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Mapping and assessing the condition of Europe's ecosystems: progress and challenges

EEA contribution to the implementation of the EU Biodiversity Strategy to 2020

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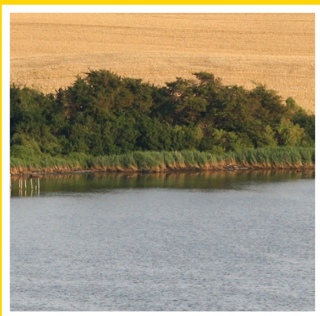

European Environment Agency

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Contents

Abbreviations, acronyms and units

BISE	Biodiversity Information System for Europe
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CLC	Corine Land Cover
CO_2	Carbon dioxide
Corine	Coordination of Information on the Environment
dB	Decibel
DG	Directorate-General of the European Commission
DG-ENV	Directorate General of the European Commission for the Environment
DPSIR	Drivers, Pressures, State, Impact and Response framework
EAP	Environment Action Programme
EASIN	European Alien Species Information Network
EC	European Commission
ECA	Ecosystem capital accounting
ECNC	European Centre for Nature Conservation
EEA	European Environment Agency
ETC/BD	European Topic Centre on Biodiversity
ETC/ICM	European Topic Centre on Inland, Coastal and Marine waters
ETC/SIA	European Topic Centre on Spatial Information and Analysis
ETC/ULS	European Topic Centre on Urban, Land and Soil Systems
EU	European Union
EUNIS	European Nature Information System
GES	Good environmental status
GIS	Geographical information system
HELCOM	Baltic Marine Environment Protection Commission (Helsinki Commission)

HNV	High nature value
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
LEAC	Land and Ecosystem Accounts
MAES	Mapping and Assessment of Ecosystems and their Services
MCPFE	Ministerial Conference on the Protection of Forests in Europe
MA	Millennium Ecosystem Assessment
MESEU	Mapping of Ecosystems and their Services in the EU and its Member States
MODIS	Moderate Resolution Imaging Spectroradiometer
MSFD	Marine Strategy Framework Directive
NCA	Natural capital accounting
NDVI	Normalised Difference Vegetation Index
NEA	National Ecosystem Assessment
NNSS	Non-native Species Secretariat
NUTS	Nomenclature of Territorial Units for Statistics
RBMP	River basin management plans
SEBI	Streamlining European Biodiversity Indicators
SEEA	System of Environmental–Economic Accounting
SEEA-EEA	System of Environmental–Economic Accounting — Experimental Ecosystem Accounting
SFM	Sustainable Forest Management
SNA	System of National Accounts
TEEB	The Economics of Ecosystems and Biodiversity
UMZ	Urban morphological zone
UN	United Nations
UNEP	United Nations Environment Programme
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WFD	Water Framework Directive
WHO	World Health Organization
WEI	Water exploitation index
WISE	Water Information System for Europe

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Executive summary

We depend on healthy and resilient ecosystems to continue to deliver a range of essential services, such as food, water, clean air and recreation, into the future. However, our natural capital is being lost to or degraded by pressures such as pollution, climate change, overexploitation and urban development. The EU Biodiversity Strategy to 2020 therefore sets a target to maintain and enhance ecosystems and their services by establishing green infrastructures and restoring at least 15 % of degraded ecosystems by 2020. Mapping ecosystems and their condition is essential for measuring progress towards this target.

This report synthesises the European Environment Agency's (EEA's) work on ecosystem mapping and assessment over the last few years. The EEA approach builds on the work of the Mapping and Assessment of Ecosystems and their Services (MAES) initiative, a collaboration between the European Commission, the EEA and Member States, which developed an analytical framework for assessment based on the DPSIR framework (Drivers, Pressures, State, Impact and Response). This framework allows an understanding of the causal chain of connections from human actions to impacts on the environment. For example, drivers such as increased consumption create pressures such as pollution and habitat loss, which affect the state (condition) of ecosystems and their ability to provide services essential for human well-being. Mapping and assessment of ecosystems aims to analyse the pressures and their effects on the condition of ecosystems, so that policymakers can design suitable responses.

The challenge is to implement this framework using the data and other information that are available. There is a large amount of data and information, but much of it is not available for all regions or all ecosystems, or it is based on inconsistent classifications. Therefore the EEA has devoted considerable effort to assessing the existing data and information and building a feasible methodology around it.

The EEA's approach therefore consists of the following stages:

1. developing a suitable typology (classification) of broad ecosystem types to be used as the basis of the analysis, following the MAES approach and based on EUNIS (European Nature Information System) habitat classes and Corine (Coordination of Information on the Environment) land cover data;

2. mapping the physical extent of these ecosystems across Europe;

3. assessing the pressures acting on ecosystems, classified into five main groups — habitat change, climate change, overexploitation of resources, invasive alien species, and pollution or nutrient enrichment;

4. assessing the current condition of ecosystems using data from the Habitats Directive (EC, 1992), the Birds Directive (EC, 2009), the Water Framework Directive (EC, 2000), the Marine Strategy Framework Directive (EC, 2008a) and other sources (e.g. soil quality);

5. investigating how to use available information on the relationship between pressures and biodiversity to map potential impacts of individual pressures on ecosystems, and exploring methods of weighting and summing multiple pressures onto a single map to assess their combined effect on biodiversity, environmental quality and ecosystem service delivery.

The last step is at an early stage of development because of a lack of empirical evidence and is therefore only briefly mentioned in this report.

This report describes the stages of the methodology, with a focus on data requirements, and then presents the ecosystem map for Europe. Analysis of the underlying data reveals that many ecosystems are highly concentrated in a small number of countries, which could increase their vulnerability to environmental change, and a substantial proportion of the most vulnerable ecosystems are not protected within Natura 2000 sites, Marine Protected Areas or equivalent zones.

The main body of the report then applies the first four stages of the methodology to each of eight broad ecosystem types in Europe: urban, cropland, grassland, heathland and shrub (reported jointly with sparsely vegetated land), woodland and forest, wetlands, freshwater, and marine (the four MAES marine ecosystem classes were combined owing to lack of data on the separate classes). The report describes the main characteristics of each ecosystem and then assesses the pressures acting on it and the impact of those pressures on its component habitats and species. Finally, there is a section on policy response, which considers the tools available for policymakers to protect and restore the ecosystem and to manage the synergies and trade-offs between different ecosystem services.

The assessments reveal similarities and differences, but also strong linkages between many ecosystems. Most striking is the level of threat to European ecosystems — well over half of all the habitats and species covered by the Habitats Directive are assessed as being in 'unfavourable' condition, and their status is generally declining or stable, with only a small proportion 'improving'. This is true for all eight ecosystem types.

The EEA also carried out an initial assessment of current impacts and observed trends for the five main categories of pressures for each ecosystem. Habitat change, including loss and fragmentation, and pollution have had the greatest overall impact across ecosystems to date, and pressures are still increasing in more than 60 % of the cases. However, climate change pressures are projected to increase significantly across all ecosystems in future, which will probably lead to further impacts worsening their current condition.

Ecosystem assessment and mapping can form a valuable knowledge base for policymakers, enabling them to look at the spatial variations in the pressures on different ecosystems across Europe. Information on the resulting impacts of these pressures on ecosystem condition can confirm the need for a policy response to tackle the underlying causes of ecosystem damage, for example by protecting key habitats or controlling pollution. The knowledge base can also be applied in planning the most effective green infrastructure investments and developing methods for natural capital accounting, so that the value of ecosystems can be taken into account in national or corporate policy decisions. Both of these opportunities are described in the report.

Finally, the report identifies key gaps in knowledge and data that will need to be resolved to allow the future development of ecosystem assessment, including a lack of data on urban and marine ecosystems, a lack of understanding of the combined impacts of multiple pressures, a lack of detailed spatial data for mapping impacts on biodiversity, and a lack of understanding of the links between ecosystem condition, biodiversity and ecosystem service delivery.

1 Introduction

1.1 Why do we need to map and assess ecosystems?

Human well-being depends on natural capital, which provides vital services including fertile soil, fresh water, pollination, natural flood protection and climate regulation. However, the ecosystems, habitats and species that provide this natural capital are being degraded or lost as a result of human activity (Newbold et al., 2015), and spatially explicit mapping and assessment is needed to understand to what extent and where these processes take place. There is therefore an urgent need to protect and enhance this natural capital, as recognised in the European Union's (EU's) Seventh Environmental Action Programme, which sets out the priorities for environmental policy until 2020 and includes an outlook up to 2050 (EC, 2013c). This commits the EU and its Member States to speeding up the implementation of existing strategies to protect natural capital, to fill gaps where legislation does not yet exist and to improve existing legislation. The key strategy for mapping and assessment is the EU Biodiversity Strategy to 2020 (EC, 2011a), which mirrors the global Aichi targets of the Convention on Biological Diversity (EC, 2014e). The strategy builds on a number of earlier measures including legally binding commitments in the Habitats Directive (EC, 1992), the Birds Directive (EC, 2009), the Water Framework Directive (EC, 2000), the Marine Strategy Framework Directive (EC, 2008a) and the Air Quality Directive (EC, 2008b).

The Biodiversity Strategy has 6 targets and 20 supporting actions. Target 2 aims to maintain and restore ecosystems and their services and, within that, Action 5 calls for all Member States to map and assess the state of ecosystems and their services (Box 1.1). The ultimate goal of Action 5 is to inform policy, with the aim of triggering policy responses that will protect, enhance or restore ecosystems in line with the targets of the EU Biodiversity Strategy. This knowledge base will support the Green Infrastructure Strategy (EC, 2013b) and the establishment of ecosystem capital accounting. It also underpins other targets of the Biodiversity Strategy and related EU initiatives (see Figure 1.1).

1.2 What is ecosystem mapping and assessment?

An ecosystem is a 'dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit' (UN, 1992). Although ecosystems can be of any size, from a single drop of water to the entire planet, this report concerns mapping and assessment on national and European scales, which is based on broad land cover types such as 'woodland and forest'. An ecosystem at this scale may consist of one or more different habitats, which are defined by the location and biotic and abiotic features of the environment in which an organism lives (see Glossary). Ecosystems support a

Box 1.1 Target 2, Action 5, of the EU Biodiversity Strategy to 2020

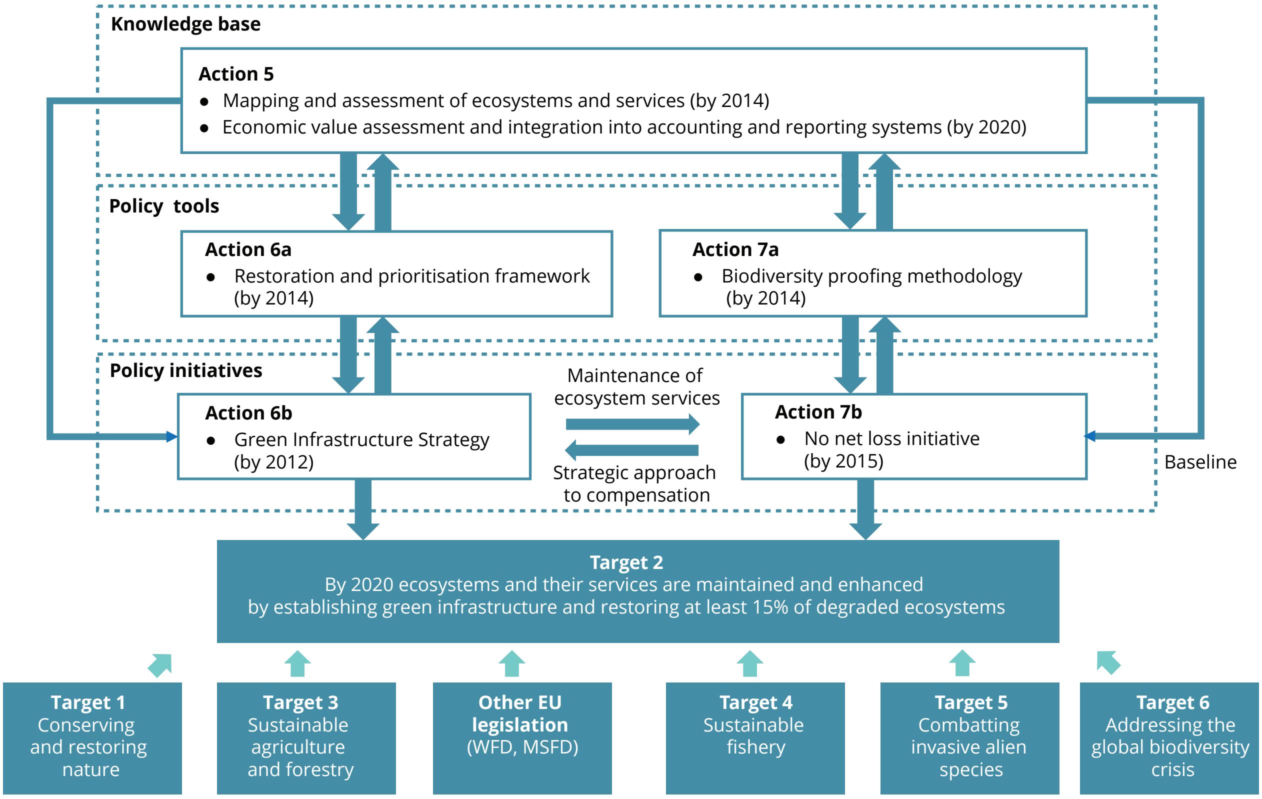
Target 2: Maintain and restore ecosystems and their services

By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems.

Action 5: Improve knowledge of ecosystems and their services in the EU

Member States, with the assistance of the Commission, will map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020. Action 5 is implemented by the **MAES (Mapping and Assessment of Ecosystems and their Services) Working Group.**

Figure 1.1 **Importance of Action 5 in relation to other supporting actions under Target 2 and to other targets of the EU Biodiversity Strategy to 2020**



Note: MSFD, Marine Strategy Framework Directive, WFD, Water Framework Directive.

Source: Maes et al., 2013.

range of functions, such as plant growth, soil formation and water filtration. These directly or indirectly provide services for human well-being including food, timber, clean air and water, climate regulation, flood protection and attractive landscapes. Interactions between ecosystems are also important in mapping and assessment. Ecosystem functioning often depends on the location and spatial context and the relationships between ecosystems. For example, flood protection depends on the location, spatial distribution and extent of the different ecosystem types and their capacity for water retention. Habitats — such as those for large mammals and birds — often cover more than one ecosystem type for feeding and reproduction, requiring assessments on the landscape scale and beyond (EEA, 2015a). Ecosystem mapping and assessment is a systematic process consisting of the following steps.

1. **Mapping:** This involves identifying and delineating the spatial extent of different ecosystems through the spatial integration of a wide range of data sets on land/sea cover and environmental characteristics.

2. **Assessment of ecosystem state / condition** (see Box 1.2): This is analysing the major pressures on ecosystems at the European scale and the impact of these pressures on the condition of ecosystems in terms of the health of species, the condition of habitats and other factors including soil, air and water quality. If impacts or condition cannot be quantified, the pressures are also used as indicators of ecosystem condition.

3. **Assessment of ecosystem service delivery**: This means assessing the links between ecosystem condition, habitat quality and biodiversity, and how they affect the ability of ecosystems to deliver ecosystem services, and then evaluating the consequences for human well-being.

This report focuses on the first two steps of the process — mapping and assessment of condition — but also considers the outlook for addressing the knowledge gaps that currently restrict the application of the third step, which is currently being investigated in cooperation with the European Commission's Joint

Box 1.2 Status, state and condition of ecosystems

In this report the term 'condition' is used instead of 'state' to avoid confusion with the term 'status', which describes the legal aspects such as protection of ecosystems under Natura 2000, Water Framework Directive or Marine Strategy Framework Directive.

