling-to-annual-increment ratio of approximately 70 % has been recommended in order to ensure

Box 6.2 The sustainable use of forests in Europe

The ratio of fellings to the net annual increment indicates whether or not the use of forest resources is sustainable in the long term. In general, in Europe, felling rates are lower than annual increments (i.e. the ratios are less than 1:1), which indicates that forests are being used in a sustainable way, and that the growing and carbon stocks are increasing. This ratio shows substantial variation across Europe, suggesting wide variation in the degree of use of forests, varying from 20 to almost 100 %; on average, for Europe as a whole, the ratio is approximately 65 .

This ratio should preferably be derived from assessments performed on a relatively large spatial scale and over a relatively long period of time, taking into consideration any silvicultural practices and the age–class distribution of the forest. Moreover, the felling-to-increment ratio indicator does not capture how and whether or not forest management acknowledges and incorporates aspects of biodiversity. For example, it is not apparent whether or not the increment could be attributable to fast-growing alien species.

Figure 6.2 The utilisation rate of forests in 2010



Note: Ratio expressed as the annual felling as a percentage of the annual increment for the year 2010, for countries reporting in accordance with Forest Europe.

No data from Greece, Malta and Portugal.

Source: Forest Europe et al., 2015.

the sustainable management of forests. Any further expansion is likely to result in unsustainable production. For instance, an increase in the demand for bioenergy would result in an increase in imports of wood from outside Europe, to allow forest biomass resources in Europe to be rebuilt to a sustainable level. However, such displacement of land use is very likely to lead to the collapse of forest resources, in the form of deforestation, in other parts of the world.

Another option would be to promote resource-efficient energy consumption by, for instance, increasing the bio-based circular economy. The reuse, recycling and renovation of wood in the circular economy chain would also reduce the consumption and waste of wood, and its by-products.

Forests play an integral role in bio-economies and green economies. Sustainably managed forests and their products are materials for the circular economy. The principles of the circular economy offer options for the more efficient use of wood (Mabee, 2011). Wood/timber is a biological and clean material, especially if used as a natural material, it has a long lifetime, it can be reused and recycled, and it has options related to renewal and innovation. In a cascading approach to forest product manufacture, each fibre product serves as an input for another product downstream. The use of wood, especially high-quality wood, should be cascaded across the forest value chain and expanded at each phase of the cascade. The first use of wood fibre that is high in quality and has a long half-life would be for residential housing. After such use, wood panels could be used in non-residential buildings, such as warehouses, then recovered and recycled to produce furniture. Finally, such wood could be used for pallets or other short-lived wood products. During this entire cascade, the wood retains its capacity to store carbon: carbon is stored over 80 % of the cycle, which, therefore, slows the carbon cycle in the atmosphere. The manufactured product is expected to have lower material costs but be more labour intensive to produce. Finally, such a cascading approach means that fibres are used over a longer time for multiple applications, and most wood is available for energy generation at the end of its lifespan. Such a complete use of wood could increase the supply of forest ecosystem services in order to meet increasing demands.

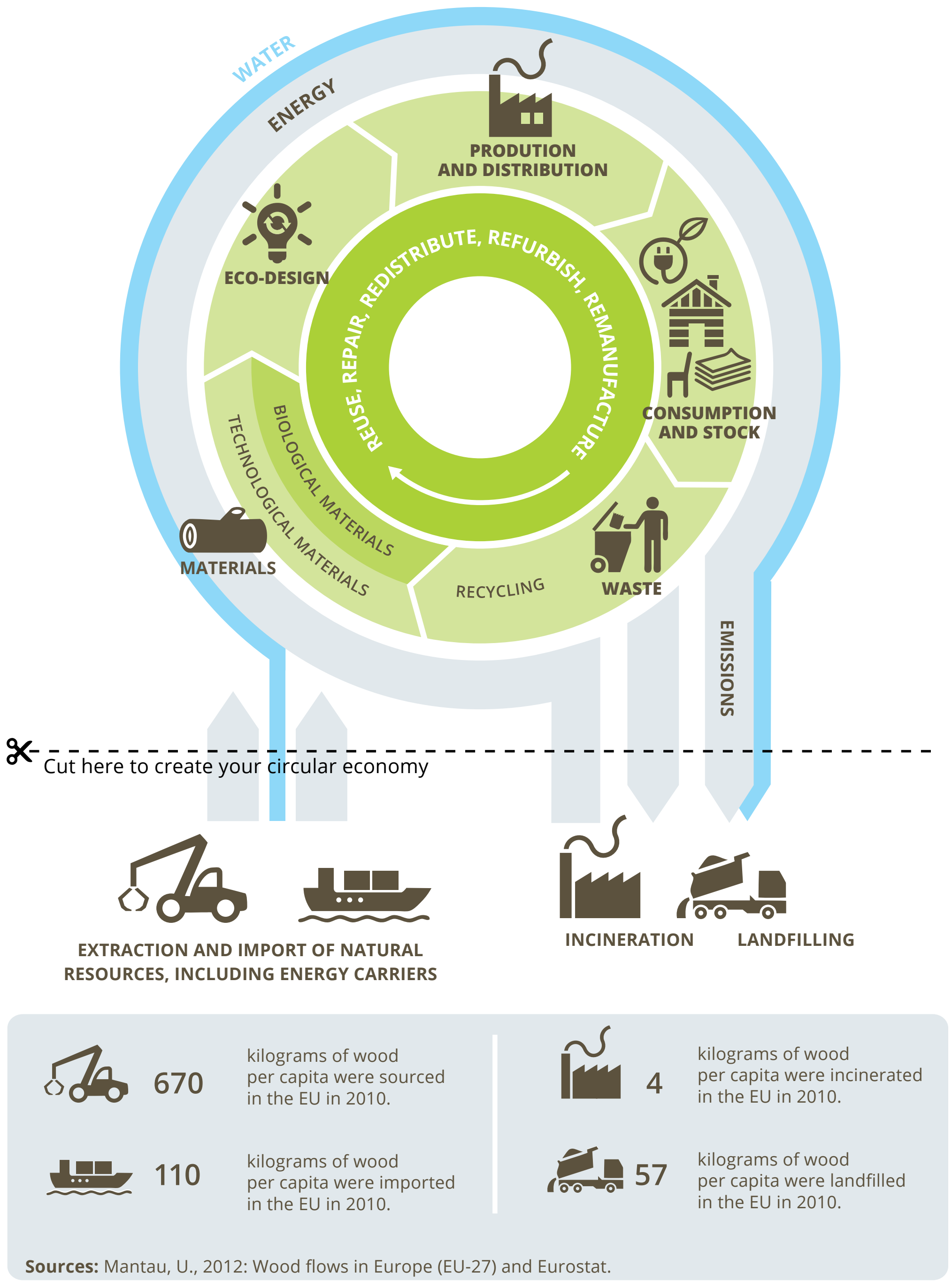
This cascading use of forest products should be optimised as much as is feasible across forest industries — that is, woodworking industries to paper and pulp industries — and also across sectors (e.g. construction, retail and manufacturing). For instance, there is huge potential for a circular economy based on wood use in construction, housing, furniture

Photo 6.3 Picking mushrooms is popular in all of Europe's forests

and panel industries. In this regard, the recycling of wood by the construction industry could be increased to more than the current 10 %. The cascading use of wood in the forest value chain is still too fast, that is, residues from logging, industrial processes and manufacturing could be reused and recycled to a larger extent. Wood should be used for bioenergy as a last option and only if no alternatives for its use are left.

The infographic on the bio-based circular economy in Figure 6.3 is a simplified illustration of the potential of wood as a natural, renewable, recyclable and innovative raw material and, as such, demonstrates its ideal suitability to the circular economy. Barriers of acceptance need to be broken down. Consumers need to understand the benefits of using sustainably managed and supplied wood that, for example,

Figure 6.3 Forests and the forest sector as part of a circular economy



Source: Adapted from Eurostat, 2015.

replaces non-renewable resources and fossil fuels, is a climate-neutral material and has is associated with relatively low CO_2 emissions. The use of timber products should be promoted and decoupled from deforestation.

As presented in Chapter 5, forest ecosystems have the capacity to deliver an enormous number of ecosystem services and high potential to create new jobs, and new and sustainable products. These opportunities are dependent on innovation and on given framework conditions. They are also strongly dependent on major policy changes with regard to climate change. In addition, for economic sustainability, forests should not be used beyond their long-term capacities for the production of wood and NWFPs.

Forests are complex systems that involve interactions between natural and human components through flows of ecosystem services, and that respond dynamically to global change. Thus, the task of assessing and achieving the overall sustainability of forests is complex.

Even if the forests in Europe are considered sustainable, the main objective of forest management is to maximise economic gain. These approaches need to be considered in light of global changes and a highly uncertain future, and, therefore, new approaches may be necessary (Rist and Moen, 2013). The challenge is to maintain and protect forest ecosystems in order to provide valued ecosystem services in the long term.