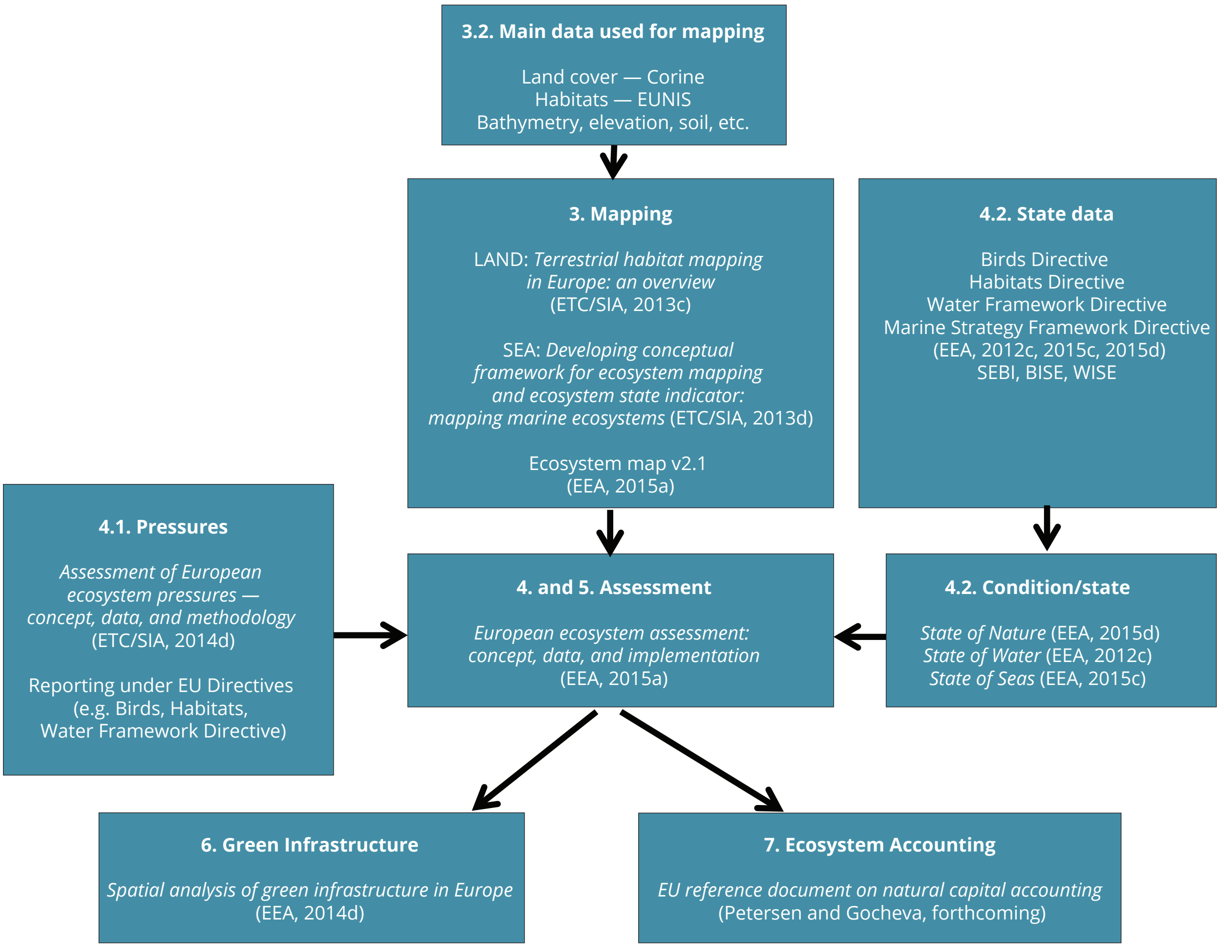
Research Centre (JRC). The final goal is to carry out a harmonised assessment of ecosystems and ecosystem services for the whole of Europe, allowing comparisons across Member States. This will help policymakers to identify 'hot spots', where there are multiple pressures affecting ecosystem condition, and enable them to develop more effective strategies for protecting and restoring ecosystems. It will also allow them to monitor progress towards meeting the objectives of the EU Biodiversity Strategy as part of a pathway towards sustainable development.

1.3 What is the aim of this report?

Since 2012, the European Environment Agency (EEA) has supported the implementation of the EU Biodiversity Strategy through its activities on ecosystem mapping and assessment. There has been a particular focus on investigating how to map and assess the condition of ecosystems, based on the available data, and on examining the contribution that ecosystem assessment can make to supporting the mapping of ecosystem services, promoting green infrastructure and undertaking natural capital accounting. Major EEA reports have recently been produced in related thematic areas. This report synthesises these activities, summarising the methods used and the key outcomes. It forms part of the wider contributions of the EEA to the *Mid-term review of the EU Biodiversity Strategy to 2020* (EC, 2015c). Figure 1.2 shows the main stages of the mapping and assessment process described in this report, with the key input documents and data sources, and the numbers of the chapters and sections that deal with each stage.

Chapter 2 outlines the conceptual assessment framework, the data requirements and the way in which the framework has been applied at European level (in this report) and at Member State level. Chapter 3 then describes the data and methods used to produce the ecosystem map for Europe and presents the map, together with a brief analysis of the spatial distribution of ecosystem types. Chapter 4 describes the assessment of ecosystem condition, both indirectly, by assessing the key pressures on ecosystems, and directly, by using available data on species, habitats and environmental quality. The main body of the report is Chapter 5, which presents summary assessments of each of the main broad ecosystem types in Europe. Chapters 6 and 7 show how the mapping and assessment of ecosystems and their services can be used to inform policy on green infrastructure and develop methods for ecosystem capital accounting. Finally, Chapter 8 presents key findings and the way forward, including recommendations for improvements to the knowledge base. A glossary of key acronyms and abbreviations is appended to the report.

Figure 1.2 Major EEA activities and publications synthesised in this report, showing relevant chapter and section numbers



2 Framework for ecosystem mapping and assessment

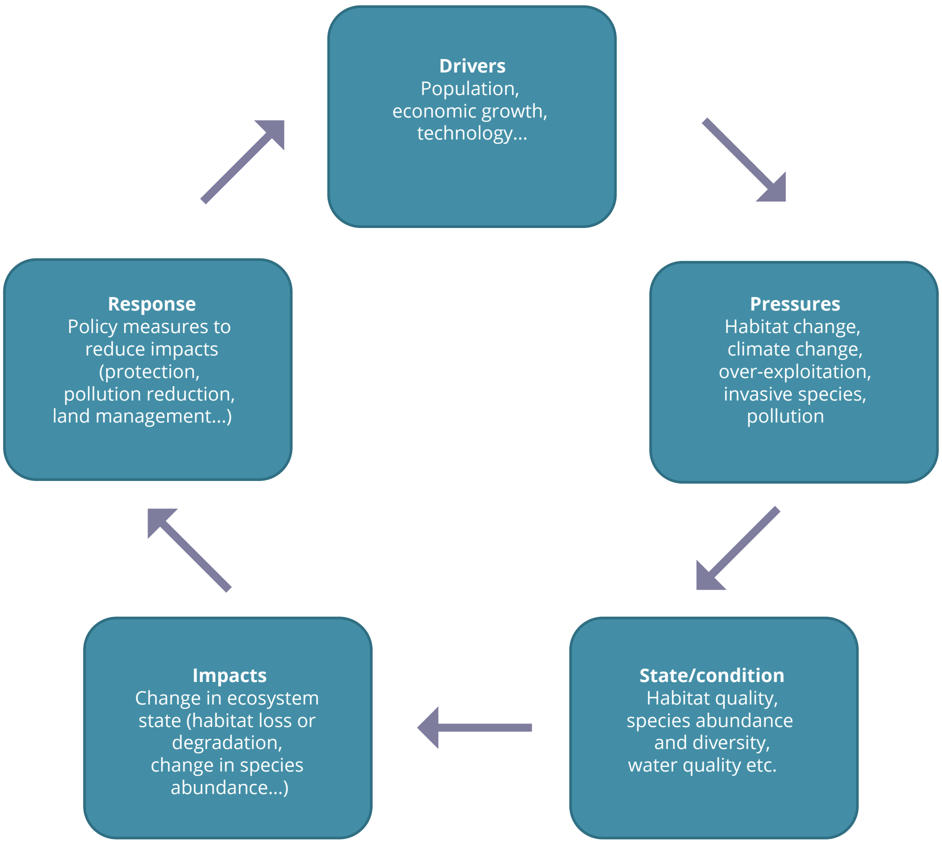
2.1 The DPSIR framework

The mapping and assessment process can be coherently structured using the well-established DPSIR (Drivers, Pressures, State, Impact and Response) framework. This is used to classify the information needed to analyse environmental problems and to identify measures to resolve them (Turner et al., 2010). Drivers of change (D), such as population, economy and technology development, exert pressures (P) on the state (condition) of ecosystems (S), with impacts (I) on habitats and biodiversity across Europe that affect the level of ecosystem services they can supply. If these impacts are undesired, policymakers can put in place the relevant responses (R) by taking action that aims to tackle negative effects. This framework is particularly useful, as it can be adapted and applied for any ecosystem type at any scale. Figure 2.1 shows how ecosystem assessment fits within the DPSIR framework.

2.2 The MAES analytical framework

The European Commission services, led by the Directorate-General of the European Commission for the Environment (DG Environment), have developed the MAES (Mapping and Assessment of Ecosystems and their Services) initiative in collaboration with Member

Figure 2.1 Ecosystem assessment using the DPSIR framework



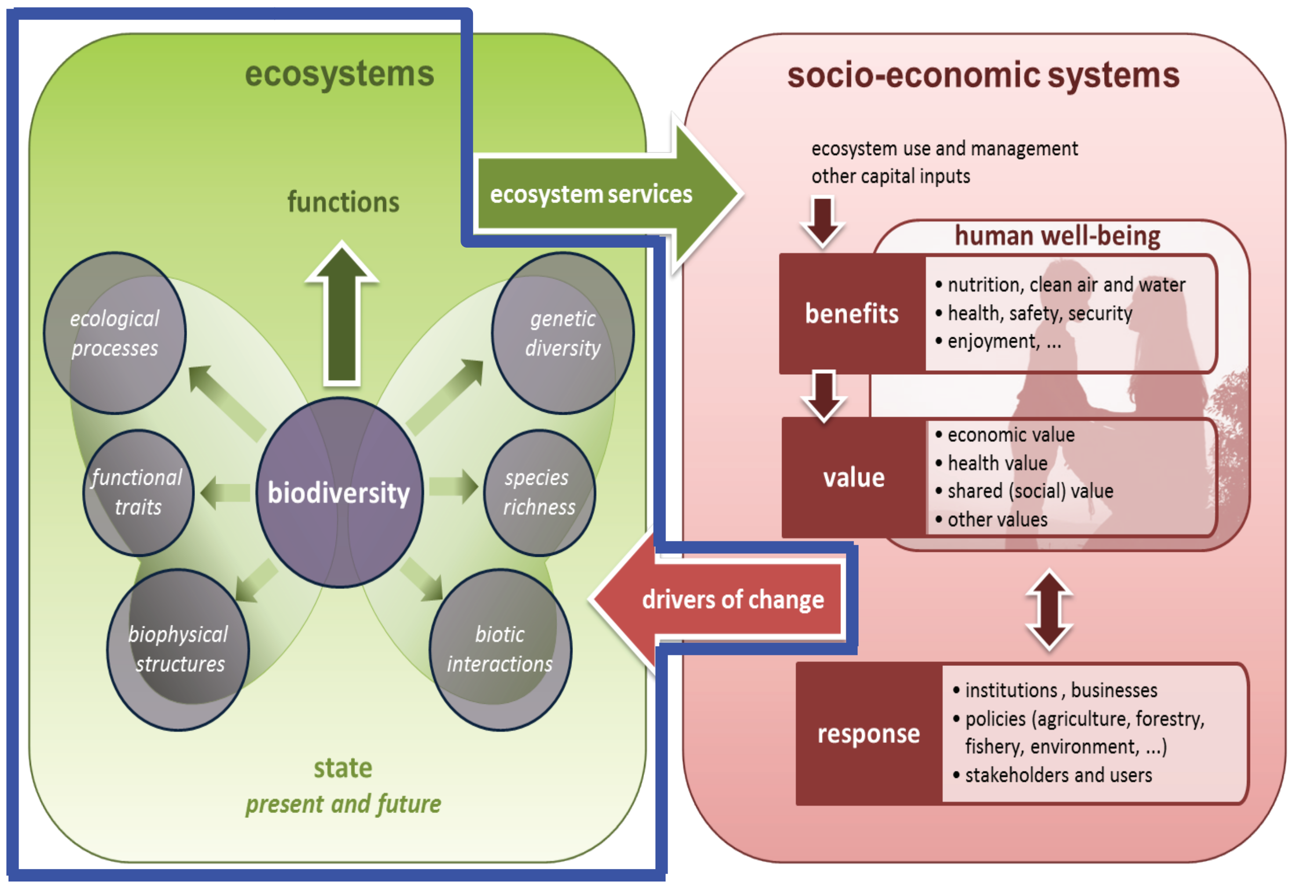
Source: Adapted from EEA, 2015a.

States, EEA, JRC and other EU-level stakeholders (EC, 2015d). The first MAES Technical Report (Maes et al., 2013) provides a common analytical framework for mapping and assessment across Europe in order to assess the condition of ecosystems, spatially identify synergies and trade-offs between ecosystem services, and prioritise action (Figure 2.2). It incorporates elements of the DPSIR framework and other ecosystem assessment frameworks into a simplified approach adapted to fit the needs of ecosystem assessments under Action 5 of Target 2 of the EU Biodiversity Strategy. It also targets supporting ecosystem accounting to help assess the value of our natural capital and to promote the integration of these values into accounting and reporting systems at EU and national levels (Maes et al., 2013; UNSD, 2014). The framework is intended to be applied by the EU and its Member States in order to ensure consistency in approaches and comparability of data.

The second MAES Technical Report proposes indicators that can be used at European and Member State levels to map and assess biodiversity, ecosystem condition and ecosystem services (Maes et al., 2014). This is based on the outcomes of six thematic pilot studies (agriculture, forest ecosystems, freshwater, marine environment, conservation status, and natural capital accounting) using an approach similar to the one applied in this report.

Other approaches to ecosystem classification and ecosystem service mapping have been developed. The EU Seventh Framework Programme (FP7) project OPERAs (OPERAS, 2015) has undertaken a critical review of these and their application, as well as relating them to MAES, while a new EU Horizon 2020 project, ESMERALDA (ESMERALDA, 2015), aims to provide a 'flexible methodology' for European, national and regional integrated mapping and assessment of ecosystem services and their biophysical, economic and social values at different scales to support the delivery of Action 5 by Member States. However, the EEA has adopted the MAES approach for the assessment illustrated in this report.

Figure 2.2 Conceptual framework for EU-wide ecosystem assessment



Note: The blue box frames the content of the ecosystem condition assessment described in this report.

Source: Maes et al., 2013.

2.3 Implementation of the MAES approach using existing data

Ecosystem assessment is often constrained by scientific knowledge and data availability, but pragmatic decisions have to be made (Maes et al., 2013). The information needed for the different steps of a European assessment is outlined in Table 2.1. A full typology of the key data sets required is provided in the EEA report *European ecosystem assessment — Concept, data, and implementation* (EEA, 2015a).

This section describes how the EEA has applied the MAES framework to work towards ecosystem mapping and assessment for Europe, using the available data sources. A simplified diagram of the steps involved is shown in Figure 2.3. Starting from the green boxes on the right-hand side, the first stage is to compile an ecosystem map for the whole of Europe, using available data on land cover, habitats and other factors (Chapter 3). The next stage is to assess the condition of ecosystems, as shown in the blue boxes (Chapter 4). This is done taking two approaches: firstly by assessing the main drivers and pressures that affect ecosystems (Section 4.1), and then by assessing the actual impacts on habitats, species and environmental quality, based largely on reporting data from EU directives (Section 4.2). These approaches are applied to each of the main ecosystems in Chapter 5. The next stage is to produce maps of ecosystem condition, showing the impact of the pressures on biodiversity and environmental quality (blue box). However, this is often challenging because there is a lack of quantitative information on how pressures affect condition (see upper box outlined in orange) and also because most of the condition data (such as habitat assessments) are averages for a region, rather than detailed maps. A few examples are provided in Chapters 4 and 5, but this is an area where more research is needed.

Ecosystem condition maps could, in theory, be used to map the capability of ecosystems to deliver services. However, this is rarely done because of the difficulty in producing ecosystem condition maps, as outlined above, and also because there is a lack of quantitative information on the links between ecosystem condition and ecosystem service delivery (see lower box outlined in orange) or, in other words, how the condition of ecosystems affects their capacity to deliver services. However, a number of authors have produced maps of ecosystem service supply using direct indicators or process-based models (see Section 4.3).

The ultimate goal of ecosystem mapping and assessment is to inform policy, with the aim of triggering policy responses that will protect, enhance or restore ecosystems in line with the targets of the EU Biodiversity Strategy. The policy response can focus on reducing drivers and pressures of ecosystem change, or on directly restoring damaged ecosystems, possibly through green infrastructure projects (see Chapter 6). Although there are currently some data and information gaps, outputs from different stages of the process can already be used to inform policy.

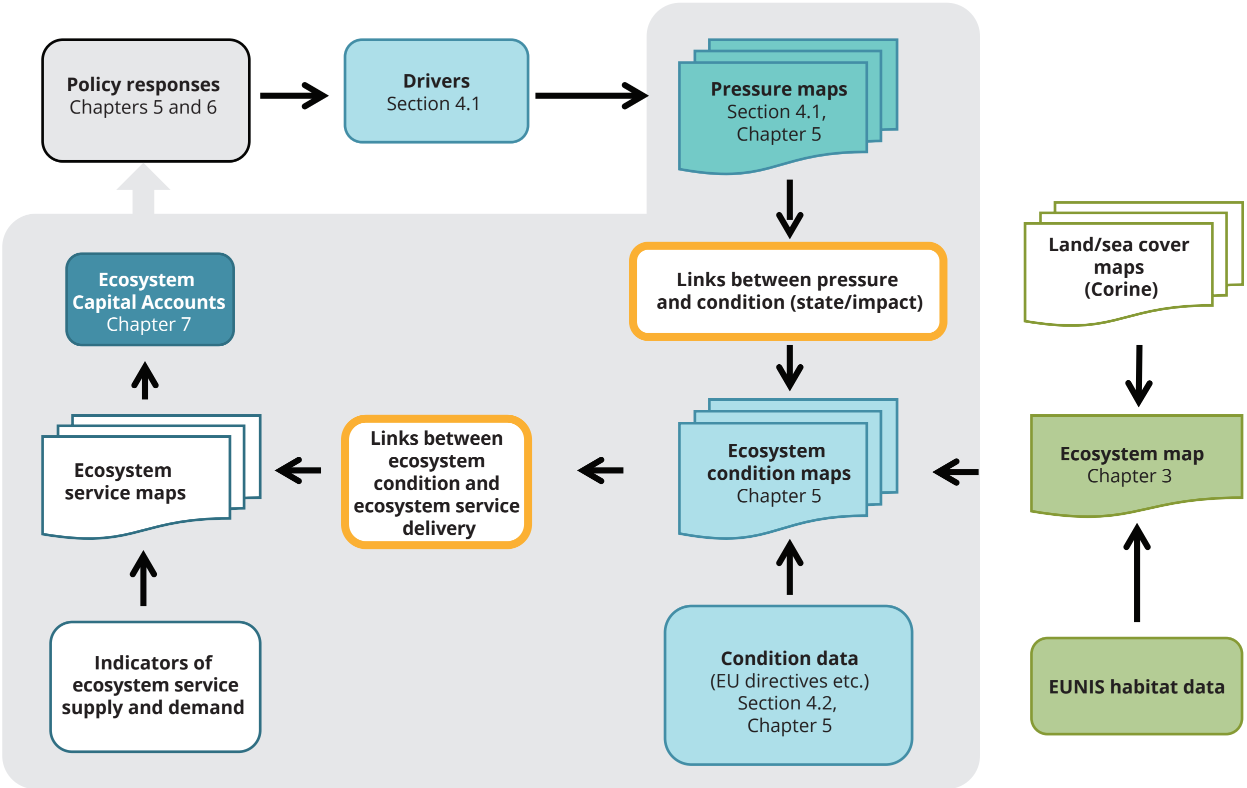
Table 2.1 Data and information needs for Europe-wide ecosystem assessment

Analytical step	Action and information requirement
Mapping ecosystems	Define a typology of ecosystems suitable for the European scale, and map their spatial extent based on their biotic and abiotic characteristics (data from the Corine land cover and EUNIS habitats databases, bathymetry, elevation, soil and other reference data)
Mapping pressures on ecosystems	Assess direct and indirect pressures (habitat change, climate change, overexploitation, invasive alien species and pollution) and their trends in space and time (data from many sources)
Assessing condition of ecosystems	Use data on habitats, species and environmental quality to define condition of ecosystems (EU directives reporting and other sources). Changes over time can show how pressures have affected habitat quality, biodiversity and the capacity to supply ecosystem services
Mapping condition of ecosystems	Condition can be mapped if data on condition are available in sufficient spatial detail (frequently poor data)
Links between ecosystem condition and ecosystem services	Collect information, quantitative if available, about how ecosystem condition affects habitat quality, biodiversity and the capacity to supply ecosystem services (data gaps)
Mapping ecosystem service capacity	Combine ecosystem maps with data on condition and on the links between condition, functions and ecosystem service capacity (data gaps)

Note: Corine, Coordination of Information on the Environment; EUNIS, European Nature Information System.

Source: Adapted from information in EEA, 2015a.

Figure 2.3 The ecosystem mapping and assessment process, with steps covered in this report identified in coloured boxes and data gaps outlined in orange



Note: Each component in the grey area feeds either directly or indirectly via the other elements into the policy process.

Source: Adapted from EEA, 2015a.

Policymakers can make use of pressure maps, ecosystem condition maps, ecosystem service maps and valuation of ecosystems through ecosystem capital accounting (see Chapter 7). Ecosystem condition data and ecosystem service maps can be used to help policymakers target suitable green infrastructure and habitat restoration projects, and these projects in turn can improve ecosystem condition and optimise the delivery of ecosystem services.

2.4 Member State initiatives

Following on from the global Millennium Ecosystem Assessment (MA, 2005), some European countries have undertaken ecosystem assessment and mapping initiatives at a national and/or regional scale. As part of MAES, the Mapping of Ecosystems and their Services in the EU and its Member States (MESEU) project, funded by the European Commission, has been collating information on Member State activities and seeking to provide assistance to Member States in the context of Action 5 on the mapping and assessment of the state (condition) of ecosystems and their services in their national territories, enabling them to make best use of work already undertaken at EU and Member State levels. At the end of 2014, the vast majority of Member States were reported to be in the process of implementing or developing activities that can be considered to be part of Action 5 (Braat, 2014).

Various sub-regional or specific assessments have been undertaken, mostly focusing more on ecosystem services than on ecosystems, often using different data sources more appropriate to the scale of study (e.g. Flanders, Belgium (INBO, 2015), Portugal (P-MEA, 2015), Spain (ES-MEA, 2015) and the United Kingdom (UK-NEA, 2015)). These are very valuable in that they can advance our understanding of how to map and assess ecosystems and their services, but often they are not appropriate to a European assessment owing to their finer resolution and use of more local data. Nevertheless, they all start with mapping ecosystems and, in some cases, some form of assessment of their state/condition, and examples from Flanders and Spain are given here. The Spanish National Ecosystem Assessment followed on from the Millennium Ecosystem Assessment (MA, 2005), and it aimed to demonstrate the relevance of ecosystem services in Spain and their importance to societal and human well-being (Santos-Martín et al., 2013). It also sought to identify options for responses to environmental challenges. It applied a DPSIR framework to understand the relationship among ecosystems, their services and human well-being and started by mapping the ecosystems and developing indicators.

Flanders has taken a three-stage approach to ecosystem assessment, the first of which, assessment of the condition of and trend in ecosystems, has just been completed (Stevens et al., 2015). This used the MAES classification of ecosystems as the basis for its ecosystem map, which is being used to develop an integrated ecosystem service map. It is now applying methods and tools to take ecosystem services into account when making policy decisions, before, in the third phase, exploring how different scenarios could affect ecosystems and their services in the future.

A history and overview of habitat mapping for various purposes in EU and EEA member states and cooperating countries has been undertaken (EEA and MNHN, 2014). It found, for example, that many countries have recently endeavoured to map and assess particular ecosystems. For example, since 2001, France, Latvia, Lithuania, the Netherlands, Slovakia, Spain and the United Kingdom have undertaken national grassland inventories and large-scale vegetation mapping.

The MAES catalogue of case studies (EEA, 2015j) and the MAES digital atlas (EEA, 2015k), both integrated in the Biodiversity Information System for Europe (BISE) platform, provide an overview of Member States' activities and progress. The assessment process will be further triggered by the regional assessment of biodiversity and ecosystem services for Europe and Central Asia as part of the sub-global assessment of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), to be finalised early 2018 (IPBES, 2015), and the United Nations (UN) Environment Programme (UNEP) Global Environmental Outlook GEO-6 report, to be launched mid-2017 (UNEP, 2015).

3 Ecosystem mapping

Ecosystem mapping is increasingly being undertaken at a variety of scales and for various purposes. It is a powerful tool for decision-makers that can be used as a communication tool to initiate discussions and engagement with stakeholders. Ecosystem maps can also be used to identify priorities and problems for different locations, to assess interactions between ecosystems and their services, to target policy measures at specific locations, and to demonstrate and evaluate the costs and benefits of policy options.

Once a map has been compiled from land cover, habitats and other data, the underlying spatial data can be analysed using geographical information system (GIS) techniques to provide statistical information on the area and distribution of the main ecosystem types. For example, a global map of ecological land units has been produced by combining maps of bioclimate, landforms, rock and soil types and land cover (Sayre et al., 2014). Despite uncertainties implied in the delineation of statistical data using spatially explicit units (as explained in EEA, 2015a), this map is seen as potentially contributing to conservation objectives, such as assessing the degree to which different ecosystems are covered by protected area networks and assessing the supply of ecosystem services.

This chapter first describes the selection of a suitable typology (classification) of ecosystems to be mapped (Section 3.1), and then describes how the available input data were used to map ecosystems at the European scale (Section 3.2). The map of ecosystems is presented in Section 3.3, and Section 3.4 presents an analysis of the spatial distribution of the main ecosystems in Europe.

3.1 Typology of ecosystems for mapping

The first step is to develop an agreed typology (classification) of ecosystems. The typology will depend on the purpose of the mapping, the required scale and the data availability. Through the MAES process, Member States, together with DG Environment, JRC and EEA, have agreed a list of 12 main Europe-wide ecosystem types that are feasible to map, in terms of both the aggregation of national and local data and the disaggregation of European data (Table 3.1). These were selected to reflect the main policy themes and the availability of data through the environmental reporting requirements from certain EU directives (see Section 4.2.1). A detailed description is available in Maes et al. (2013).

The MAES marine ecosystem typology had several potential limitations, as acknowledged in Maes et al. (2013, 2014), which have required some adaptation to make it operational (see ETC/SIA, 2013c; EEA, 2015a).

3.2 Input data and method of aggregation of inputs

Ecosystems can be mapped by building up a series of overlays of significant factors, such as the distribution of different communities of organisms, the biophysical environment (soil types, drainage basins, depth of water bodies) and spatial interactions (e.g. migration patterns). Ecosystem boundaries are likely to coincide with discontinuities in these factors. Thus, ecosystems within each category share a suite of climatic, geophysical and biochemical conditions, biological conditions (including species composition and interactions) and socio-economic factors shaping land cover (as dominant uses by humans tend to differ across ecosystems) (Maes et al., 2013). Mapping provides information on the spatial distribution of ecosystems that is important for many functions, such as the breeding and feeding of birds, which requires different neighbouring ecosystems or mosaics of cropland, grassland and forests that are more attractive for recreation than uniform landscapes.

For the European ecosystem map, the starting point was the Corine (Coordination of Information on the Environment) land cover (CLC) data set for 2006, obtained from high-resolution satellite imagery. This was enhanced with additional data sets to provide more details, for example on forest cover, water bodies and roads. Spatial maps of the CLC classes were combined with the EUNIS (European Nature Information System) (EEA, 2015l) categorisation of habitat types. This remapping (called a 'cross-walk') allows land cover information to be underpinned by more detailed habitat-related information. This provides insights into the biodiversity we may expect for each ecosystem type across Europe, and allows integration of national and local classifications that vary across Europe (Maes et al., 2014). The benefits of combining CLC and EUNIS, especially for ecosystem service assessments at national to regional scales, have been demonstrated by Vihervaara et al. (2012).

The typology links the MAES level 2 ecosystem types shown in Table 3.1 with the corresponding EUNIS level 1 habitat types (Table 3.2). CLC levels 1, 2 and 3 are then linked to EUNIS level 2, which, for example, splits the level 1 category of 'Woodland and forest' into five sub-categories (coniferous, broadleaved deciduous, etc.). The full typology is provided in an EEA Technical report (EEA, 2015a). A simple link between CLC classes and EUNIS habitats was not always possible, as sometimes a single CLC class contains multiple habitats, and some habitats also occur in more than one CLC class.

Table 3.1 Typology of ecosystems for mapping

MAES level 1 ecosystem category	MAES level 2 ecosystem type	Description
Terrestrial	Urban	Urban, industrial, commercial and transport areas, urban green areas, mines, dumping and construction sites
	Cropland	The main food production area including both intensively managed ecosystems and multifunctional areas supporting many semi- and natural species along with food production (lower intensity management). Includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics)
	Grassland	Areas covered by a mix of annual and perennial grass and herbaceous non-woody species (including tall forbs, mosses and lichens) with little or no tree cover. The two main types are managed pastures and semi-natural (extensively managed) grasslands
	Woodland and forest	Areas dominated by woody vegetation of various ages or with succession climax vegetation types on most of the area, supporting many ecosystem services. Information on ecosystem structure (age class, species diversity, etc.) is especially important for this ecosystem type
	Heathland and shrub	Heathland and shrub are areas with vegetation dominated by shrubs or dwarf shrubs. They are mostly secondary ecosystems with unfavourable natural conditions. They include moors, heathland and sclerophyllous (small, hard-leaved) vegetation
	Sparsely vegetated land	Sparsely vegetated land often has extreme natural conditions that might support particular species. They include bare rocks, glaciers and dunes, beaches and sand plains.
	Wetlands	Inland wetlands are predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. Includes natural or modified mires, bogs and fens, as well as peat extraction sites
Freshwater	Rivers and lakes	Permanent freshwater inland surface waters, including water courses and water bodies
Marine ([a])	Marine inlets and transitional waters	Ecosystems on the land–water interface under the influence of tides and with salinity higher than 0.5 %. Includes coastal wetlands, lagoons, estuaries and other transitional waters, fjords and sea lochs and embayments.
	Coastal	Shallow coastal marine systems that experience significant land-based influences. These systems undergo diurnal fluctuations in temperature, salinity and turbidity, and they are subject to wave disturbance. Depth is between 50 and 70 m.
	Shelf	Marine systems away from coastal influence, down to the shelf break. They experience more stable temperature and salinity regimes than coastal systems, and their seabed is below wave disturbance. They are usually about 200 m deep.
	Open ocean	Marine systems beyond the shelf break with very stable temperature and salinity regimes, in particular in the deep seabed. Depth is beyond 200 m

Note: ([a]) Most of the information available at the EU level, from the implementation of the relevant EU environmental legislation and from other sources needed to assess marine ecosystem condition, does not as yet discriminate between each of the MAES marine ecosystem classes. In the specific case of the Marine Strategy Framework Directive, which is the widest ranging common information pool on the marine environment at the EU level, reporting allows a consistent and comparable (across and between Member States) discrimination of the overall condition of seabed and water column habitats at the EU level (see EEA, 2015c), but not of further differentiation within these habitat types (e.g. depth of seabed habitats, type of seabed substrate) or of their distance to the coast, as would be needed to link them to the MAES marine ecosystem classes. A proposal for a revised marine classification has been outlined (ETC/SIA, 2014f).

Source: EEA, 2015a, adapted from Maes et al., 2013.

Table 3.2 Correlation between ecosystem map legend and MAES ecosystem types, based on EUNIS habitats

MAES categories		Units in legend of ecosystem map (Map 3.1, version 2.1)	
Level 1	**Level 2**	**EUNIS level 1**	**EUNIS level 2**
Terrestrial	**Urban**	**J Constructed, industrial and other artificial habitats**	
	Cropland	**I Regularly or recently cultivated agricultural, horticultural and domestic habitats**	
	Grassland	**E Grassland and land dominated by forbs, mosses and lichens**	
	Woodland and forest	G Woodland, forest and other wooded land	**Broadleaved deciduous and evergreen woodland**
			Mixed deciduous and coniferous woodland
			Coniferous and broadleaved evergreen woodland
	Heathland and shrub	F Heathland, scrub and tundra	**Tundra**
			Arctic, alpine and subalpine scrub and grassland
			Mediterranean scrub and bushes
			Heathland scrub
	Sparsely vegetated or unvegetated land	H Inland unvegetated or sparsely vegetated habitats	**Screes, inland cliffs**
			Snow- and ice-dominated habitats
			Miscellaneous inland habitats with no or very sparse vegetation
	Attributed to sparsely vegetated land	**B Coastal habitats (land)**	Coastal dunes and sandy shores
			Coastal shingle
			Rock cliffs, ledges and shores including supralittoral
	Wetlands	**D Mires, bogs and fens**	
Freshwater	Rivers and lakes	C Inland surface waters	**Inland waters and shores**
Marine	Marine inlets and transitional waters	A Marine habitats B — Coastal habitats (water)	**Legend related to EUNIS and bathymetry data (see Table 3.1)**
	Coastal		
	Shelf		
	Open ocean		

Source: Based on EEA, 2015a. Bold type in the first two columns indicates ecosystem classification used in the report; bold type in columns three and four indicates the category used in the map legend. Coloured boxes represent the categories on the ecosystem map (Map 3.1).

Additional reference data were therefore used to specify the areas where habitats are present according to their environmental characteristics, as described in the EUNIS classes. For terrestrial ecosystems, this includes information on elevation, soil and geological conditions, and climate, as well as potential natural vegetation (based on a map developed by Bohn and Neuhäusl, 2003) and phenological data derived from remote sensing using MODIS (Moderate Resolution Imaging Spectroradiometer), which can distinguish arable land from grassland. For example, altitude can be used to separate 'Alpine and subalpine grasslands' from the CLC 'grasslands' class; data on soil-water balance and soil type can be used to distinguish wet grasslands from dry grasslands; and geological data can help to separate acidic bogs from calcareous fens.

The marine part of the map has been developed using data sets of Water Framework Directive conditions (EUNIS habitats), bathymetry and the current draft of the European sea zones combined with coastlines and coastal areas derived from CLC data.

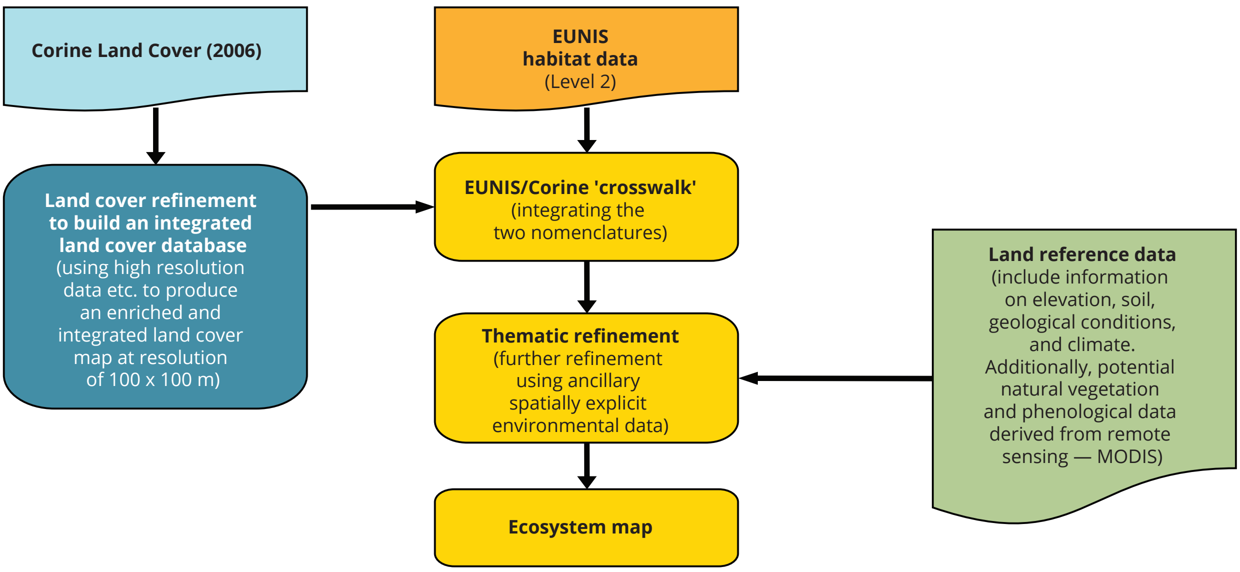
A simplified version of the ecosystem map development process for terrestrial ecosystems is shown in Figure 3.1. Further details are available in a report provided by ETC/SIA (ETC/SIA, 2013c).