6.3 Multifunctional forests depend on health and productivity

Forests are multifunctional, as the same forest area often provides multiple ecosystem services at the same time. The increasing demands of society for forest products and services puts pressure on their multifunctionality. Forest ecosystem services are derived from forest resources, which are also known as forest natural capital. The capacity and quality of the delivered ecosystem services depend on well-functioning forest processes such as nutrient and water cycling, and photosynthesis. The outputs of these interactions are the functions of the forest ecosystem ('primary production'). The maintenance and protection of biodiversity in forests support and enhance the ability of forests to provide a range of ecosystem services, including timber production, climate regulation and the maintenance of clean drinking water. The potential delivery of ecosystem services is thus linked to the health of forest ecosystems, as these possess the full range of ecosystem functions on which the services are based (EC, 2013a). Forest ecosystem services are increasingly being considered as at least as important as timber production. Healthy, diverse and productive forest ecosystems provide a wide range of ecosystem services that support life and benefit, often at the same time and place, forest owners, managers and society as a whole (Forest Europe et al., 2011).

6.3.1 Ecosystem-resilience issues for forests

Healthy, diverse and productive forests are highly relevant to human well-being, especially in the light of the rapid changes that are being caused by climate change. Ecosystem resilience refers to how forest ecosystems are able to cope with stress (also called 'resistance'), to recover from the impacts of disturbance, and to adapt to stress and change. Strategies to build forest resilience involve the management of forests in order to increase the resilience of forests and trees to the negative impacts of climate change, and to help maintain resilient forested landscapes; key include the maintenance of healthy forest ecosystems, the restoration of degraded forests, and the conservation, enhancement and use of biodiversity. Healthy forests cope better with stress, recover more easily from damages and adapt better to disturbances and changes than unhealthy forests. The loss of species and habitats decreases the resilience of forest ecosystems and makes forests more vulnerable to pressures from human activities, which exacerbates their effects and may cause a corresponding loss of ecosystem services.

Although there is a need for a better understanding of how biodiversity loss might affect the dynamics and functioning of ecosystems and, consequently, their services, hardly any data are available for the assessment of the resilience and sensitivity of forest ecosystem services to change.

An increase in the awareness of forest natural capital and the value of forest ecosystem services to society might help to maintain and protect forest ecosystems, and to promote consideration of the complex relationships that exist between risk, human well-being and ecosystem health, and that are associated with using forest resources.

The evaluation of forest ecosystems and, in particular, the assessment of the costs of forest degradation, may help to quantify the value of forests in order to evaluate the provision of ecosystem services. A first step towards this evaluation is the quantification or accounting of forest natural capital, in order to monitor changes in the productive capacity of forest resources and in the contributions of forest resources to human well-being.

6.4 Quantifying forest natural capital

In Europe, nature as capital, ecosystem services and the benefits from forest ecosystems are increasingly being considered as part of decision-making and policymaking approaches, see the definition in Box 6.3.

Being able to identify, delineate and quantify ecosystem services is crucial for the sustainable management of forest ecosystems. Natural capital accounting is a way of monitoring changes in the productive capacity of forest resources and the contributions of forest resources to human well-being. As such, natural capital accounting supports policymaking and influences practices in land-use planning, including planning with regard to forest land use and the assessment of forest condition. As proposed in the MAES initiative, a first step in natural capital accounting involves the identification of ecosystems and their services and, as far as is feasible, the assessment of their value.

Accounting for natural assets calls for a measurement of the stocks and flows of ecosystem services, and must ensure that the people who rely on these assets understand their value and the costs of losing them. Ecosystem services are the benefits that the stocks provide and represent the final products from ecosystems that are directly consumed, used or enjoyed by people (see Figure 6.4).

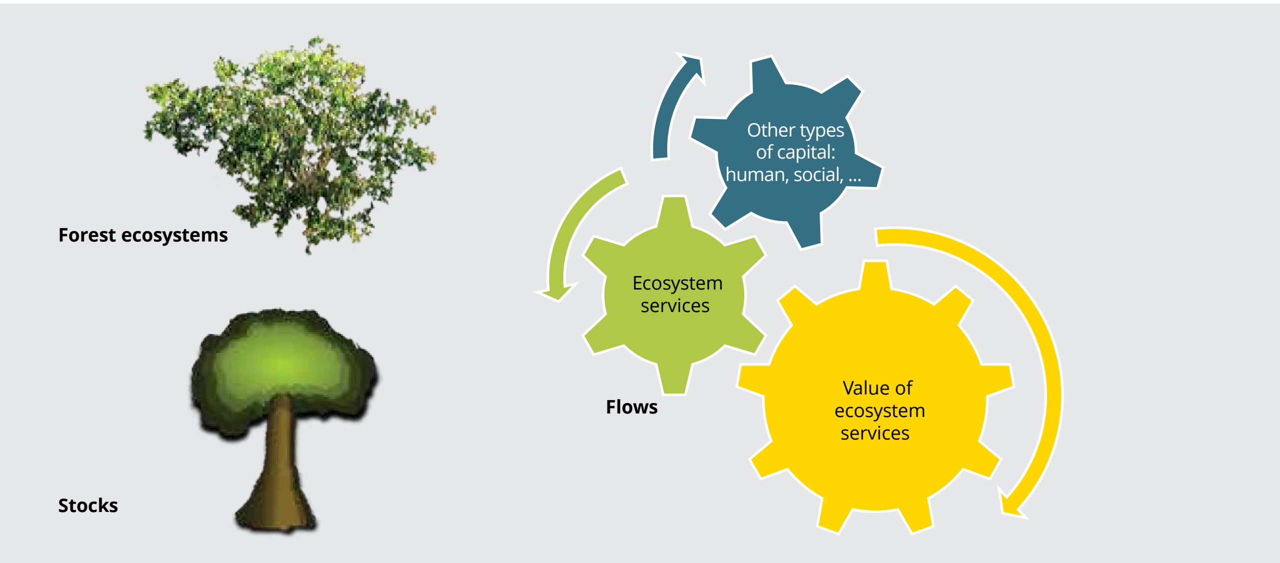
Socio-ecological systems generate ecosystem services. The exact contribution of forests to human well-being is challenging to assess, as it depends on many factors that influence ecosystem health and functions. These factors comprise ecological factors, which influence the functional and process integrity of forest ecosystems, and socio-economic, which include institutions or the way in which people value forests. Forest capital has been roughly estimated based on values of timber and NWFPs, and can be expressed as physical accounting units of, for example, area, volume or biomass.

Box 6.3 The definition of natural capital

Natural capital refers to the living and non-living components of ecosystems — other than people and the products they manufacture — that contribute to the generation of ecosystem services that are of value to people. It describes non-renewable resources, renewable resources and ecosystem services, in order to demonstrate the importance of ecosystems for providing the biophysical basis of societal development for all human economies.

Source: Costanza and Daly, 1992.

Figure 6.4 Forest ecosystems and ecosystem services: stocks and flows, and natural capital

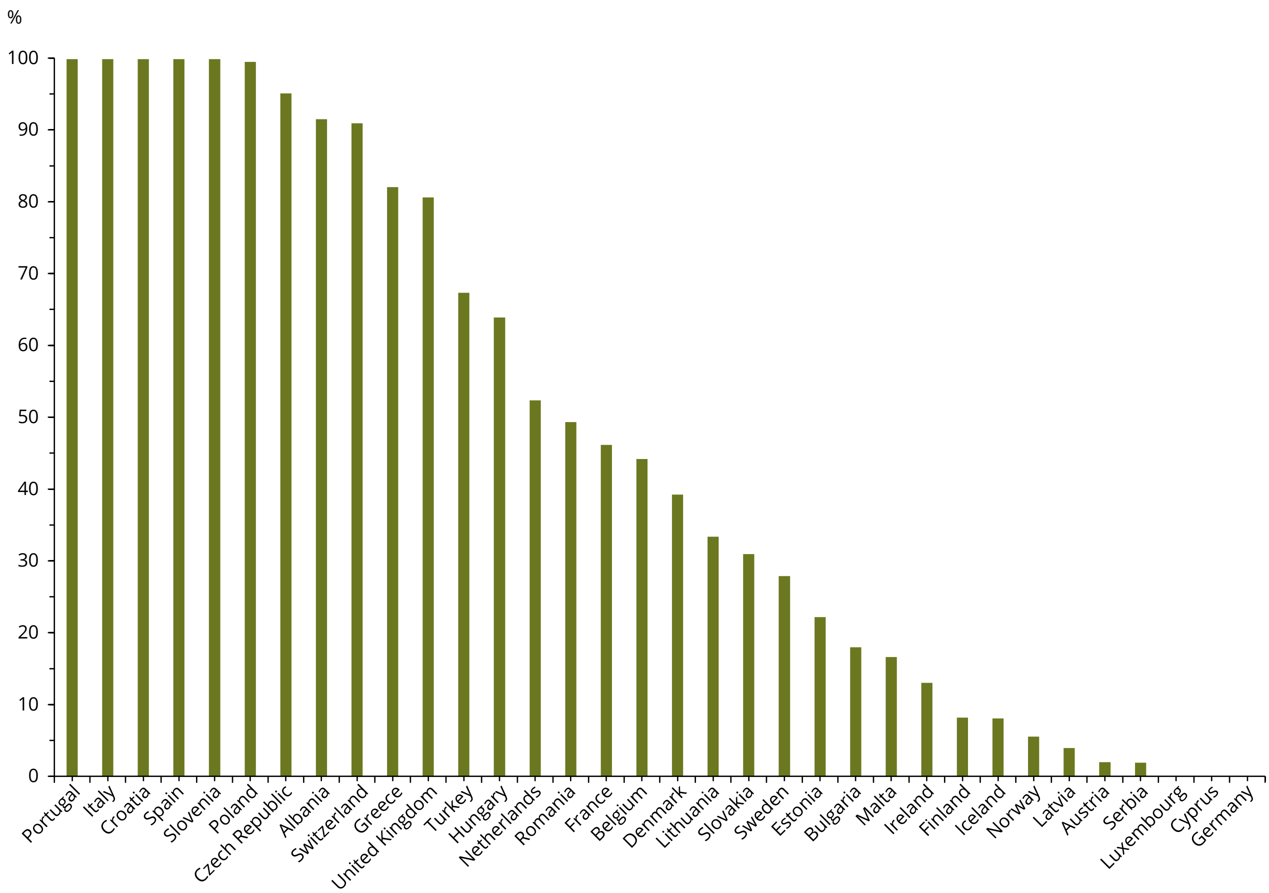


Source: Adapted from UNEP, 2014.