3.3 Current ecosystem map of Europe

Map 3.1 presents version 2.1 of the European ecosystem map produced by the EEA and the European Topic Centre for Spatial Information and Analysis (ETC/SIA), using the approach described in Section 3.2. For land and freshwater it maps ecosystem types for EEA member countries (EEA-39) at 1 ha spatial resolution. The map presents a combination of EUNIS level 1 habitats (equivalent to the MAES ecosystem types) and, where there is enough detail, level 2 habitats (see Table 2.1). It represents the distribution of major habitats across Europe, and it is the basis for the assessment of the condition of these habitats and of the pressures they are subject to, as reported in Chapter 4.

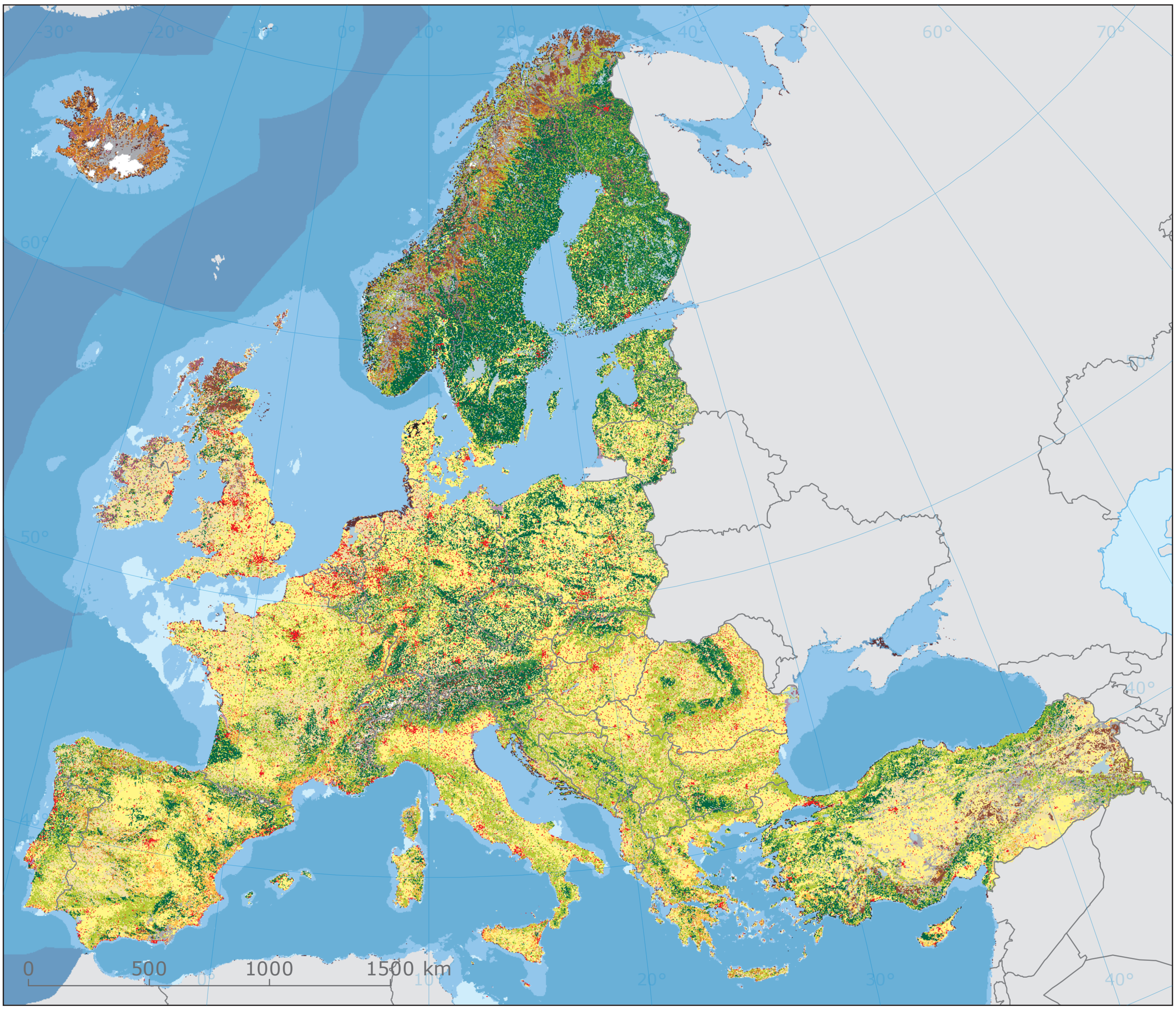
Methods have to be developed for spatially explicit mapping of changes of ecosystem and habitat distribution across Europe. This will provide important information about gains and losses of ecosystem types and habitats, including their value in relation to condition and pressures. Copernicus land monitoring, especially the CLC update, high-resolution layer mapping and data from very high-resolution mapping, such as Urban Atlas and riparian zones (Copernicus, 2015), will be the basis for detecting change.

Figure 3.1 Simplified development process for an ecosystem map for terrestrial ecosystems



Source: Adapted from ETC/SIA, 2013c.

Map 3.1 Ecosystem map for EEA-39 (version 2.1)



Ecosystem map (aggregated)

Marine waters
- Open waters
- European regional seas

Marine seabed and coastal habitats
- Sublittoral sediment
- Infralittoral and circalittoral rock and other hard substrata
- Marine habitats
- Coastal habitats

Inland surface waters
- Inland waters and shores

Inland vegetation and habitats
- Tundra
- Arctic, alpine and subalpine scrub and grassland
- Mediterranean mountain scrub and brushes
- Heathland scrub
- Grasslands and land dominated by forbs
- Regularly or recently cultivated agricultural, horticultural and domestic habitats
- Broadleaved deciduous and evergreen woodland
- Mixed deciduous and coniferous woodland
- Coniferous and broad leaved evergreen woodland
- Wetlands — mires, bogs and fens

Inland unvegetated or sparsely vegetated habitats
- Screes, inland cliffs
- Snow or ice-dominated habitats

Human made constructions and habitats
- Constructed, industrial and other artificial habitats

Non classified areas
- Unclassified areas
- Outside area of interest

Note: EUNIS classes with little spatial extension were aggregated for clarity (see Table 3.3).

Source: EEA, 2015a, based on analysis by ETC/SIA.

3.4 Analysis of results from mapping European ecosystems

Spatially explicit mapping of ecosystems provides a first overview of their location across Europe, their distribution in the Member States and their protection status. Biogeographical regions identify areas of similar environmental conditions for plants and animals. The 33 EEA member counties and 6 collaborating countries are divided into 11 terrestrial and 5 marine biogeographical regions. The 11 terrestrial regions are the Alpine, Anatolian, Arctic, Atlantic, Black Sea, Boreal, Continental, Macaronesian, Mediterranean, Pannonian and Steppic regions; the 5 marine regions are the Marine Atlantic, Marine Baltic, Marine Black Sea, Marine Macaronesian and Marine Mediterranean regions. In combination with the member countries' boundaries, the regions are the basic reporting unit for the Habitats Directive (EEA, 2015d).

Because European sea boundaries and reporting on protected areas were not available during the drafting of this document, marine ecosystem extension and protection status are not included in this section.

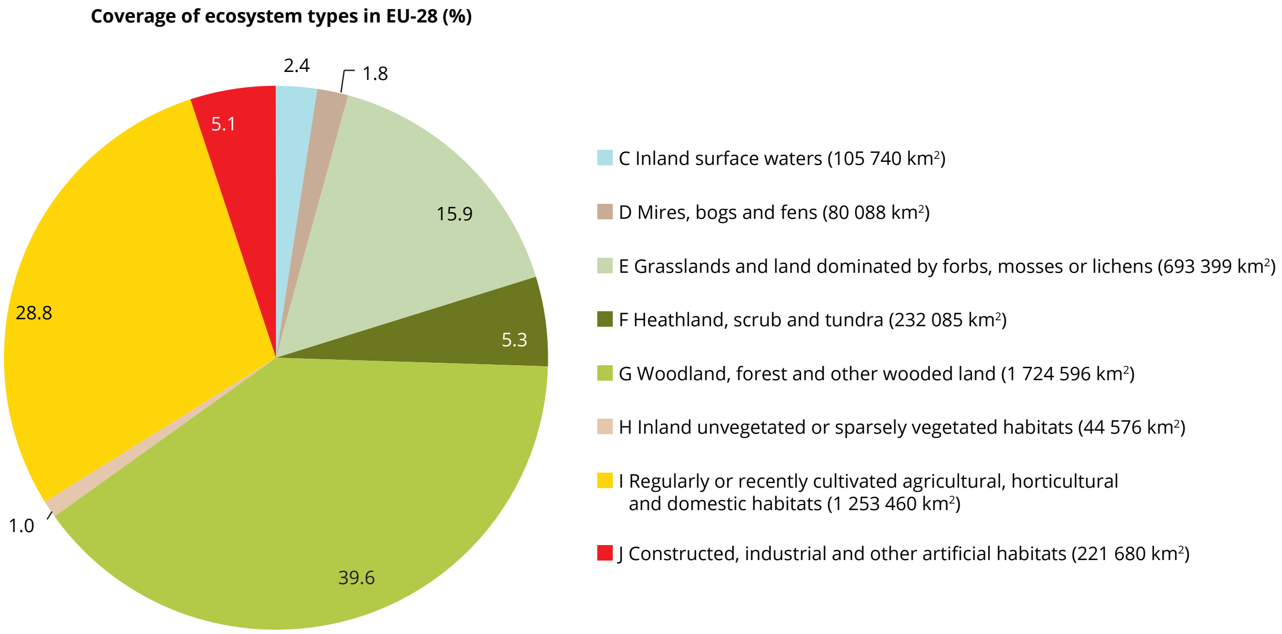
3.4.1 The spatial distribution of terrestrial and freshwater ecosystems

Figure 3.2 shows the areas and percentages of the MAES terrestrial and freshwater ecosystem types in Europe (for the EU-28). Woodland and forest is the most common ecosystem type (40 %) followed by cropland (29 %) and grassland (16 %).

Figure 3.3 shows how terrestrial and freshwater ecosystems are distributed between countries. Some ecosystems are concentrated in just a few countries, whereas others are more evenly distributed. Sweden and Finland contain more than half of all freshwater and wetland habitats, for example, and Spain contains almost one-third of heathland and almost one-quarter of sparsely vegetated land.

Map 3.2 shows that the broad ecosystem types each span a range of biogeographical regions (these are regions that are environmentally and ecologically similar, shown in Figure 3.4). For example, the 'Woodland and forest' ecosystem occurs widely in the Boreal, Atlantic, Alpine and Mediterranean regions, among others. The habitats within this ecosystem are

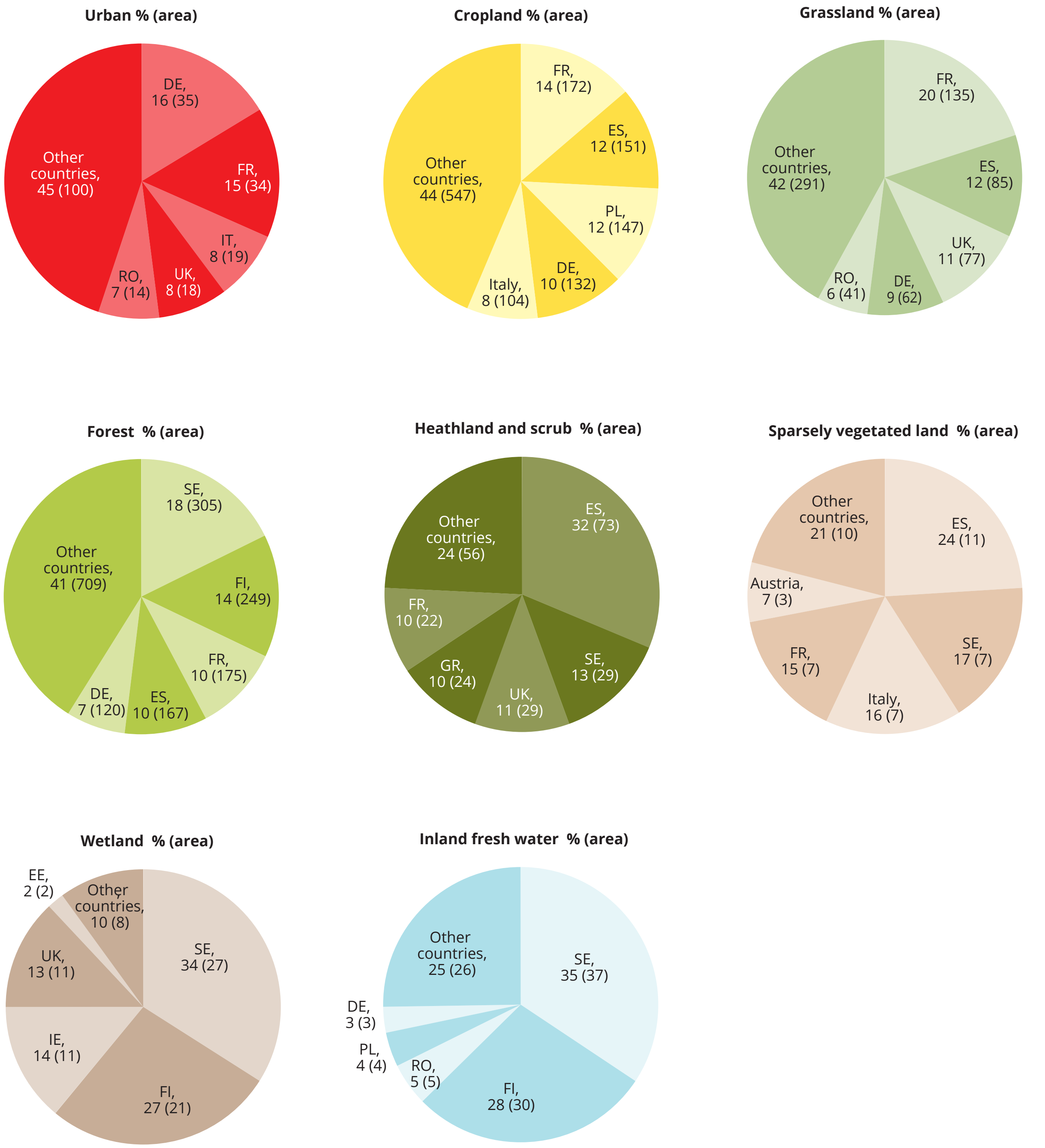
Figure 3.2 Area and percentage of MAES terrestrial and freshwater ecosystem types in the EU-28



Note: This chart shows MAES ecosystem types, as used throughout this report, and hence there are some differences to ecosystem areas cited in EEA, 2015d, which was based on CLC level 2. Sparsely vegetated land covers only coastal dunes and is therefore a significant underestimate (the previous data set estimated coverage at 6 %). Marine ecosystems are not included owing to data issues.

Source: Analysis by the European Topic Centre on Urban Land and Soil Systems (ETC/ULS) in 2015.

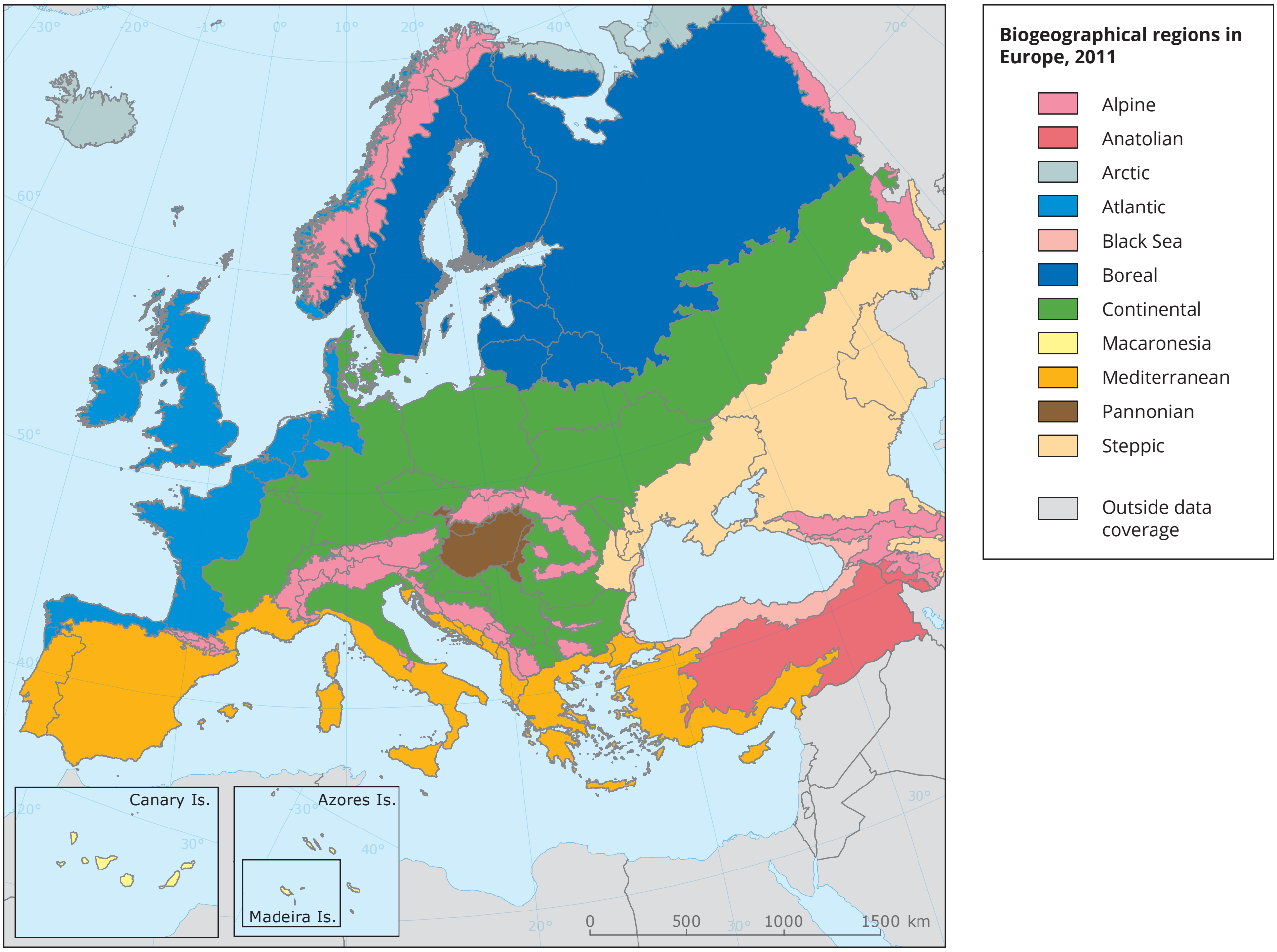
Figure 3.3 **Distribution of terrestrial and freshwater ecosystems in percent (and by area in 1 000 km²) — showing the five countries with the greatest area of each ecosystem type vs the area for all other countries**



Note: AT, Austria; DE, Germany; EE, Estonia; ES, Spain; FI, Finland; FR, France; GR, Greece; IE, Ireland; IT, Italy; PL, Poland; RO, Romania; SE, Sweden; UK, United Kingdom.

Source: Analysis by ETC/SIA in 2015.

Map 3.2 Biogeographical regions in Europe, 2011



Source: http://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-2, accessed 12 December 2015.

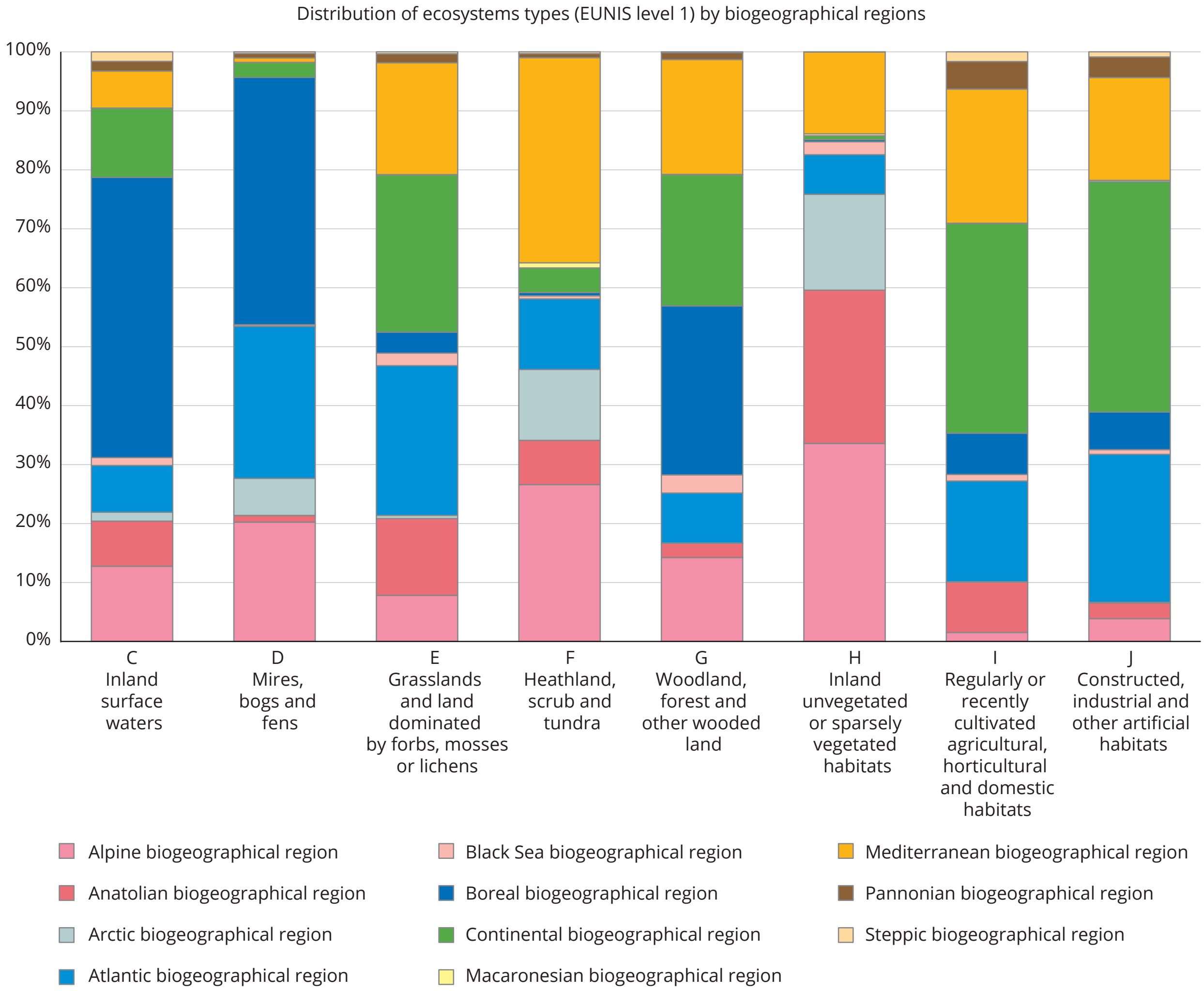
very diverse, including those specific to a region, such as Boreal coniferous forest and Mediterranean evergreen oak (*Quercus*) woodland, and many that can occur in more than one region, such as beech (*Fagus*) woodland. However, certain ecosystem types are heavily concentrated in particular regions. For example, a large proportion of wetlands are in the Boreal and Atlantic regions, while much of Europe's sparsely vegetated land is in the Alpine, Anatolian and Steppic regions.

3.4.2 The protection status of the mapped ecosystems

Protecting ecosystems from pressures such as management and habitat loss can improve their condition, and thus increase their potential to support biodiversity and supply ecosystem services. There is abundant scientific literature which, for example, is summarised in Harrison et al. (2014) or Science for Environment Policy (2015). This hypothesis has also been tested by Maes et al. (2012), who found that habitats in favourable conservation status had more diversity and potentially could supply more regulating and cultural ecosystem services. They emphasised the importance of these findings for the EU Biodiversity Strategy to 2020.

The main instrument for protecting ecosystems in the EU is the Natura 2000 network. This comprises sites protected because of their importance for rare or threatened species or habitats, as specified by the Habitats and Birds Directives. It covers 18 % of the EU's land surface and, as a first estimate (EEA, 2015h), about 5.9 % of its seas, forming the world's largest coordinated network of nature conservation areas (EEA, 2015d). Figure 3.5 (bottom graph) shows the proportion of the main ecosystem types that are protected by Natura 2000 sites. As expected, the more natural ecosystems have higher levels of protection, such as sparsely vegetated land (54 %) and wetlands

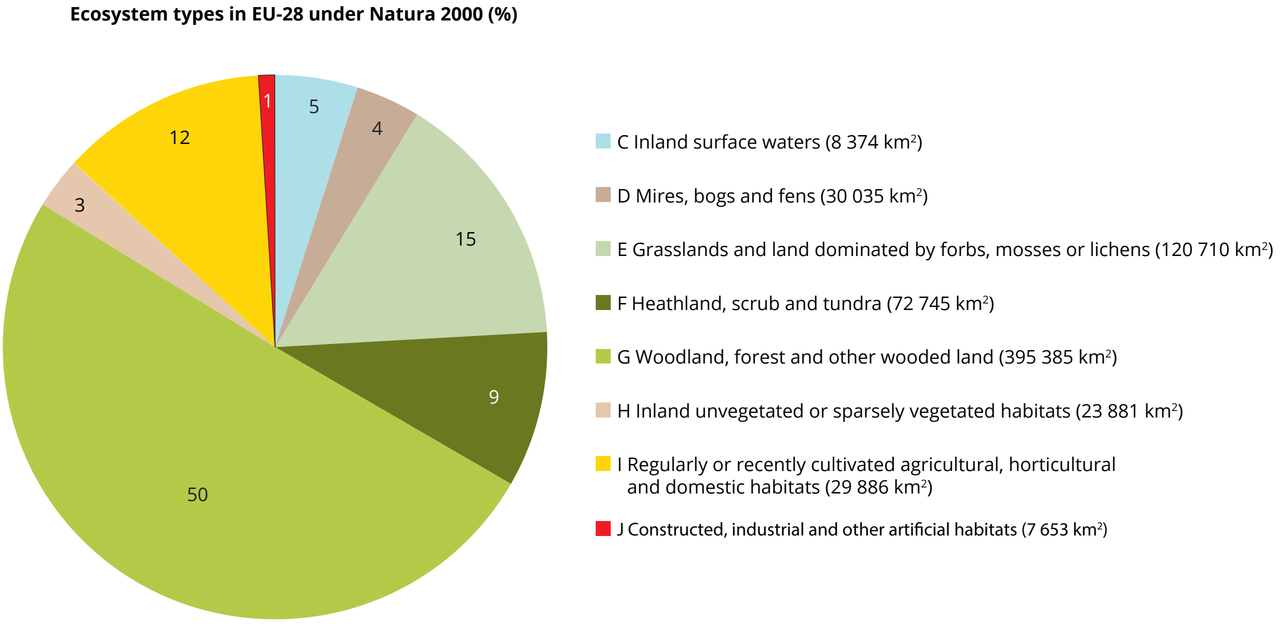
Figure 3.4 Percentage of terrestrial and freshwater ecosystem types by biogeographical region

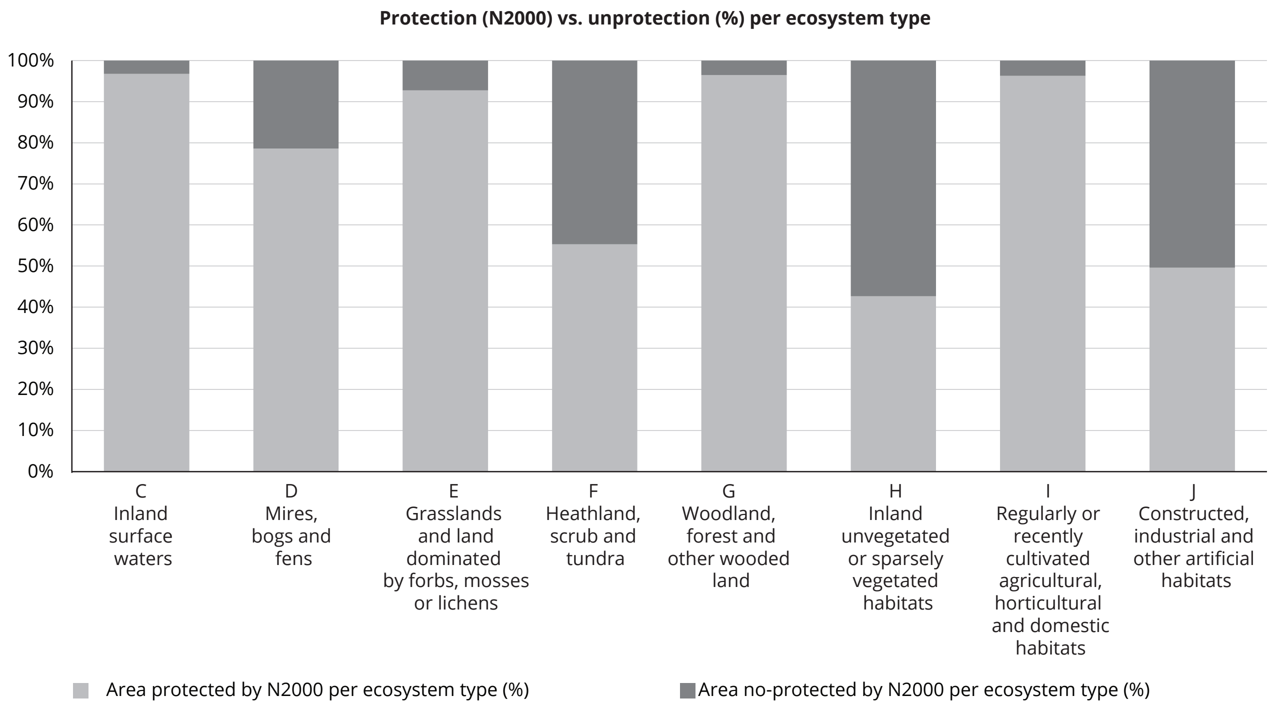


Note: Ecosystems are shown as EUNIS level 1 habitats instead of MAES ecosystem types (see Table 3.2).

(38 %). More intensively managed ecosystems such as urban (3 %) and cropland (8 %) have much lower levels of protection. This reflects the relative lack of species or habitats of conservation importance within those ecosystems and also the general focus on food provisioning as the main function of cropland. However, there is still a need and an opportunity for policymakers to protect biodiversity and ecosystem services in these highly modified ecosystems (see Sections 5.1.4 and 5.2.4).

Figure 3.5 Area and percentage of terrestrial and freshwater ecosystem types in the EU-28 (top) and percentage of each ecosystem type protected by Natura 2000 (bottom)





Note: N2000, Natura 2000.

Source: Analysis by ETC/ULS, 2015.

4 Assessment of ecosystem condition

Having mapped the distribution of ecosystems across Europe, the next stage in the assessment is to evaluate the state (condition) of the ecosystems, which affects their ability to provide ecosystem services. This chapter describes the approach to assessing ecosystem condition, as developed by the EEA in support of and in collaboration with the MAES process.

Ecosystem condition is defined as the effective capacity of an ecosystem to provide services, relative to its potential capacity (MA, 2005). The Millennium Assessment calls for a well-defined ecosystem that has strong interactions among its components and weak interactions across its boundaries. It defines a useful choice of ecosystem boundaries — the place where a number of discontinuities coincide, such as in the distribution of organisms, soil types, drainage basins and depth in a water body (MA, 2005). At a larger scale, regional and even globally distributed ecosystems are evaluated based on a commonality of basic structural units (MA, 2005). The EEA has used this approach by developing an ecosystem-specific assessment, as set by the MAES ecosystem categories.

Ecosystem service capacity depends on the physical, chemical and biological condition of an ecosystem at a particular point in time, and is controlled by both the natural condition (affected by factors, such as soil, elevation and aspect) and the anthropogenic pressures to which it is exposed, such as habitat change and pollution. The effect of the flow of pressures through time affects the ecosystem condition measured at a specific moment in time, and so pressures can be used as a proxy for assessing ecosystem condition, although there may be a time lag between the application of the pressure and the resulting impact on ecosystem condition.

There are, therefore, two complementary approaches to assessing condition: an indirect approach based on evaluation and mapping of the pressures acting on ecosystems, as described in Section 4.1, and direct assessments of habitat condition, biodiversity and environmental quality, as described in Section 4.2. Ideally information from both approaches is available, and data sets can be used for comparison and validation and for interpreting how pressures affect current conditions. These two approaches are applied to evaluate ecosystem condition, as outlined in Chapter 5.

The next stages in the assessment would then be to produce spatial maps of ecosystem condition, including the impact of multiple pressures, and to use the knowledge of ecosystem condition to assess the ability of the ecosystems to supply ecosystem services. However, as discussed in Section 2.4, this is constrained by lack of quantitative information on the way in which condition affects service delivery. Section 4.3 discusses the data and knowledge gaps in the assessment process and indicates possible future options for extending the assessment.

4.1 Pressures on ecosystems

Drivers of change, such as population growth and increased consumption, create environmental pressures that have the capacity to change the condition of habitats, the health of species and the species composition of ecosystems (biodiversity), decreasing their resilience and affecting their capacity to supply services. Information on these pressures can be used as a proxy for assessing the condition of ecosystems. It is also essential for informing policies to reduce the pressures and to avoid crossing ecological 'tipping points', namely critical levels of pressure that, if crossed, will result in an entire ecosystem shifting into a new state / condition, which may have a different species composition and changed level of resilience and is often less conducive to human well-being (EEA, 2015b).

Overall anthropogenic pressures are mostly increasing (MA, 2005; EEA, 2015b), despite efforts to reduce them through measures to reduce pollution and to meet objectives such as the Aichi Targets and the Sustainable Development Goals. In Europe, the two most frequently reported pressures and threats for terrestrial habitats listed in the Habitats Directive are agriculture (both intensification and abandonment) and the modification of the natural conditions of water bodies, mostly through hydrological changes (EEA, 2015d). For marine ecosystems, the main pressures are (over-)fishing, modification of natural habitat conditions and pollution

(EEA, 2015c). The Millennium Ecosystem Assessment (MA, 2005) identified the most important pressures, and these have been combined into five major groups as part of the MAES framework (Maes et al., 2014), as shown in Table 4.1.