The IWR2014 attempted to incorporate broader values of forest capital with a measure of wealth, in order to assess the value of forest ecosystem services other than timber (UNU-IHDP and UNEP, 2014). Overall wealth includes direct benefits from natural, produced and human capitals (the 'productive base'), as well as their contributions to production and links to consumption, which, again, have feedback effects on the productive base.

For the purpose of constructing ecosystem accounts, the value of wealth from forest ecosystems was approximated to be the sum of all benefits provided by a land area of standing forest as a basic unit. This information on forest area can then be combined with information on the value of benefits provided by forest ecosystem services (Kumar, 2000: EC 2013; EC, 2014). The IWR2014 estimated the contribution of forest natural capital to wealth in 34 European countries, based on information on forest area, growing stock and carbon stock from the FAO database and the ecosystem values published in the TEEB database (see Figure 6.5). Forest resources include wood and non-wood resources. The exercise demonstrates how the social value of natural capital, including forest natural capital, can be assessed. The overall contribution of natural capital to wealth in Europe has been estimated to be approximately 6 %, almost 50 % of which is forest capital. There is a trend, as reported by the IWR2014, for a decline in natural capital, with 14 countries in Europe also showing a decline in forest capital between 1990 and 2010. However, the results confirm that forest resources are a main part of natural capital in many European countries. The dominating ecosystem service delivered by forests is the provision of wood for both commercial and non-commercial use. Because of the lack of available information, the non-wood resources generally appear to constitute only a small percentage of forest resources (approximately 5 %). There is, however, an increasing recognition and interest in the wide variety of other services that are provided by forest ecosystems (see Table 5.1), but most ecosystem services remain unevaluated.

Figure 6.5 Estimates of the share of forest resources (%) of natural capital for 34 European countries, 1990–2010



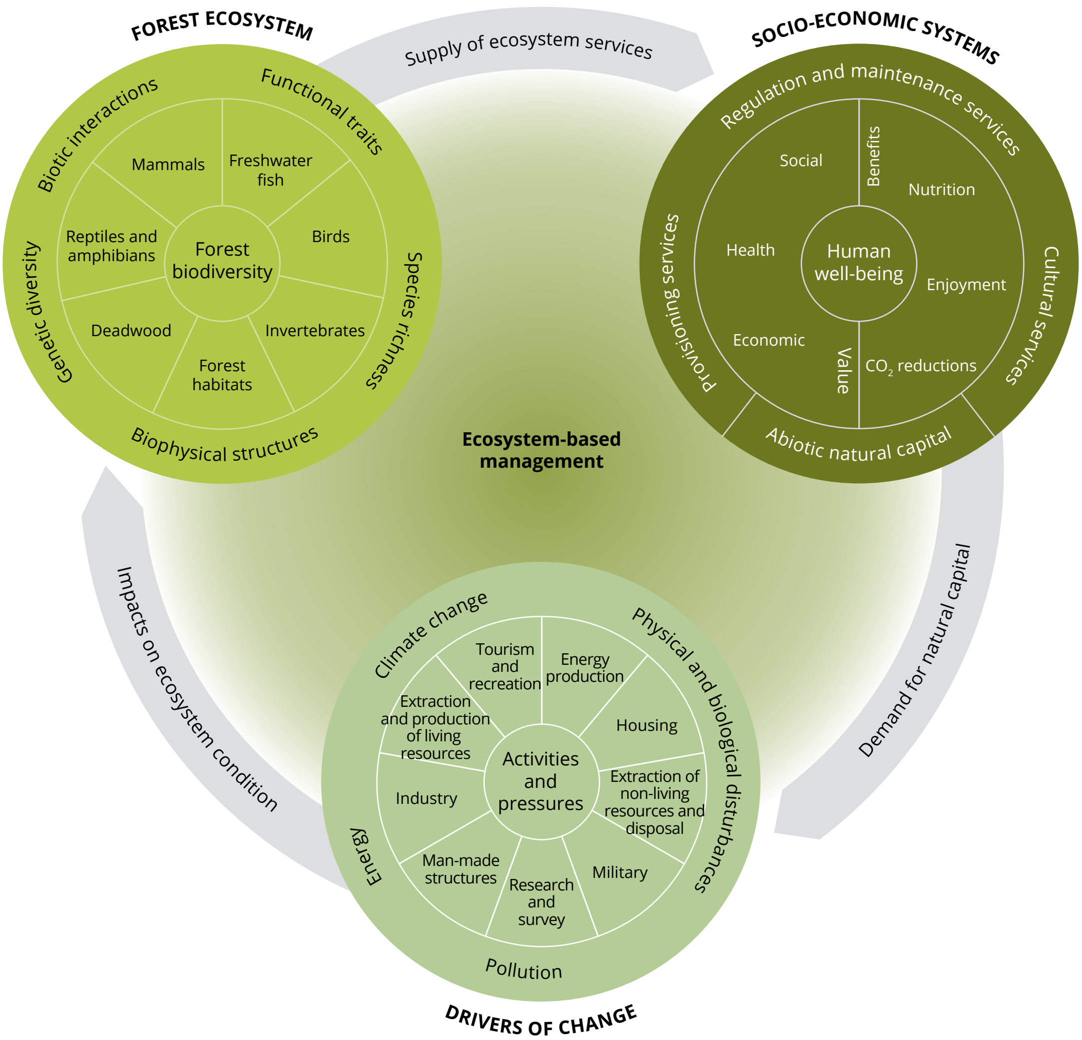
Source: UNU-IHDP et al., 2014.

6.5 Biodiversity, natural capital and the delivery of forest ecosystem services

Figure 6.illustrates the interconnections among the structural elements of an ecosystem, which comprises living and non-living elements that are based on fundamental ecosystem processes. This figure helps to identify the flow of ecosystem services from physical assets and how these flows can be linked to benefits that people value. One way of doing this is to base the calculation of ecosystem value on physical accounting units. The values of the flows of benefits from forest ecosystem services to society can only be approximated, as scarcely any data that would allow such a valuation exist. The value of the stock of forest capital has been roughly estimated from values of timber and the available values of a few NWFPs. The outputs of such interactions are functions of the ecosystem, such as primary production. This expresses the potential of the ecosystem to deliver ecosystem services, which are linked to ecosystem health. A healthy forest ecosystem would be fully functioning, as it would include the full range of ecosystem interactions needed for the support of service generation.

Obtaining benefits from ecosystem services requires further inputs of capital, energy and labour. The production of food, wood, fibre and drinking water are considered provisioning services. These services depend on several regulating ecosystem processes such as water retention and climate regulation. Other services are cultural services, which are important for aesthetics and recreational purposes. Finally, ecosystem services also support biodiversity. In the EU Biodiversity Strategy, biodiversity and ecosystem services are defined as natural capital.

Figure 6.6 Conceptual framework for forest ecosystems



Note. Socio-technical systems as drivers of change are dependent on natural capital and its benefits with regard to meeting societal needs, contributing to economies, contributing other value and promoting well-being

Source: Adapted from EC, 2013 and EEA, 2015b.

7 Sustainable forest management — the way forward?

The nature of forestry has, to some extent, gradually shifted over time, from single-use forestry, such as forestry for only timber production, to multiple-use forestry for, for example, timber production and recreation, and even to multifunctional forestry that recognises the role of public participation and the provision of multiple services by forest ecosystems for human well-being and society (Quine et al., 2013; Messier et al., 2015). SFM (see also Box 7.1) underpins modern forestry practices by broadening the objectives and recognising the need to maintain and enhance the social, ecological and economic values of forests for the benefit of present and future generations (see Box 6.2). SFM is the global forestry sector's response to the need for sustainable development. It seeks to maintain biodiversity and the ecosystem services that forests and trees provide, and, at the same time, to balance the provision of society's growing demands for forest products and services (Holvoet and Muys, 2004).

Increasingly, strategies for the management and conservation of forest ecosystems need to deal with emerging challenges. The growing uncertainties with regard to climate change, and the rapidly changing social and environmental pressures on forest resources, have underlined the need for the sustainable management of forest ecosystems and, potentially, the need to go even further. Moving towards SFM has led to necessary reforms and changes, such as economic policy and land tenure, in the forestry and other sectors. The management of forest ecosystems is increasingly considered to be part of an integrated system that links forest management with the management of other land resources in a way that takes into account the cross-sectoral effects of sectoral strategies. Increasingly, forest management is merely concerned with the functional integrity of ecosystems, and the protection and restoration of healthy forest ecosystems that are resilient to human-induced and natural stresses. Modern forest management strategies aim to allow forests to deliver a mix of ecosystem services, while keeping the option to fulfil new services in the future open, without endangering or impoverishing ecosystems (Balvanera et al., 2014).

New approaches to the stewardship of forests in Europe are required. New methods and instruments are urgently needed to ensure the long-term protection and maintenance of diverse, healthy and productive forests. Many initiatives have been launched that aim to support such new and practical applications of sustainable development. For instance, the ecosystem approach developed in the early 2000s emphasises that both ecological and social systems must be considered (Axelsson et al., 2011), see also Box 7.2.

Several policy initiatives and international processes recognise the need to understand forests on multiple levels, with regard to both time and space, and to manage forests in a more holistic, integrated and systemic way. For instance, the need for an integrated ecosystem approach to the management of human activities (i.e. EBM) that does not threaten essential ecosystem functions and services has been recognised by, for instance, the CBD, the new Global Strategic Plan for Biodiversity 2011–2020 and the 'Beyond GDP' initiative (see also Box 7.2). The EBM approach embraces the systemic approach used by the Unesco (UN Educational, Scientific and Cultural Organization)

Box 7.1 Definition of sustainable forest management (SFM)

Although no universally agreed-upon definition exists, the following Forest Europe (formerly the Ministerial Conference on the Protection of Forests in Europe, Helsinki Resolution 1 (H1) in 2003) definition of SFM is used in this report: the 'stewardship and use of forest lands in a way, and at a rate that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels and that does not cause damage to other ecosystems'.

Man and the Biosphere (MAB) programme, the scientific ecosystem management approach (Gauthier et al., 2009), and as part of work carried out by the IUCN, the World Wide Fund for Nature (WWF), on landscape restoration (Mansourian et al., 2005), and other environmental NGOs. Such EBM approaches recognise the importance of biodiversity and the interacting processes at both stand and landscape levels (Messier et al., 2015).

EBM involves an integrated approach to the management of forest land that considers ecosystems and society. Its aim is to sustain the capacity of forest ecosystems to meet current and future needs. The primary objectives of EBM are to ensure the sustainability of forest ecosystem structures and functions, to promote the recognition of the dynamics of forest ecosystems over time and space, and to accept that ecosystem functions are closely dependent on ecosystem structure and diversity. EBM is closely associated with ecological resilience, as it aims to protect forest ecosystems and restore degraded forests.

7.1 What is then the difference between sustainable forest management and ecosystem-based management?

In many ways, EBM is similar to SFM: both are geographically specified, take account of current knowledge and uncertainties, recognise that multiple factors affect ecosystems and their management, and aim to balance diverse societal goals. EBM and the concept of ecosystem services are increasingly being integrated into strategies for the sustainable management of natural resources, including forest management (Lindenmayer et al., 2012; Johansson et al., 2013; Quine et al., 2013).

Forest stakeholders may claim that SFM already supports ecosystem services and that the EBM approach may confuse the discussion and support for SFM. If only forest-related aspects are considered, SFM could be considered to be an application of EBM (Wilkie et al., 2003; Sayer and Collins, 2012). Both acknowledge the dependence of human well-being on the multiple

Box 7.2 Definition of ecosystem-based management

EBM, in the context of forest ecosystems, is defined as the sustainable management of forest ecosystems, as well as the sustainable use of forest ecosystems and their services (i.e. allowing for the maintenance of essential forest ecosystem functions). It is an integrated approach to management that considers the interdependence of human activities, ecosystems and human well-being, with a long-term outlook across different spatial scales. In contrast, other approaches may focus on a single species, sector or issue, and have a short-term outlook and limited spatial scale. Furthermore, EBM focuses on ecosystem services and evaluating these services before management decisions are made.

No ecosystem approach	Ecosystem approach
• Mono-culture	• Managing whole ecosystems
• Single sector	• Integrating all sectors that impact, or are impacted, by the ecosystem
• Local scale management	• Coordinated management at all levels, relevant to the ecosystem
• Short-term outlook	• Long-term outlook of more than 25 years
• Managing commodities	• Managing with systems thinking in mind.

Sources: Layzer, 2012; Cormier et al., 2013.

A systems approach is key to EBM and assessments. It might mean a transition from a narrow framing of problems and solutions to addressing systemic implications that signal changes in the culture of decision-making. Decision-makers would be aware that maximising one ecosystem service may have damaging effects on other services, as well as on long-term provision and resilience. Therefore, trade-offs would have to occur as not all services are positively correlated. For instance, targeting policies for carbon sequestration by limiting the enrolment to forest managers might be effective for achieving carbon-storage objectives, but might not necessarily be effective at protecting biodiversity. Several pervasive trade-offs may occur between provisioning and other types of services.

There are concerns about EBM being too complex. Nevertheless, it is crucial to recognise this complexity and to account for it. Overlooking it may be costly to society and damaging to the ecosystems that sustain it. A clear goal, in line with the EU environmental targets and vision, would be to maintain forests in healthy, productive and resilient conditions, in order to provide humans with the services and benefits needed for well-being.

benefits from the environment and aspire to a holistic view that spans multiple spatial and temporal scales. Both recognise the need to make management choices that achieve synergy and reduce trade-offs, and both seek mechanisms to encourage a balanced delivery of private and public benefits. Therefore, SFM could be a component of EBM; however, EBM also allows the forest sector to look and engage beyond itself.

The pan-European concept of SFM is considered to be consistent with an ecosystem-based approach to sustaining forest ecosystems. In fact, Forest Europe (MCPFE, 2005) has noted that SFM is an appropriate way in which to implement the ecosystem approach in Europe. However, differences in uptake between different European institutions suggests that significant further efforts are required in order for the EBM approach to be adopted coherently by the forest sector.

One difference between the two concepts is the focus of EBM on ecosystem services, and the need to evaluate these services before management decisions are made. The EBM approach allows synergies and trade-offs in the delivery of different forest goods and services to be identified and negotiated. The evaluation of and payment for ecosystem services are being developed as mechanisms of promoting EBM to forestry managers as a valid means for planning and managing forests. The use of EBM approaches by forestry managers would help to ensure that cumulative pressures on forests from human use and activities are not detrimental to the health, diversity and productivity of forest ecosystems. Neither the capacity of forest ecosystems to respond to human-induced changes nor the sustainable use of forest ecosystem services by present and future generations must be compromised.

The EBM approach, as defined by the CBD, is not yet coherently endorsed by forest-relevant EU policies. For instance, the EBM approach is not mentioned at all in the new EU Forest Strategy (EC, 2013c). By contrast, it is included in the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (EC, 2000; EC, 2008). EBM is concerned with preserving the long-term potential or capacity of ecosystems to continue to deliver services and benefits. This more systemic approach explicitly addresses natural and ecosystem capitals and their assessments, including biophysical quantification and monetary valuation, as is also presented in the 7EAP. The EEA has articulated the need for an EBM approach to European ecosystem assessments (EC, 2013a, 2014). EU legislation increasingly incorporates EBM approaches as a way of enhancing ecosystems, functions and services. NGOs and foundations are also increasingly engaged in forest EBM efforts through their support of demonstration projects and related research at local, national and international levels.

7.2 Current instruments for the assessment of the sustainable management of forest ecosystems

Tools have been developed to assess the degree of sustainability of forest management and to support decision-making with regard to integrating biodiversity and forest management. The main instruments are the criteria and indicators of SFM, as developed by Forest Europe and FRA, the certification of forest products (FSC, 2014, 2015; PEFC, 2015) and FMPs. Today, new objectives go beyond sustaining wood supplies, food and energy, and also focus on the maintenance of ecosystem services, the protection of biodiversity, rural development and human well-being.

The Forest Europe criteria and indicators are used to monitor and assess pan-European and national trends in forest condition and forest management at a range of scales. The criteria and indicators have been developed on the basis that forests are ecosystems that provide a wide, complex and dynamic array of environmental and socio-economic benefits and services. A forest ecosystem management approach is sustainable only if it explicitly recognises these aspects of forest ecosystems and seeks to achieve trade-offs among them that meet with broad societal approval while passing tests for economic, ecological and social viability in the long term. The criteria and indicators have also helped to identify key indicators at national, regional and forest management unit levels, and to make links between the different aspects of SFM. The present report heavily relied on this very valuable source of information. However, very few attempts have tried to assess whether or not countries manage their forests in a sustainable way based on, for example, an overall score determined from values assigned to indicators that relate to agreed sustainability levels. Such approaches would support forest management planning and decision-making as well as policy development at national and local levels.