Assessing the different pressures and their trends and impacts for each ecosystem type is difficult owing to the lack of coherent data, and thus the assessments in Chapter 5 are based on multiple sources, including data from environmental directives on biodiversity and pollution (Section 4.2.1), as well as data sets on land use, soil quality, floods, fires, timber extraction, organic farming and many other factors (see the full list in ETC/SIA, 2014d). The assessments for each ecosystem in Chapter 5 also note the main pressures and threats to habitats and species, as reported under the EU Nature Directives (the collective term for the Birds and Habitats Directives; see Section 4.2.1 and EEA, 2015d), which provide the perspectives of the Member States.

Some of the SEBIs (Streamlining European Biodiversity Indicators) also provide an indication of the pressures on ecosystems and their condition, including agricultural nitrogen balance (EEA, 2010c) and nutrients in transitional, coastal and marine waters. These were developed to support the assessment of the 2010 biodiversity target (EEA, 2012a), and were used to produce the EU 2010 Biodiversity Baseline (EEA, 2010a), which provides a 2010 reference to assess progress towards the targets of the EU Biodiversity Strategy to 2020. This baseline has meanwhile been updated and adapted to reflect the MAES ecosystem typology (EEA, 2015g). The EEA is also developing the Biodiversity Information System for Europe (BISE) (EEA, 2015m), including an ecosystem assessment platform for communication and outreach, which will contribute to the baseline assessments of Europe's land, freshwater and marine environments.

The combined impact of all these pressures over time is reflected in the severity and extent of the resulting changes in ecosystem condition. These impacts are not evenly distributed but depend on spatial and temporal factors, as well as on the sensitivity of the biodiversity within a particular ecosystem. Some pressures, such as long-range air pollution, can have a widespread impact, affecting multiple countries, while others such as land management may have a more localised effect. Some may have a severe impact on certain ecosystems while posing little threat to others. Human activity is responsible for almost all of these pressures.

This section briefly reviews each pressure at a European scale, with the main pressures for each ecosystem being addressed in Chapter 5.

Table 4.1 Main pressures causing ecosystem change

Pressures	Description
Habitat change	The main pressure causing habitat change in terrestrial ecosystems is land take. This causes impacts, such as fragmentation, soil sealing, soil erosion and soil degradation, that can cause direct degradation of a habitat or its loss and replacement by another habitat type. For some areas, abandonment of farmland leading to replacement by shrub or forest is also significant. For marine and coastal ecosystems, the main pressures are destructive fishing techniques and coastal development, and, for freshwater ecosystems, they are human modifications such as the creation of dams and diversion of rivers.
Climate change	Anthropogenic climate change causes fluctuations in the life cycles of plants and animals and extreme events such as floods, droughts and fires that change the health and characteristics of habitats and the species present.
Overexploitation (unsustainable land or water use or management)	Pressures arise from the use of ecosystems for production of food, fuel and fibre. Intensive land management and overexploitation of natural resources, including overfishing and overextraction of water, has already seriously reduced habitat quality and biodiversity in Europe.
Invasive alien species	Invasive alien species can replace native species, occupying their habitats, reducing their survival and abundance and leading to loss of biodiversity.
Pollution and nutrient enrichment	Pollution and nutrient enrichment occur when excessive harmful components such as pesticides, fertilisers and industrial chemicals are introduced into an ecosystem, exceeding its capacity to maintain their natural balance and resulting in their ending up in the soil, groundwater, surface water and seas, leading to ecosystem changes.

Source: Adapted from EEA, 2015a.

4.1.1 Habitat change

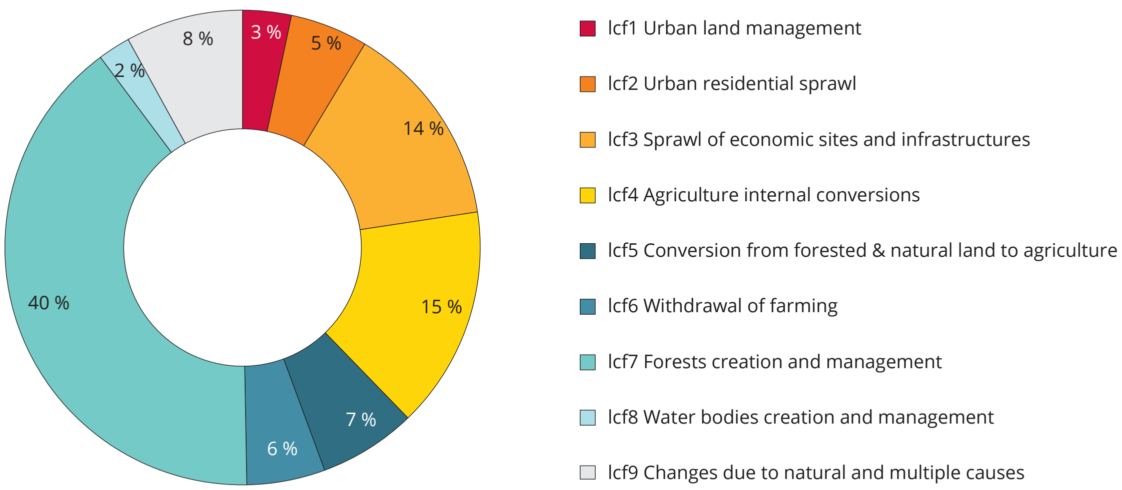
Habitat change is considered to be the primary threat to the survival of wildlife in Europe (ETC/SIA, 2014c). The main driver in terrestrial ecosystems is land use: roughly half of Europe's land area is farmed, most forests are exploited, and natural areas are increasingly fragmented by other land use, mainly urbanisation and infrastructure development (EEA, 2010d). Abandonment of cropland and pasture also drives habitat change in some areas, with both positive and negative effects on biodiversity. For marine and coastal ecosystems the main pressures are destructive fishing techniques mainly affecting sea-bed habitats and coastal development, and for freshwater ecosystems they are human modifications such as the creation of dams, channelling and diversion of rivers, and drainage and infilling of ponds.

Figure 4.1 shows the application of the operational Land and Ecosystem Accounts (LEAC) method (EEA, 2011a, EEA, 2012i) for the main drivers of terrestrial land use change from 2000 to 2006. A large part of the changes are due to forestry operations (felling and replanting/regrowth) and internal conversions in agriculture (especially pasture to arable land), but 22 % are due to urban and industrial development, 7 % to land conversion for agriculture and 6 % to abandonment of farmland, usually resulting in woodland creation.

Habitat change includes direct degradation of habitat elements or functions (e.g. soil erosion or water pollution), or loss of a habitat and its replacement by another habitat type (e.g. deforestation or land abandonment), both of which affect biodiversity (CBD, 2013). In addition, fragmentation by transport and energy infrastructure, urban sprawl or barriers in freshwater bodies changes habitat size. As habitats incorporate both biotic and abiotic features, habitat change includes changes to the natural area (terrestrial or aquatic), changes to plant and animal species and changes in the conditions present and necessary for their survival (EEA, 2015a). Destruction, fragmentation or degradation of habitats can increase the vulnerability of animal and plant populations to local extinction, as migration and dispersal is hampered, leading to biodiversity loss and further destabilisation of the ecosystem structure and function. Fragmented and isolated habitats are therefore less resilient to external pressures and may struggle to sustain the supply of ecosystem services.

Habitat change in terrestrial and freshwater ecosystems is closely linked to land use change and land take. Conflicting land use demands arise, for example, from the accelerating rate of urbanisation, increased mobility and growth of transport infrastructure, changing demographic and diet patterns, technological changes, market integration and climate change (EEA, 2015b, *Land systems*). Map 4.1 demonstrates the breadth of and geographical variation in the environmental challenges related to land use and some of the complexity of the multiple demands on land resources, with urban sprawl, agricultural intensification and irrigation exerting pressures on biodiversity and water resources. The map illustrates the concept of co-forcing, the combined impacts of two or more pressures affecting ecosystem condition and biodiversity.

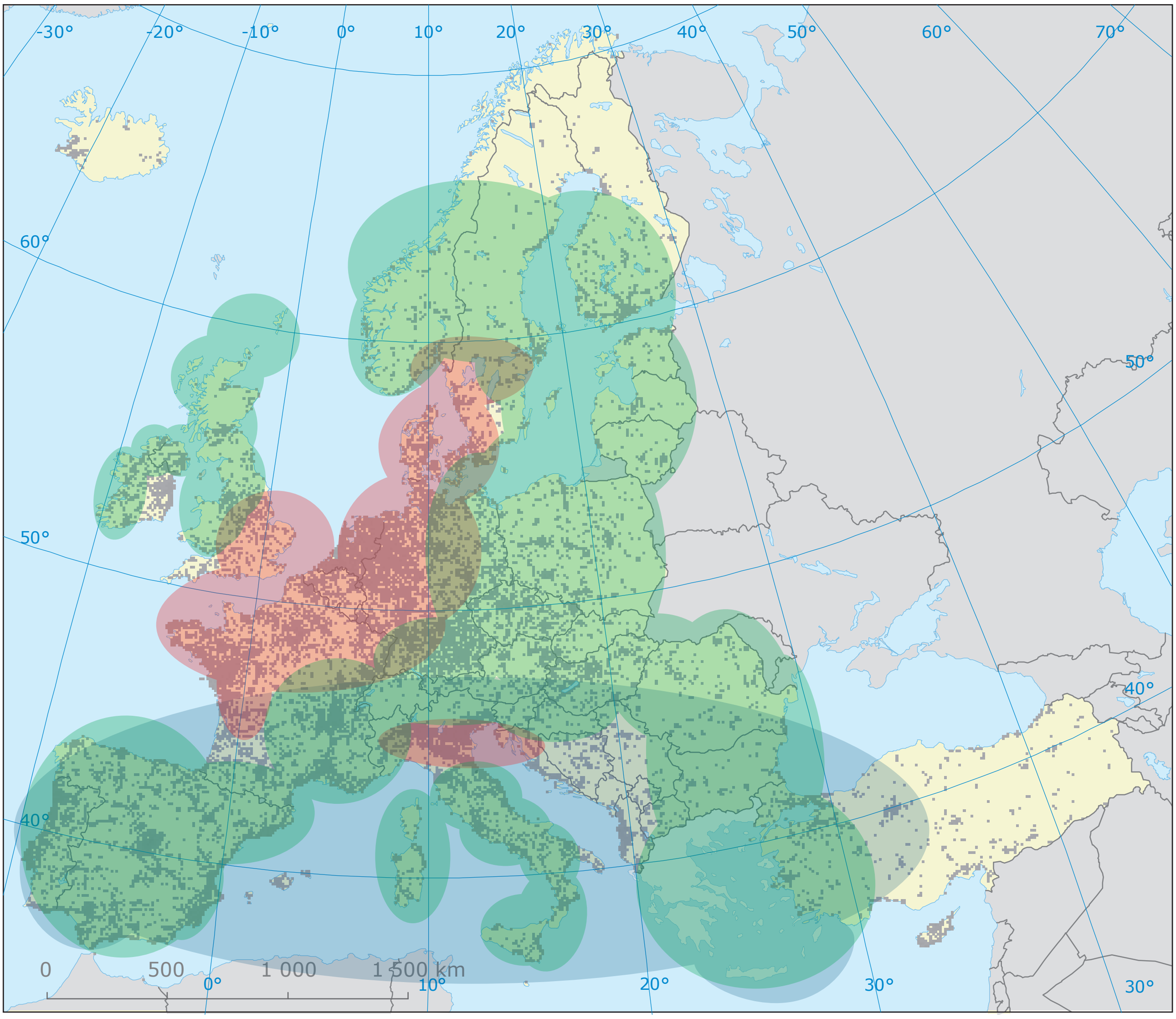
Figure 4.1 Main drivers of land use change 2000–2006, as land cover flows (lcfs)



Source: Analysis of CLC data 2000–2006 (http://www.eea.europa.eu/data-and-maps/data/corine-land-cover accessed 12 December 2015). Preliminary results from Corine 2006–2012 analysis indicate a general reduction in conversion for all land cover flows, with cropland still contributing most to urban land take.

Among these competing demands, land take for artificial areas and the built environment has seen the greatest increase, driven by increasing needs for housing, services and tourism, often combined with inefficient spatial planning (EEA, 2011c). CLC data reveal a 2.7 % increase in artificial areas between 2000 and 2006, and preliminary results for countries indicate that the in the period 2006–2012, the expansion in artificial surfaces has continued (e.g. urban sprawl, infrastructure) compared with the period 2000–2006, but the rate

Map 4.1 Indicative map of combined environmental challenges related to land use



Indicative map of combined environmental challenges related to land use

Marginal agricultural areas

Challenges: maintain on-field biodiversity, stimulate favourable practices, increase profitability without intensifying

Prime agricultural areas

Challenges: reduce pressures on air, soil and natural habitats, nature reserve approach to remaining high nature value agri patches

Main irrigated areas

Challenges: reduce water stress

Urbanising areas

Urban land take 2000–2006
Challenges: minimising and mitigating habitat loss and fragmentation

Outside coverage

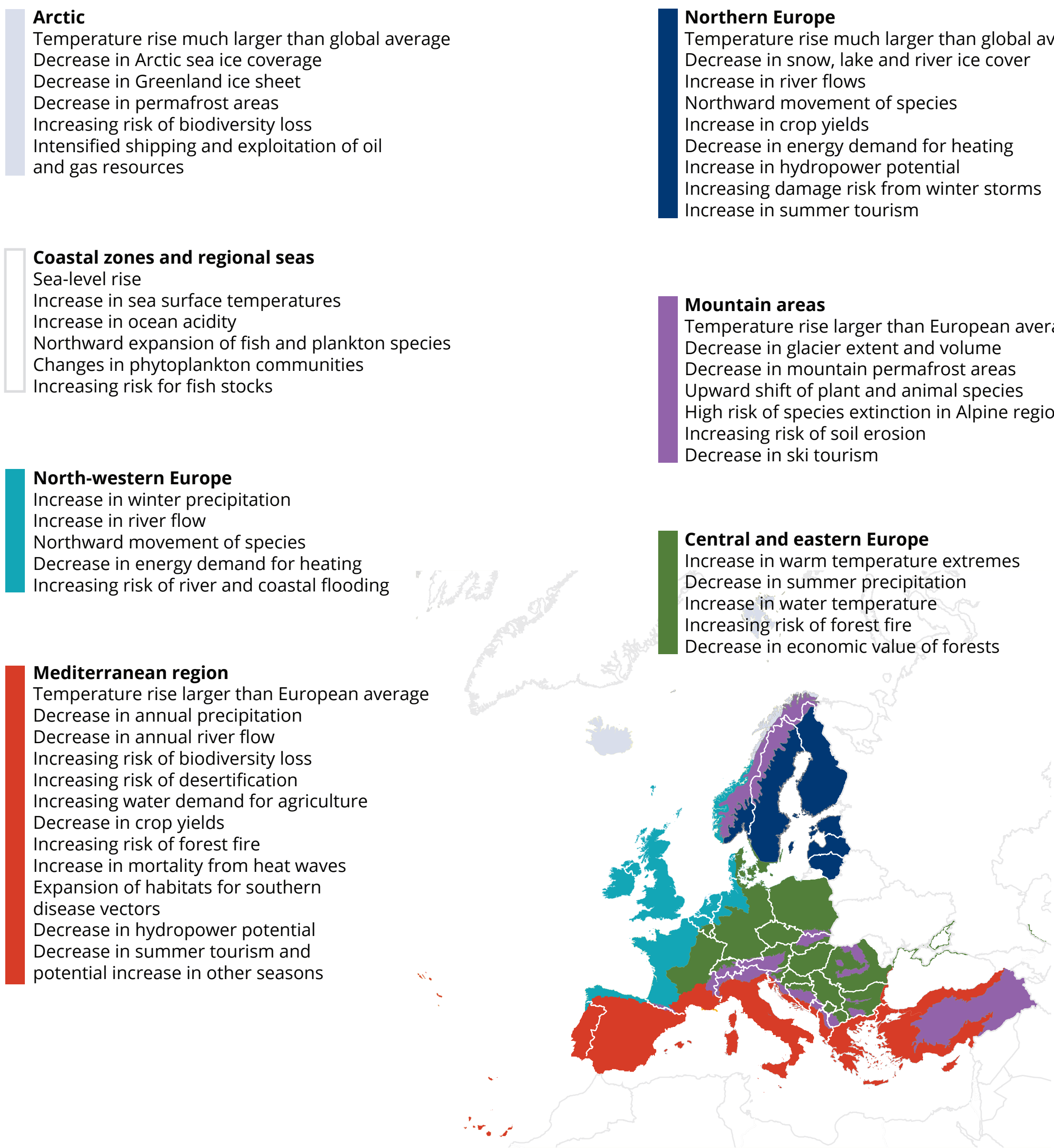
Source: EEA, 2013a.

of expansion may have decreased by approximately 20 %. Almost 46 % of all areas that changed to artificial surfaces were originally arable farmland and permanent crops, although some came from semi-natural vegetation, wetland and open spaces (land take indicator; EEA, 2015n), a trend which seems not to have changed significantly in the period 2006–2012 (see also EC, 2015a). It is important to note that land use changes are accompanied by trade-offs in ecosystem services — in the case of land take for artificial areas diminishing the supply of basic provisioning, as well as that of maintaining and regulating services such as food production, prevention of soil erosion and flood mitigation (EEA, 2015b, *Land systems*).