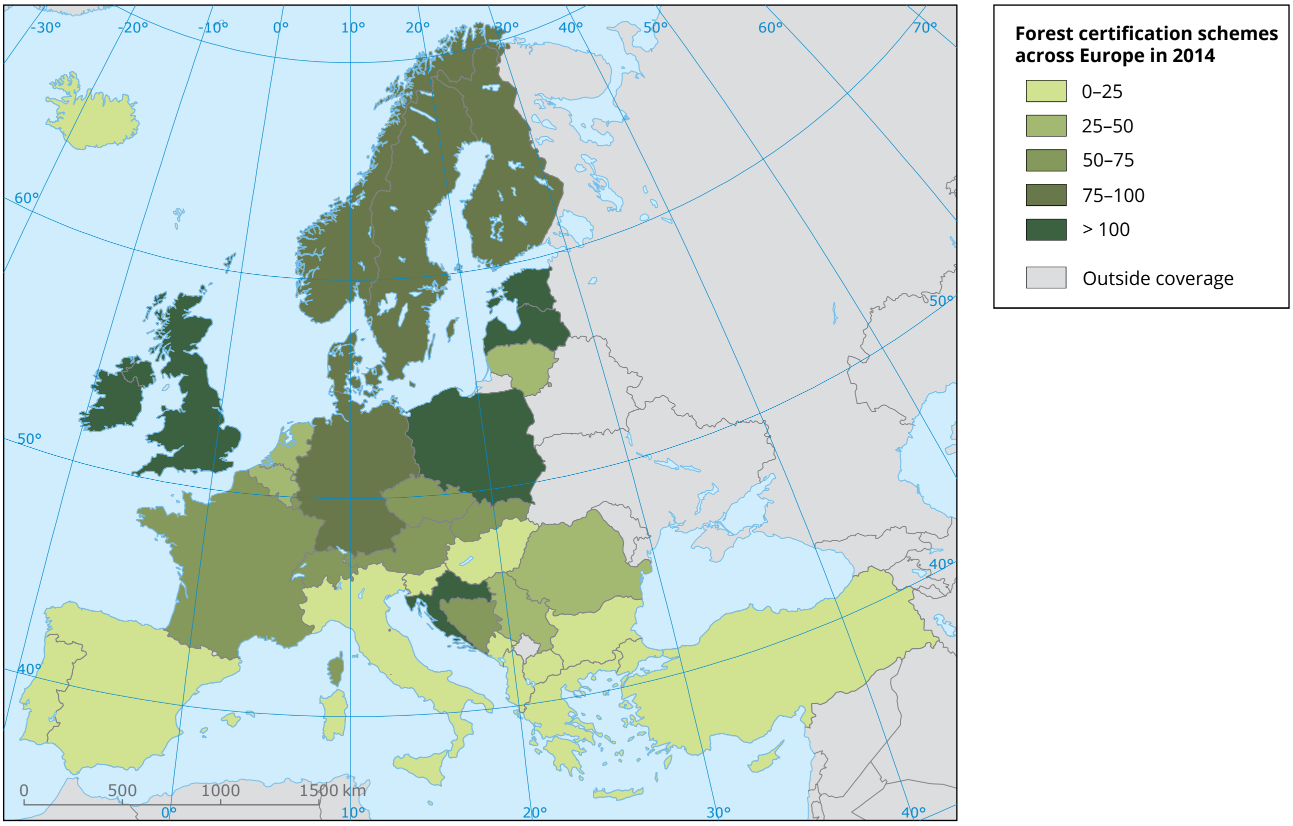
Forest certification schemes are more detailed and prescriptive than the proposed criteria and indicators of the Forest Europe process, and aim to assess the sustainable management of forests (FSC 2014; PEFC, 2015). The area of forests under certification is often assumed to give an indication of the quality of forest management with regard to wood supply. Forest certification was introduced in early 1990 to address concerns about the loss of biodiversity, deforestation in the tropics and the perception that unsustainable forest management was occurring in areas with high levels of trade in wood products (Rametsteiner and Simula, 2003). Forest certification relies on voluntary commitments to adhere to SFM principles, as they are applied in particular areas. Certification schemes require the adoption of forest practices that can reduce the impacts of forest operations. Certified forests are expected to represent forests that are managed responsibly with respect to biodiversity conservation, particularly with regard to the protection of critical ecosystems, and promote the social, economic, cultural and ethical dimensions of the sustainable management of forests (McCarthy et al., 2011). Several supply chain controls make use of certification schemes to identify sustainable and legal forest products. The two most widely applied schemes are the Forest Stewardship Council (FSCS) and the PEFC.

More than 60 % of forests in EU-28 are certified, mostly under the FSC or PEFC or both, although there are substantial differences among countries (FAO, 2015a) (see Map 7.1). The proportion of certified forests in Europe is substantial compared with the world as a whole, as only 12 % of the world's forest areas are certified. This area has been increasing in recent years and this could reflect an increase in the area for which evidence of SFM is available. To date, this is probably the best way to evaluate the sustainability of forest management.

FMPs or equivalent instruments can also be used for the implementation of SFM at the operational level. FMPs usually contain some information on planned operations for individual stands or compartments, in order to meet management goals. FMPs are thus strategic and operational tools for forest owners and managers. They are voluntary tools for production, as well as for the implementation of conservation measures in Europe's forests. They are can also be used for forest certification.

One of the main challenges with regard to EBM is that the approaches are still rather abstract to understand and interpret, and offer more of a problem-framing approach than practical tools for implementation. Implementation must include the identification of practices that would provide the greatest range of ecosystem services and allow trade-offs and synergies to be gained. Ecosystem management is an improved form of management for natural resources that is

Map 7.1 Forest certification schemes across Europe in 2014



Source: FSC, 2014; PEFC, 2015.

Photo 7.1 Forested landscape in Finland

already being applied to several ecosystems. Its main characteristic is that it represents a shift from the single-sector approach that disregards the multiple connections within and among components of the forest ecosystems and social systems. There are many examples of forest management systems in Europe, the so-called best-practice approaches, that reflect the principles of ecosystem management ([11]). All of these approaches focus on the condition and functioning of ecosystems after human intervention (see Table 7.1). The overall goals of these various best-practice examples of forest management are to maintain forest biodiversity, and the capacity of forests to adapt to rapidly changing and uncertain future conditions. The adaptive management approach has recently received more attention as it recognises gaps in the knowledge of ecosystem processes and functions, and allows the integration and adaptation of knowledge if it becomes available. This flexibility is fundamental to the convenient use of the precautionary principle and for 'participative learning'. Other examples of EBM include close-to-nature forest management, continuous cover forestry (Duncker et al., 2007, 2012) and retention forestry (Gustafsson et al., 2012; see Box 7.3).

Protected forests and, in particular, areas that are permanently allocated for the protection of natural forests are essential for the conservation of species that depend on specific forest habitats. Best-practice approaches cannot replace the need for large protection areas, as there are species and ecological processes that depend on these areas. The traditional approach to biodiversity conservation has been to protect relatively large areas and allow only a minimal level of human intervention; the forest area designated for conservation has increased steadily over time (FAO, 2010). Integrated forest approaches for the protection of forest biodiversity and ecosystem services are complementary to the provision of protected areas. Land sharing for the forest sector could be an efficient way to protect biodiversity and ecosystem services in Europe's forests. However, the ecosystem approach to forest practices, such as retention forestry, could also benefit from land sharing. A reduction in the

([11]) There are also many examples, especially in southern Europe, of cases in which subsidies still encourage the planting of monocultures of exotic species that provide neither environmental nor societal benefits.

Table 7.1 Examples of best practice with regard to provisioning and regulating services

Service	Best-practice example
Synergies of provisioning services (e.g. timber) and regulating services (e.g. climate change adaptation)	Reforestation and afforestation in the context of climate change adaptation: best practice would be to use tree species that are resilient to environmental changes. The provenance of seeds would be tested, and the genetic variation would assessed among populations. The climatic trends would also be analysed to support the selection of species.
Synergies of regulating services (e.g. carbon stock and biodiversity)	Increasing carbon storage: best practice would be to adopt longer cycles in old, healthy forests that are at low risk of pests and other disturbances. Forests prone to fires and storms would be managed more intensively with shorter rotation cycles. Thinning would be carried out to promote more efficient use of light and nutrients leading to increased carbon sequestration, new growth and increased structural diversity.
Regulation of disturbances	The selection of resistant families and clones is crucial to the reduction of the risk of damages from pests and diseases. With regard to fires, actions should be supported to reduce the accumulation of fuel by, for example, burning, thinning, pruning or biomass removal; grassing; and the creation of mosaics of forest types that include less flammable tree species such as cork oaks.These approaches are much less expensive than conventional air- and ground-based firefighting.
Ecosystem services	Introducing payments for ecosystem services and non-market benefits would encourage forest owners to manage forests in a sustainable way.

Box 7.3 Examples of forest practices that are applied in retention forestry

Retention forestry practices are based on the provision of continuity with regard to the key habitat elements and processes of forest ecosystems, over both time and space. The principle is to retain structures and organisms from pre-harvest forests in order to enrich the structure and composition of the post-harvest forest (e.g. Kruys et al., 2013; Seidl et al., 2014). The off-site impacts of harvesting on, for instance, aesthetics, or the impacts on aquatic ecosystems are minimised by this approach, and there is a greater acceptance of forest harvesting and forest use by the public (Edwards et al., 2012; Raitio, 2012; Bigot et al., 2014).

The objective of retention forestry is to protect and maintain biodiversity, as well as connectivity, in managed forest landscapes, and to sustain and enhance the supply of ecosystem services.

The area or volume that must be retained within stands will vary depending on local conditions and should be adapted to those conditions. It has been suggested that a minimum of between 5 % and 10 % should be retained in order to achieve the desired ecological objectives. However, several studies suggest that this percentage should be larger and that retention practices should be implemented more widely to facilitate the dispersal of organisms.

production of wood from retention forests may lead to the further intensification of forest biomass extraction from other forests. This outcome is highly likely to be an eventual result of international trade. Leakage would also be likely to occur because of the displacement of lands in other countries, as a consequence of reduced land use in one country (Meyfroidt et al., 2013).

Local examples demonstrate ways in which multifunctionality can be achieved so as to maintain healthy and diverse forests, while doing away with the jobs-versus-environment debate and building community capacity (Kelly and Bliss, 2009). One such example was the development of the Model Forest initiative ([12]). The Model Forest initiative is based on six principles: partnership, landscape sustainability, governance activities, knowledge sharing, capacity building and networking. Model Forests are considered living laboratories, in which, for instance, the criteria and indicators for the sustainable management of forest ecosystems are developed and monitored at the local level (Box 7.4). They help to deliver enhanced inputs for policymakers and transfer knowledge to national forest programmes. Usually, a Model Forest covers a large forested landscape. The Model Forest approach is collaborative and practical. It brings diverse

([12]) More examples of Model Forest initiatives are available on: http://www.ofme.org/foretmodele-provence/; http://planbleu.org/sites/default/files/upload/files/6_Diaporama_Castellini(2).pdf.

Box 7.4 Model Forest initiatives in Europe

There are several Model Forest networks in Europe. The Baltic Landscape Network of northern Europe (Estonia, Finland, Latvia, Norway, Poland and Sweden) aims to implement locally relevant landscape-level approaches to sustainability. The Mediterranean countries (Croatia, France, Greece, Italy, Morocco, Spain, Tunisia and Turkey) recently participated in a successful EU-funded project, Med Forêt Modèle. The objectives of this project were to promote Model Forests as an innovative tool for territorial governance of forest-dominated landscapes and to integrate this tool into European regional policies.

The Model Forest approach is an example of how expertise in forest restoration and ecosystem services, climate change mitigation and adaptation, the green economy, food security and livelihoods can be incorporated and connected. Such partnerships help to share essential knowledge and have made a significant contribution to the concept and practice of sustainable natural resource management. The Model Forest concept has evolved and adapted to a number of emerging ideas and paradigms, including integrated resource management, the sustainable management of forest ecosystem and, more recently, broader integrated landscape management. Such networks are essential for the continued exploration of approaches and the development of tools to help address new and emerging challenges for the sustainable management of natural resources.

Another successful example is the Istrian Model Forest. This broad partnership comprises forest experts, private and public stakeholders, as well as relatively small private enterprises, such as honey producers, mushroom pickers and cattle breeders. Several working groups were set up to represent interests in, for example, forest management and renewable energy resources, agriculture, cattle breeding, sustainable development, rural and cultural tourism, NWFPs, education, information and nature protection. This arrangement ensures that the inhabitants of the area and representatives from different economic activities and associations are involved. Forest and nature resource managers are informed and familiar with the Model Forest concept. The partnership helps to facilitate options for sustainable development by improving the territory and consolidating the economic and non-economic priorities that will, again, contribute to an increase in the use of resources and, eventually, the development of new resources.

people together, who hold different interests and opinions. It usually recognises that local community members have valuable knowledge and real power to mobilise, and care for and use forests with the most sustainable management practices possible. The aim is to manage forests while considering their history, economic situation, cultural identity and future generations.

Working as a network of ideas, knowledge and experiences, each Model Forest provides a framework for stakeholders to develop, test and implement sustainable development initiatives that benefit everyone. Understanding the role of forest stakeholders, managers and owners and their use of forests is essential for all actors concerned with forests, as it indicates the use and function of forest ecosystems.

7.3 Europe's forests — a multigovernance reality

The governance of forests has become increasingly complex and now involves multiple actors at multiple levels and in multiple sectors. The word 'governance' used here refers to the assessment of the importance of private actors and relevant networks in the making of public policies and the use of soft-law instruments. Despite the increasing demands being placed on forest resources, there is no major shift in governance arrangements or in how forest issues are coordinated. In the absence of a consistent regulatory framework for forests, each Member State is likely to continue to do as they wish with regard to their forest ecosystems, which means that they may or may not develop an EBM approach. However, the key to managing forest ecosystems in the future lies in adopting the shared goals. A systems view on forests could help to identify a balanced approach that would accommodate all interests (and, for example, the necessity to deal with trade-offs), not only with regard to how forest policy should be now, but also with regard to the vision for the use of forests in the future.

Nevertheless, the value of forest ecosystem services has been recognised in the EU Forest Strategy. Forests are included in natural capital accounting. Billions of euros have been earmarked for forest measures for the 2014–2020 period, as part of the EU rural development fund, in order to meet the targets of the EU Biodiversity Strategy. Forest owners and managers can apply for financial support to help them implement SFM strategies, in order to secure forests and their ecosystem services now and for future generations.

Practitioners advocate national policies and international commitments on the sustainable management of forests, but point out that these can be achieved only through efforts at local levels with the participation of people that live in and from forests. Measures for the implementation of SFM have to fit local conditions.

The efficiency of the implementation of SFM and other approaches to the management of forests is strongly linked to the ownership structure, for instance the size and number of forest holdings. In several countries in Europe, forests occupy a great deal of space, but only a relatively small number of people are directly concerned with forests and their uses; forests cover more than 40 % of the total land surface of Europe yet only 3 % of Europe's population is directly involved in forest management.

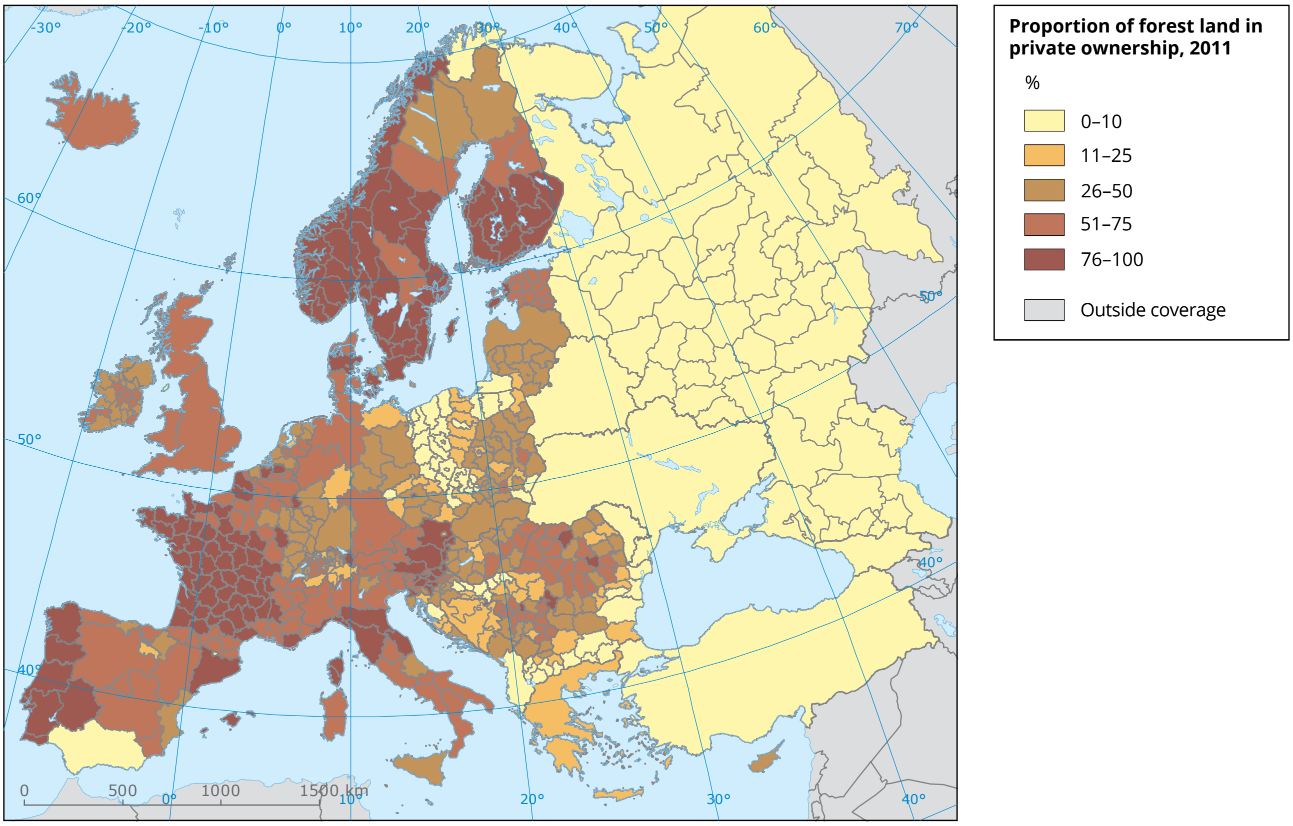
The impact of forest governance on forest management in Europe is difficult to assess because of relatively poor information. The following section aims to describe forest ownership in Europe and how it impacts on the management of forests and forested landscapes.