4.1.2 Climate change

Climatic changes observed over the past decades are becoming more extreme and widespread in their influence, while also having the potential to trigger chain reactions that severely impact human and natural systems (IPCC, 2014). Observed climate change include melting of ice and glaciers, rising sea levels, rising temperatures and changes in precipitation, all of which are projected to result in increased frequency of extreme events such as droughts, floods, storms and fires. These will have effects such as enhanced influx of pests, diseases and invasive alien species (Map 4.2). Some changes have already influenced, or

Map 4.2 Key observed and projected impacts from climate change for the main regions in Europe



Source: EEA, 2012b.

are projected to change, the life cycles of many plant and animal species in Europe, affecting migratory patterns or pushing species to the brink of extinction. Key climate change impacts on terrestrial ecosystems and biodiversity are listed below (EEA, 2012b).

- The timing of seasonal events in plants and animals is changing across Europe, and climate change is regarded as the main cause of these changes. Breeding seasons of thermophilic insects such as butterflies, dragonflies and bark beetles are lengthening, allowing for extra generations to be produced during the year, which can increase pressures on vegetation by insect calamities and present opportunities for invasive alien species to establish.

- Many European plant and animal species have shifted their distribution northwards and to higher altitudes in response to observed climate change.

- The rate of climate change is expected to exceed the ability of many species to adapt and migrate, especially where landscape fragmentation may restrict movement.

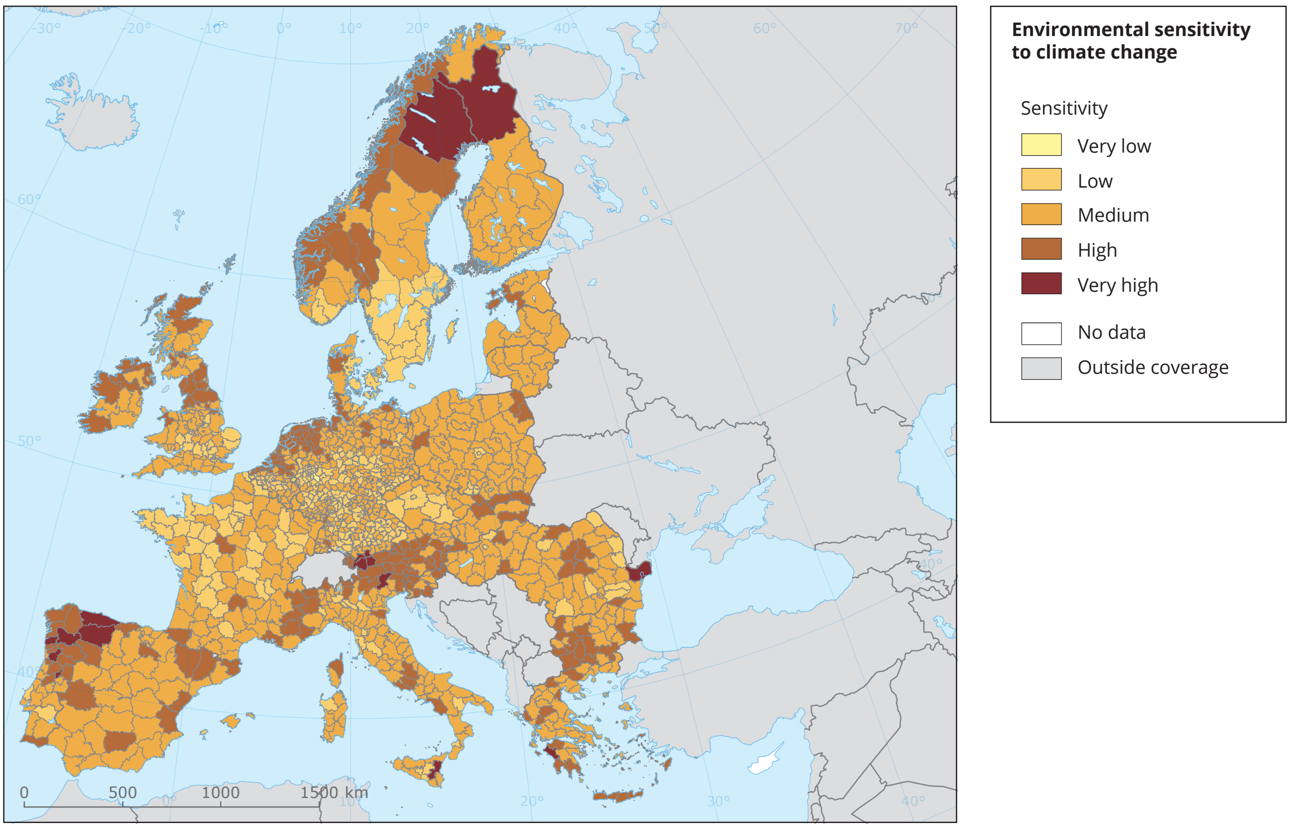
- Direct effects on single species are probably amplified by species interactions, such as disruption of present food webs.

- Almost one-fifth of habitats and 12 % of species of European interest are potentially threatened by climate change over their natural European range. Bogs, mires and fens and Arctic and Alpine ecosystems are considered to be the most vulnerable habitat types.

A wide range of climate change impact and vulnerability indicators have been developed. The ESPON Climate project (2011) developed a series of indicators using aggregated data, including the environmental sensitivity of European regions to climate change (see Map 4.3). This focuses on natural entities that are highly sensitive (such as protected natural areas or fire-prone forests), as well as relatively stable entities, such as soils, that underpin animal and plant ecosystems, yet have only limited capacities to adapt.

The direct use of climate data in ecosystem assessment is challenging, because it requires separate

Map 4.3 Environmental sensitivity to climate change



Source: ESPON Climate, 2011.

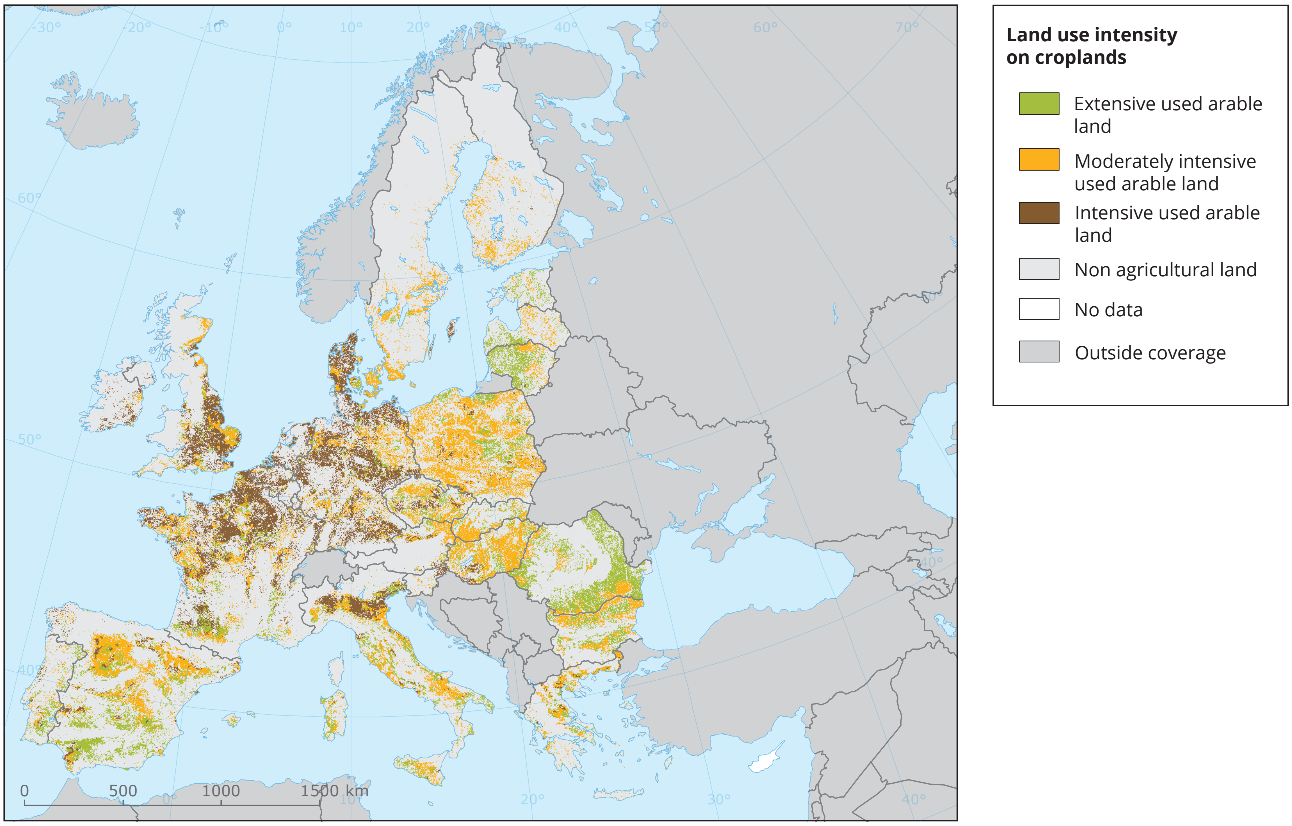
sensitivity analyses of habitats and biodiversity of different combinations of impacts (e.g. temperature, precipitation and humidity) for changes in both average and extreme events (EEA, 2012b).

4.1.3 Overexploitation

Overexploitation, through unsustainable use and management, continues to be a major threat to biodiversity (CBD, 2013) because of the increasing demand for resources, driven by population growth and increased consumption. In contrast to land take, which changes ecosystem type from one class to another, overexploitation does not change the ecosystem type but degrades its capacity to deliver services. In Europe, the land take for housing and infrastructure (see Section 4.1.1) has considerably reduced the amount of land available for agriculture and forestry, increasing the pressure on the remaining land and its ecosystems. In the mid- and long term, intensive land use or overexploitation can eventually reduce the productivity of the land and its ability to provide multiple functions and services, with significant impacts on quality of life (EEA, 2015a). This may occur, for example, when the harvesting rate exceeds the reproduction rate of flora and fauna. The key examples are intensive crop cultivation and biofuel production, intensive management with high fertiliser inputs and frequent harvesting or overgrazing of grasslands, overharvesting in forest ecosystems and overfishing in freshwater and marine ecosystems.

Information to assess the pressures on ecosystems resulting from human management activities is heterogeneous in terms of availability and quality (EEA, 2015a). Good information is available to address terrestrial ecosystems, especially agro-ecosystems and woodlands. Map 4.4 illustrates the land use intensity on croplands in Europe, derived from combined statistics on crop yield and nitrogen fertiliser application. Some information is available to assess the effects of overexploitation on biodiversity, such as species abundance (EEA, 2015a), but information on overfishing in Europe's seas is still scarce, as it is reported using different methods in different seas.

Map 4.4 Land use intensity on croplands derived from crop yields and nitrogen fertiliser application



Source: EEA, 2015a.

4.1.4 Invasive alien species

Invasive alien species are plants, animals, pathogens and other organisms that are not native to an ecosystem, and that may cause economic or environmental harm or adversely affect ecosystem functioning and human health. They are seen as one of the greatest threats to biodiversity and to the ecological and economic well-being of the planet (EEA, 2016c). Transported outside their natural past or present ranges as a result of human action, they 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.

Invasive alien species may drive local native species to extinction via competitive exclusion, niche displacement or hybridisation with related native species (EEA, 2015a). This may result in extensive changes in the structure, composition and global distribution of the biota of affected sites, leading ultimately to the homogenisation of the fauna and flora and the loss of ecosystem service capacity and biodiversity. All ecosystem types in Europe are affected and there is a wide variety of impacts (EEA, 2012h; EEA, 2015c).

On 1 January 2015 EU Regulation 1143/2014 (EC, 2014f) on invasive alien species entered into force. It seeks to address the problem of invasive alien species in a comprehensive manner so as to protect native biodiversity and ecosystem services, as well as to minimise and mitigate the impacts on human health or the economy that these species can have. The regulation envisages three types of interventions; prevention, early detection and rapid eradication, and management. The EU Biodiversity Strategy to 2020 also refers to the significant threat that invasive alien species pose to biodiversity, with Target 5 aiming to identify invasive alien species pathways, control or eradicate priority species, and manage pathways to prevent the introduction and establishment of new invasive alien species.

The SEBI on invasive alien species is based on the cumulative number of alien species established in Europe (EEA, 2010c, 2012c). For marine/estuarine waters, data from all European countries and non-European countries bordering Europe's seas are included (EEA, 2015c), and for terrestrial and freshwater ecosystems data are currently available for 11 European countries. The indicator shows the number of the most threatening invasive alien species per European country, and presents a first approximate estimate of their density. The information used to develop the indicator is still incomplete and gaps have to be filled to make the indicator feasible for monitoring invasive alien species. Data coverage will be expanded to cover more European countries in the near future.

Map 4.5 shows the predicted level of invasion of alien plant species in Europe. This was developed by Chytrý et al. (2009) based on the observed level of neophytes (alien plant species introduced from beginning of 16th century onwards in different habitats in the Czech Republic, Spain and the United Kingdom, and extrapolating this to CLC classes across Europe. The map projects high levels of invasion for lowland agricultural and urban habitats, mainly in the temperate zone of western and central Europe. More information will become available as a result of the recently established EU regulation (EC, 2014f).

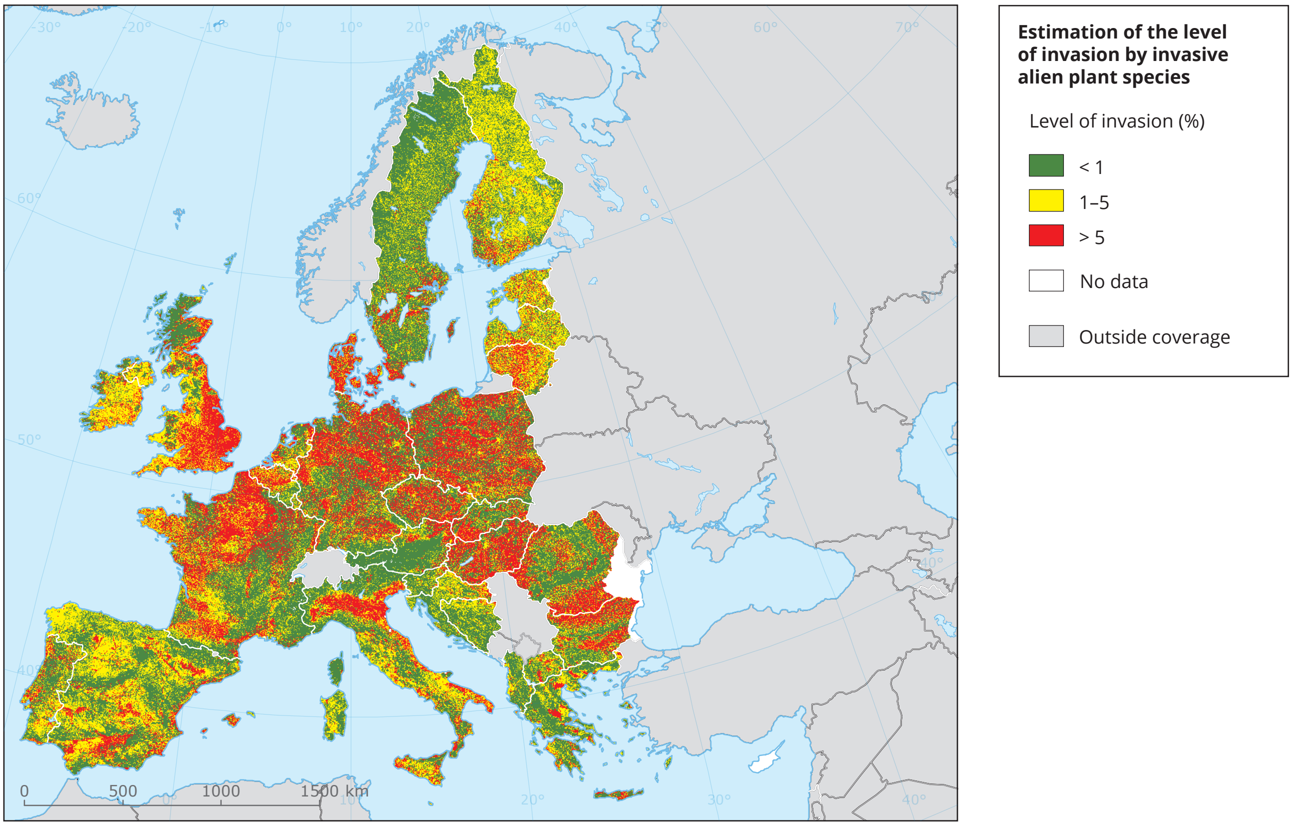
In addition, the EEA has developed two indicators on marine alien species. The first focuses on the trends in marine alien species (decadal cumulative numbers of marine alien species per Marine Strategy Framework Directive region from the 1950s to 2012; EEA, 2015o), and the second relates to the trends in pathways of marine alien species (total number of marine alien species per major pathway of primary introduction from the 1950s to 2012; EEA, 2015p).

The data come from an extensive review of all the available online databases (from research projects to international and national sources), as well as expert judgement based on these findings (see also European Alien Species Information Network, EASIN; JRC, 2015).