7.3.1 *The role of forest ownership*

The condition, use and management of forests are in the hands of forest owners and managers. However, there is no clear picture with regard to how private forest owners manage their forests. European forest owners are a very heterogeneous group. Forest ownership patterns vary considerably across Europe from small privately owned forests to large state-owned forests, and from small family holdings to large estates owned by companies. There is little information on whether private forest owners tend to provide market-based products, such as timber, or whether such forests are used more extensively for leisure or recreation purposes. Many forests are part of an estate and are kept to maintain capital; however, they may not be the main source of income.

There are estimated to be approximately 16 million forest owners in the EU, 350 000 of whom are directly employed in forest management. The overall trend is for a decrease in publicly-owned forests and an increase in small, privately owned forests. More than 60 % of Europe's forests are privately owned, and, as shown in Map 7.2, these are mainly in Austria, France,

Map 7.2 Proportion of forest land in private ownership, 2011



Source: Pulla et al., 2013.

Portugal, Slovenia and northern Europe (e.g. more than 75 % of forests in Sweden are privately owned). The proportion of private owners in the rest of Europe varies from 25 % to 50 %. Forests have been given back to their original owners after political changes in central and eastern European countries and farmland has also been converted to forests in these countries. Statistics on the number of forest holdings across Europe are sparse. More than 6 million holdings are in public ownership, whereas 5 million holdings are under private ownership. In general, the size of most private forest holdings (82 %) is less than 10 ha. For instance in Slovakia, the average size of a forest holding is less than 3 ha and, in France, 2.4 million forest holdings are less than 1 ha. Very few holdings exceed 100 ha. This represents a challenge for the sustainable management of forests, access and infrastructure, and the transfer of knowledge to forest owners and managers. In countries such as Finland and Sweden, the share of forests that are owned by companies is significant (Schmithüsen and Hirsch, 2010). Furthermore, in northern Europe, some small private forest holdings, managed under cooperative agreements, deliver raw materials to forest industries.

The ownership structure has a significant impact on forest governance and management. The management of large public/state forest holdings was, until recently, focused on intensive management related to a small number of products or functions, and was innovative with regard to introducing new technologies for management and the use of multiple forest goods and services. However, more and more, public forests are being managed in order to preserve vegetation, the environment, cultural heritage and historical sites for recreation. The implementation of national policies is usually easier in publicly owned forests than it is in privately owned forests. This also means that state forests are well placed to implement ecosystem services. For instance, the European State Forests Association (Eustafor) has demonstrated progress in the provision of services, such as water, carbon, biodiversity, protection and payments for ecosystem services (Eustafor, 2011). Currently, Eustafor has 29 members that manage 49 million ha (i.e. 30 %) of forests in the EU.

The fragmented ownership of forests across Europe may be a challenge for the implementation of SFM, and for innovation and the maintenance of a certain level of production and employment (Forest Europe et al., 2011, 2015). Other concerns are related to the aging of many private forest owners, and the fact that many forest owners move to urban areas and lose interest in and knowledge on the management and use of forests. In the future, it may become difficult to ensure participation in forest-related issues, as well as the availability of a qualified forest-sector workforce, which will be necessary for meeting the variety of demands of society and for human well-being.

The EU is increasingly proposing policies that use an integrated timeframe as a direct response to systemic challenges. Short-term targets for individual sectoral policies, mid-term goals that link policy ambitions to more comprehensive policies, as well as long-term visions (e.g. towards 2050 and beyond) are the basis, within policies, for societal transition, an improved knowledge base, a circular green economy and the resilience of society and ecosystems (EEA, 2014a).

Another issue relates to the uptake and application of new management approaches by forest managers. Forest owners, particularly owners of small forest holdings, may be disconnected from policy decisions at national and European levels. This situation represents a challenge for any policy initiative, including the implementation of the EBM concept in European forests. To date, most forest managers are inclined to apply traditional forest management practices rather than to adopt integrated ecosystem approaches. For instance, under the previous CAP (2007–2013) and EU rural development programmes, there was significant underspending by the forestry sector, especially with regard to the allocation of forest environment and Natura 2000 measures (Pülzl et al., 2013). Furthermore, the Leader approach (i.e. local empowerment through local strategy development and resource allocation), which was a promising instrument for rural development and forestry, was not utilised much by the forest sector. Instead, most of the funding available for forestry measures was used for afforestation.

In the future, forest activities should be taken into account in EU policies to a much larger extent than they are currently. Forests are a main part of rural landscapes in Europe and should contribute to several EU policies in order to ensure the sustainable use of forests and human well-being. The application of SFM and EBM should focus on the landscape level. Its implementation calls for the best available knowledge base, and the involvement of land managers and the public, particularly in the case of publicly owned land.

7.4 Strengthening the knowledge base for the sustainable development of European forests

Good decisions are based on sound knowledge of the state of forest ecosystems in Europe and the drivers of change. In this context, the knowledge base refers to the ability to provide data, develop indicators and report on thematic policies.

More and more, forests are present on the European policy agenda; recently, their role in climate change mitigation was stated at the UNFCCC 21st Conference of Parties (COP) and highlighted by the UN's SDGs. One of the objectives of the EU Forest Strategy, and its multiannual implementation plan for 2015–2020, is to coordinate different forest-relevant actions and policies. As a consequence, there has been a corresponding increase in the need for knowledge on forests in order to support established and developing policies across the policy cycle. This requires systematic flows of information and assessments.

The EEA, as the key European environmental data centre, and its European Environment Information and Observation Network (Eionet), which includes EEA Member States and the European Topic Centres (ETCs), are the main partners involved in the chain of data flows, indicator development, policy effectiveness analysis, integrated assessments, communications, and the use of new analytical methods and technologies in Europe. This partnership contributes to the development and maintenance of the knowledge base in principal areas of the EEA's work. These areas are air pollution, climate change, water management, nature protection, land use and natural resources, waste management, noise, and coastal and marine protection. Forests are embedded in almost all policy priorities. As stated many times in the present report, forests are a major natural resource, cover more than 40 % of the land surface, and encompass more than half of the biodiversity and protected areas in Europe. As such, forests contribute to national economies, and rural development, jobs and income. Most of the forest ecosystem services to society and human well-being are related to air, water, climate, noise and the bio-economy.

The availability of adequate forest-related information relies on working closely with, in particular, partners responsible for forests at the EU level, such as the DGs for Agriculture (DG AGRI), the environment (DG ENV), Eurostat, the Joint Research Centre (JRC) (Ispra, Italy), Research and Innovation (DG RTD) and research bodies, and regional and international partners, such as FAO, UNECE and Forest Europe; these partnerships are necessary for filling gaps in the knowledge base in order to help optimise policy responses.

The European Commission and its services work closely with each other to attain a broad coverage of harmonised information on the most relevant forest parameters, such as forest area, growing stock, biomass and forest damages. Since the gathering of Europe-wide forest information is likely to be a long process, large-scale approaches have been implemented by the European Commission in the meantime. The European Forest Data Centre (EFDAC), at the DG JRC, is the European focal point for policy-relevant forest data and information. The forest data portal allows users to view and download maps with a resolution of 10 km^2. The information available from this portal [13] includes modelled information, such as suitability maps for more than 30 tree species and forest biomass; data, obtained by monitoring, on forest defoliation and discolouration at the Nomenclature of Territorial Units for Statistics (NUTS)-3 level for Europe; and information on forest spatial patterns, fragmentation and connectivity. The EFFIS is an important element of the data portal because it supports the services responsible for the protection of forests in EU Member States against fires, and it provides the services of the European Commission and the European Parliament with up-to-date and reliable information on fires in Europe. The EFFIS delivers up-to-date information on the current fire situation, fire danger and forecasts, as well as information on areas burnt and damages. In addition, the EFFIS is complemented by a dedicated module that aims to assess forest damage overall, including damage related to biotic (e.g. pests) and abiotic (e.g. wind, snow and storm) factors.

At national and European levels, the EEA and Eionet partnership is an excellent tool for ensuring the continuous and targeted coverage and flow of data and information on many correlated themes. This continuous flow, complemented by new and up-to-date scientific insights from research into environment and climate issues, improves the knowledge base for forest-relevant policies, which are entangled in environment and climate policies. Such activities and developments also include the need to continue to focus on key economic sectors that affect forest ecosystems, such as the forest sector itself, and the energy, transport and agriculture sectors, which are also significant sources of pressure on the environment. Forests are well represented in the EEA indicator sets and in EEA processes for reporting on the environment.

The sustainable development of Europe's forests involves efficient governance, clear policy objectives, adequate scientific support and access to relevant data and information, as well as the full use of all available knowledge. The EBM approach formulates such objectives in a way that takes into account both knowledge and uncertainties with regard to the living, including human, and non-living components of ecosystems and their interactions, and, in this way, applies an integrated approach to forest management within ecologically meaningful boundaries.

(13) http://data.jrc.ec.europa.eu/discovery/Forest.

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Annex 1 Key facts on European forests

	Unit	North	Central-west	Central-east	South-west	South-east ([a])	EU-28	EEA-39
FOWL area	Million ha	76.7	39.7	23.2	43.6	45.8	182.1	229
FOWL as a percentage of total land	%	57.6	28.4	30.7	49.4	35.3	42.9	40.4
Forest area available for wood supply	%	78.0	81.5	94.1	62.3	81.0	83.6	79.6
Growing stock per ha (average)	m^3/ha	146	257	261	148	147	153	192
Growing stock	Million m^3	8 247	9 185	6 171	2 597	4 309	26 341	30 509
Fellings as a percentage of annual increment ([b])	%	78.8	68.1	62.3	47.7	42.0	70.5	–
Roundwood removals from forest	Million m^3	143.9	140.0	83.2	15.6	24.2	356.3	–
Forest undisturbed by humans	%	4.2	0.2	1.6	0.4	3.8	2.1	2.4
Semi-natural forest	%	67.7	82.9	65.2	85.3	67.4	80.2	73.2
Plantations	%	11.3	8.8	6.5	14.4	16.1	11.4	11.5
Share of forest dominated by introduced tree species	%	13.5	64.6	61.9	85.1	12.5	47.8	40.7
Share of forest area protected for biodiversity	%	9.2	0.4	5.2	25.1	7.1	9.7	9.2
Share of forest area protected for landscape	%	2.6	0.7	12.6	3.3	0.3	3.5	3.2
Share of forest area designated for the protection of soil, water and other ecosystem services	%	0.7	2.3	24.4	42.6	9.9	13.0	12.0

Note: Data for 2000 (Liechtenstein and Latvia) and 2005 (Poland, Luxembourg and Portugal).

([a]) Data for Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Greece, Serbia and Turkey from 2005.

([b]) Data on fellings and annual increment from 2010.

Source: Forest Europe et al., 2015.

Annex 2 Conservation status for forest habitats of Annex I reporting to Article 17 of the Habitats Directive 2007–2012

Habitats associated with woodland and forest		**ALP**	**ATL**	**BLS**	**BOR**	**CON**	**MAC**	**MED**	**PAN**	**STE**
2180	Wooded dunes of the Atlantic, Continental and Boreal region		U1	U1	U2	U1				
2270	Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*					FV		U1		
9010	Western Taïga	U1			U2	U2				
9020	Fennoscandian old broad-leaved deciduous forests				U2	U2				
9030	Nat forests of primary succession of landupheaval coast				U1					
9040	Nordic subalp/subarctic forests *Betula pub. czerepavoni*	FV			U1					
9050	Fennoscandian herb-rich forests with *Picea abies*	U1			U2					
9060	Coniferous. forests on, or connected to, glaciofluvial eskers				U2					
9080	Fennoscandian deciduous swamp woods				U2	U2				
9110	Luzulo-Fagetum beech forests	U1	U1		U2	U1		FV	U1	
9120	Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercion robori-petraeae* or *Ilici-Fagenion*)	U1	U1			FV		U2		
9130	Asperulo-Fagetum beech forests	U1	U1		U2	U1		FV	FV	
9140	Medio-European Subalpine beech woods, Acer and *Rumex arifolius*	U1				XX		FV		
9150	Medio-European limestone beech forests Cephalanthero-Fagion	U1	U1	U1		U1		U2	FV	
9160	Sub-Atlantic and medio-European oak/oak-hornbeam forests	U2	U2		U2	U1		XX		
9170	Galio-Carpinetum oak-hornbeam forests	U1	U2	FV		U1			U2	
9180	Tilio-Acerion forest of slopes, screes and ravines	U2	U2	U1	U2	U1		U1	U1	
9190	Old acidophilous oak woods with *Quercus robur* on sandy plain		U2		U2	U2			U1	
91A0	Old sessile oak woods with *Ilex* and Blechnum in the British Isles		U2							
91AA	Eastern white oak woods	XX		U1		U2		U2		U1
91B0	Thermophilous *Fraxinus angustifolia* woods					U2		U1		
91BA	Moesian silver fir forests	U1				U1				
91C0	Caledonian forest		U2							
91CA	Rhodopide and Balkan Range Scots pine forests	U1				U1				
91D0	Bog woodland	FV	U2		U1	U1	U1		U1	
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*	U2	U2	U1	U2	U2		U1	U1	
91F0	Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers	U2	U1	U1	U2	U2		U2	U1	U1
91G0	Pannonic woods with *Quercus petraea* and *Carpinus betululus*	U1		U1		U1			U1	
91H0	Pannonian woods with *Quercus pubescens*	U2		U1		U1			U1	

91I0	Euro-Siberian steppic woods with *Quercus spp.*	FV		U1		U1			U2	U2
91J0	*Taxus baccata* woods of the British Isles		U2							
91K0	Illyrian *Fagus sylvatica* forests (Aremonio-Fagion)	U1				FV			U1	
91L0	Illyrian oak-hornbeam forests (Erythronio-carpinion)	U2				U1		U1	U1	
91M0	Pannonian-Balkanic turkey oak-sessile oak forests	U1		U1		U1		U1	U1	U1
91N0	Pann. inland sand dune thicket *Junipero-Populetum albae*								U2	
91P0	Holy Cross fir forests (*Abietetum polonicum*)					U1				
91Q0	Western Carpathian calcicolous *Pinus sylvestris* forests	FV								
91R0	Dinaric dolomite Scots pine forests *Genisto januensis-Pinetum*	FV				FV				
91S0	Western Pontic beech forests			U1		U1				
91T0	Central European lichen Scots pine forests	XX	U2		U2	U2			U2	
91U0	Sarmatic steppe pine forest					U2				
91V0	Dacian Beech forests (Symphyto-Fagion)	FV				FV				
91W0	Moesian beech forests	U1				U1				
91X0	Dobrogean beech forests									U1
91Y0	Dacian oak and hornbeam forests					U1				U1
91Z0	Moesian silver lime woods	U1		U1		U1				
9210	Apennine beech forests with *Taxus* and *Ilex*	FV				U1		FV		
9220	Apennine beech forests with *Abies alba* and beech forest	FV				FV		FV		
9230	Galicio-Portuguese oak woods *Quercus robur* and *Quercus pyrenaica*		XX					XX		
9240	*Quercus faginea* and *Quercus canariensis* Iberian woods	XX	XX					XX		
9250	*Quercus trojana* woods							U1		
9260	*Castanea sativa* woods	U1	U1			U1		U2		
9270	Hellenic beech forests with *Abies borisii-regis*	U1				XX		FV		
9280	*Quercus frainetto* woods							FV		
9290	Cupressus forests (Acero-Cupression)							FV		
92A0	*Salix alba* and *Populus alba* galleries	U1	U1	U1		U2		U2	U1	U1
92B0	Riparian formations on intermittent Mediterranean water courses with *Rhododendron ponticum*, *Salix* and others							U1		
92C0	*Platanus orientalis* and *Liquidambar orientalis* woods	U1				U1		U1		
92D0	Southern riparian galleries and thickets (Nerio-Tamaricetea and *Securinegion tinctoriae*)			U1		U1	U1	U1		U1
9310	Aegean *Quercus brachyphylla* woods							FV		
9320	Olea and Ceratonia forests						U1	U1		
9330	*Quercus suber* forests		U2					U1		
9340	*Quercus ilex* and *Quercus rotundifolia* forests	U1	U1			FV		U1		
9350	*Quercus macrolepis* forests							U2		
9360	Macaronesian laurel forests (Laurus, Ocotea)						U1			
9370	Palm groves of Phoenix						U1	FV		
9380	Forests of *Ilex aquifolium*		U1					U2		

9390	Scrub and low forest vegetation with *Quercus alnifolia*							FV		
93A0	Woodlands with *Quercus infectoria* (*Anagyro foetidae-Quercus infectoria*)							FV		
9410	Acidophilous Picea forests of montane to alpine levels	U1				U1		FV		
9420	Alpine *Larix decidua* and/or *Pinus cembra* forests	FV								
9430	Subalpine and montane *Pinus uncinata* forests	U1				FV		U2		
9510	Southern Apennine *Abies alba* forests	U1						U1		
9520	*Abies pinsapo* forests							U1		
9530	(Sub-)Mediterranean pine forest with endemic black pine	U1				U1		U1		
9540	Mediterranean pine forests with endemic Mesogean pines					U2		U1		
9550	Canarian endemic pines forests						FV			
9560	Endemic forests with *Juniperus spp.*	U1	XX			U1	U1	U2		
9580	Mediterranean *Taxus baccata* woods		U1					U2		
9590	Cedrus brevifolia forests (*Cedrosetum brevifoliae*)							FV		
95A0	High oro-Mediterranean pine forests	U1						U1		

Note: Abbreviations and colour codes for conservation status classes

Conservation status	Colour	Abbreviation
Favourable	Green	FV
Unfavourable to inadequate	Amber	U1
Unfavourable to bad	Red	U2
Unknown	Grey	XX

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