4.1.5 Pollution and nutrient enrichment

Pollution and nutrient enrichment occur when substances are introduced into an ecosystem in such quantities that they exceed the capacity of the ecosystem to maintain its natural balance. Nutrients, pesticides, microbes, industrial chemicals, metals and pharmaceutical products accumulate in the soil, or in ground and surface water, and pose a serious threat to ecosystem functioning and biodiversity and human health (EEA 2012c, EEA, 2015b). Driven by industrialisation, pollution is affecting all ecosystems through the degradation of soil, water and air quality. Sulphur and nitrogen compounds from fossil fuel combustion and nitrogen compounds from fertiliser use are a significant pressure. These are dispersed in the atmosphere or washed off farmland, and can travel large distances in air or water before their deposition damages the receiving environment through acidification or eutrophication of soil and water.

Map 4.5 **Estimation of the level of invasion by invasive alien plant species**



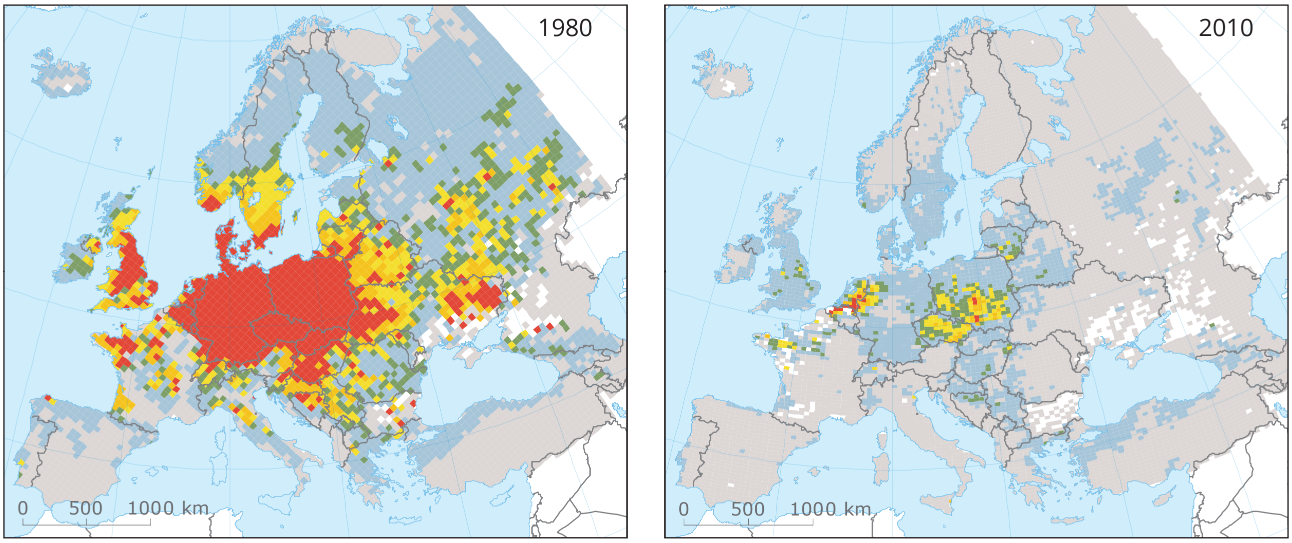
Source: Chytrý et al., 2009.

Impacts include severe declines in forest health and quality in central Europe in the 1970s, as a result of soil acidification, and devastating effects on fisheries from acidification of marine and freshwater ecosystems. Equally, nitrogen pollution can cause eutrophication in terrestrial, freshwater and marine ecosystems, resulting in excess plant (or algal) growth and increased species competition. This occurs because some species are adapted to low nitrogen availability while others thrive in high-nitrogen environments, thus outcompeting those less tolerant of high(er) nitrogen levels. As a result, eutrophication can alter the plant species composition and species richness in an ecosystem, and cause changes in biodiversity (Emmett et al., 2007). These changes may also affect the higher levels of the food chain. For example, in freshwater and marine ecosystems (e.g. small lakes, marine embayments and also major areas of the Baltic Sea), the increased plant growth and productivity (including algal blooms) can reduce oxygen levels and reduce fish survival (EEA, 2015c).

The concept of 'critical loads' is used to quantify environmental degradation. It indicates 'the upper limit of one or more pollutants, deposited to the earth's surface, that an ecosystem such as a lake or a forest can tolerate without being damaged in its function (as for example the nutrient nitrogen cycle) or its structure (as for example with respect to plant species richness)', (Nilsson and Grennfelt, 1988). As such, critical loads can be used for assessing the sensitivity of habitats to particular pollution pressures. The EEA's core set indicator, *Exposure of ecosystems to acidification, eutrophication and ozone*, was developed for this purpose (EEA, 2015e).

Maps 4.6 and 4.7 show the exceedance of nutrient critical loads for acidification and eutrophication, respectively, in 1980 and 2010. This shows how areas exceeding critical loads have decreased since the 1980s as emissions of sulphur dioxide and nitrogen oxides have fallen, mainly in response to international control measures, mainly the 1979 Geneva Convention on Long-range Transboundary Air Pollution (EC, 1981), the EU National Emission Ceilings Directive (EC, 2001), and the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (EC, 2003).

Map 4.6 Exceedance of critical loads of acidification in 1980 and 2010



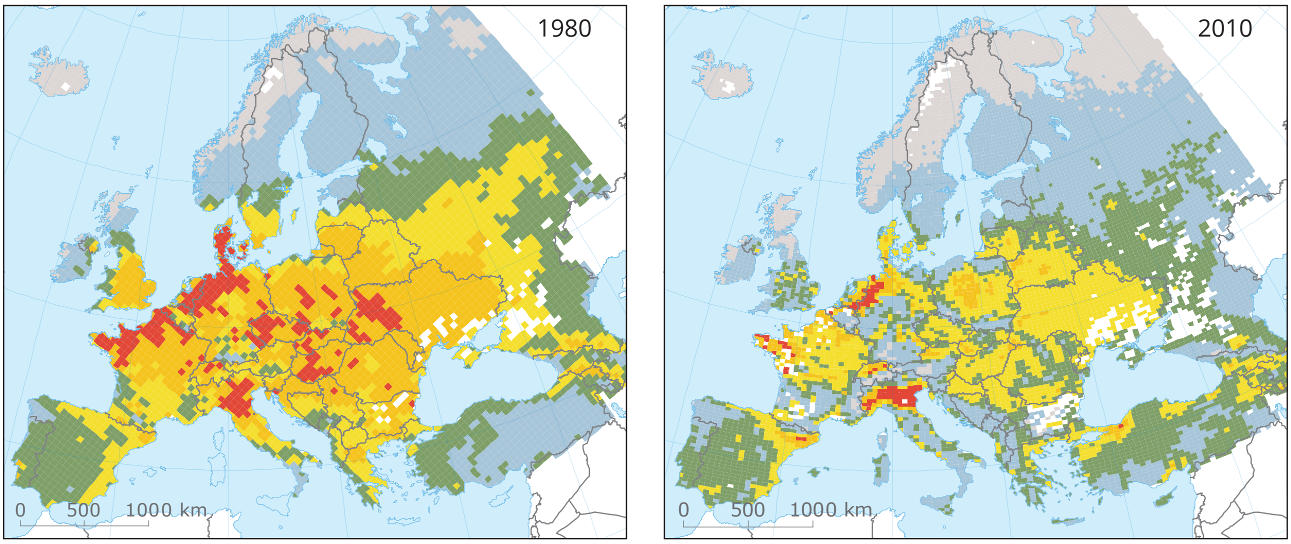
Exceedance of critical loads of acidification

Average accumulated exceedance of the critical loads for acidification (in equivalents (H+ ions) = (mol $_{charge}$) per hectare and year)

No exeedance | < 200 | 200–400 | 400–700 | 700–1 200 | > 1 200 | No data

Source: EEA, 2015e.

Map 4.7 Exceedance of nutrient critical loads for eutrophication due to the deposition of nitrogen in 1980 and 2010



Exceedance of nutrient critical loads for eutrophication

Average accumulated exceedance of the critical loads for eutrophication (in equivalents = mol nitrogen per hectare and year)

No exeedance | < 200 | 200–400 | 400–700 | 700–1 200 | > 1 200 | No data

Source: EEA, 2015e.

Nitrogen emissions (including ammonia emissions from farmland) have replaced sulphur dioxide as the main cause of acidification in most parts of Europe (Map 4.6). While pollution control measures have also significantly decreased nitrogen loads, eutrophication still remains critical in regions across Europe (Map 4.7). Member States report nitrogen pollution to be the main pollution pressure affecting the habitats covered by the EU Habitats Directive (see Section 4.2), affecting 78 % of the wetland habitats and 50–60 % of other terrestrial habitats covered by the directive (EEA, 2015d). The adoption of nutrient management plans and environmental farm plans has also had an important role in dealing with nutrient overload since the 1980s. The implementation of the Nitrates Directive (EC, 1991a) and the introduction of set-aside measures had stabilised pollution from nutrients and pesticides, although set-aside measures have been abandoned as an EU policy instrument (EEA, 2010c, 2015b). Nevertheless, the CAP reform has introduced new 'greening measures', and has tied subsidies to stricter cross-compliance with environmental legislation, but the effects of these measures are not yet known (EEA, 2015b).

Heavy metal pollution has also been decreasing in recent years, with good progress being made in most European countries. Although it is not further explored in this report, as it is mainly linked to impacts on human health rather than environmental ones, although the impacts of heavy metal pollution might be detrimental to the wider environment too. It is worth noting that a combination of targeted legislation, coupled with improved controls and abatement techniques, has led to cadmium and mercury emissions decreasing to one-third, and lead emissions falling to approximately one-tenth, of their corresponding total emissions in 1990 (EEA, 2015q).

4.2 Condition of ecosystems

The evaluation and mapping of the pressures acting on ecosystems can be complemented with direct assessments of ecosystem condition based on indicators such as soil and water quality and on the distribution and conservation status of and trends in species and habitats. These indicators illustrate the cumulative effect of pressures on ecosystems over time. This section discusses data availability and then the methodology for assessing ecosystem condition.

4.2.1 Data availability

Reporting obligations on countries under certain EU directives are an important source of information for European ecosystem assessment. These include the 1979 Birds Directive, the 1992 Habitats Directive, the 2000 Water Framework Directive and the 2008 Marine Strategy Framework Directive. Other sources include satellite and in-situ sensor data from the Copernicus earth observation programme ([1]).

Birds and Habitats Directives

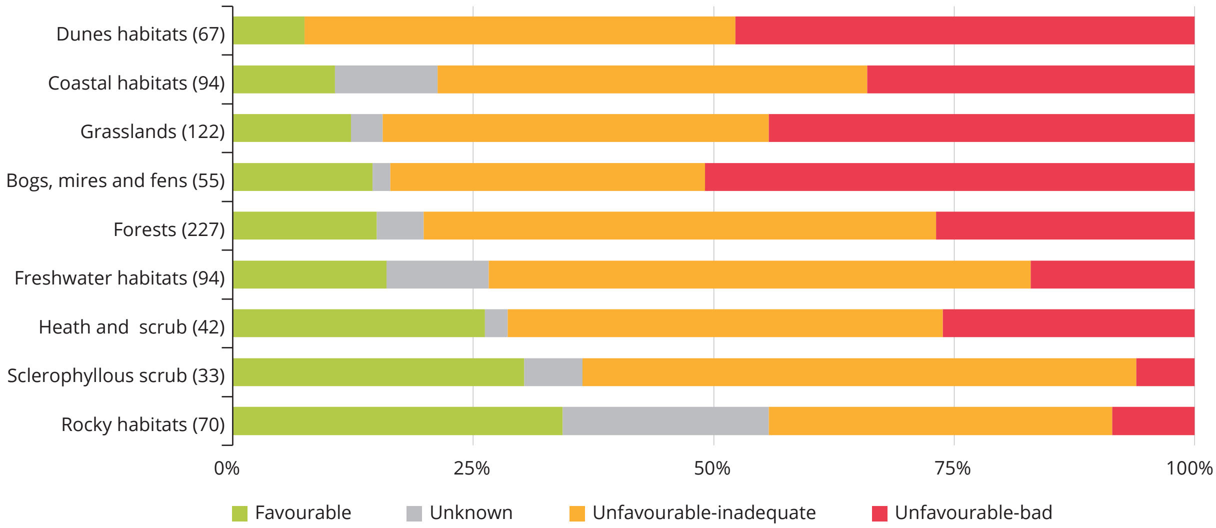
The EU Birds Directive (EC, 2009) and Habitats Directive (EC, 1992), known collectively as the Nature Directives, provide key inputs to estimating the overall current condition of ecosystems and the trend in ecosystem condition. Member States report on species and habitats every 6 years under Article 12 of the Birds Directive and Article 17 of the Habitats Directive, with the data being processed by the EEA and the European Topic Centre on Biodiversity (ETC/BD).

The Habitats Directive reports on around 1 250 species and 233 habitats of European interest that are considered to be most at risk, so it does not provide a comprehensive overview for all ecosystems. Separate reports are produced for each biogeographical ([2]) or marine region in which the species or habitat occurs, including estimates of population size or habitat area (with GIS maps of habitat and species distribution), conservation status (favourable, unfavourable-inadequate, unfavourable-bad or unknown), and trend in conservation status for the unfavourable assessments (stable, improving, declining or unknown) ([3]). Member States first reported on conservation status under the Habitats Directive in 2007 (for the period 2001–2006). The second report was in 2013 (for the period 2007–2012) and showed that the conservation status of 77 % of EU habitats of interest is unfavourable (Figure 4.2) (EEA, 2015d). However, changes in the reporting of Member States affect the way data is collected and expressed, so it is not always possible to use it to monitor changes in biodiversity over time. In addition, incomplete coverage in reporting exacerbates assessments across Europe.

For the Birds Directive, Member States report the size and trends of populations of all wild bird species. Member States do not report conservation status for these bird species, but a consortium led by Birdlife International was commissioned by the European

([1]) The European Copernicus programme was previously known as Global Monitoring for Environment and Security (GMES).
([2]) Biogeographical regions are shown in Map 3.2.
([3]) See page 40 of EEA, 2015d, for definitions of terms.

Figure 4.2 Conservation status of EU habitats (2007–2012)



Source: EEA, 2015d.

Commission to provide these European population status assessments for the period 2008–2012. For both directives, Member States also report on the main current pressures and future threats to species and habitats, although reporting practices differ between Member States. The information for 2008–2012 is summarised in the *State of nature in the EU* (EEA, 2015d). The next reporting period is 2013–2018.

It is important to consider the way the data are generated in the Member States and how the data are processed and aggregated. The EEA and the ETC/BD have produced several reports on these issues (ETC/BD, 2013 ([4])). For the use of data in a European ecosystem assessment, the EEA has produced a database on the linkages between the species and habitats covered by the Habitats Directive and the broad ecosystem types recognised under MAES (ETC/BD, 2014b).

Complementary data sources on biodiversity include the International Union for Conservation of Nature and Natural Resources (IUCN) European Red List of Threatened Species (IUCN, 2011a–d), as well as the global Birds data sets (Birdlife International, 2004). Both data sources provide species distribution maps.

Water Framework Directive

The Water Framework Directive (WFD) (EC, 2000) aims to achieve good chemical and ecological status for all water bodies by 2015. It requires Member States to produce river basin management plans (RBMPs), to assess the current status of water bodies and the pressures on them, and set out measures to protect and improve the water environment. The first 160 RBMPs were released in 2010, and the information in them, together with other water related data sets and indicators, is available through the Water Information System for Europe (WISE) online platform. An analysis of the data, containing regional harmonised information, is presented in the EEA report *European waters — assessment of status and pressures* (EEA, 2012c).

The RBMPs provide a significant amount of data, but the quality is mixed. Many water bodies have been classified without actual monitoring of biological or chemical pollutants, but by using expert judgement partly based on the information compiled in the pressure and impact analyses. Comparison between countries and between river basins is limited by differences in the methodology and data quality. The knowledge base will be updated and improved using the second set of RBMPs, which will be finalised by Member States during 2015, and will illustrate progress in reducing pressures.

Marine Strategy Framework Directive

Member States report on the physical and ecological status of their marine environment under the Marine Strategy Framework Directive (EC, 2008a), which aims

([4]) MAES Nature pilot documents at: http://forum.eionet.europa.eu/x_habitat-art17report/library/papers-maes-pilot-nature, accessed 12 December 2015.

to achieve 'good environmental status' (GES) for all marine waters by 2020. GES is defined as providing 'ecologically diverse and dynamic oceans and seas which are clean, healthy and productive', and it is based on 11 descriptors including biodiversity (species and habitats), non-indigenous species, commercial fish stocks, marine food webs, eutrophication, sea-floor integrity, hydrographic conditions, pollution, contaminants in seafood, marine litter and underwater noise. Initial assessments were generated in 2012, and a full review is due in 2018. Although the initial assessments were very limited, with reporting covering only a few of the descriptors and with 80 % of marine species and habitats and 100 % of marine ecosystems being classed as 'unknown' status, there was still a certain amount of comparable information and this was used to produce a baseline assessment on the pressures on and state of Europe's seas (EEA, 2015c).

The four Regional Seas Conventions are developing indicators to support the Marine Strategy Framework Directive, but current indicators cover only eutrophication and contaminants for the Baltic (HELCOM, the Baltic Marine Environment Commission, also known as the Helsinki Commission) and North-East Atlantic Ocean (OSPAR, Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic) regions and marine mammals for HELCOM (EEA, 2015c). Eventually all these data sets and indicators will be shared with the wider marine community via the WISE-Marine web-based portal, which is the marine component of WISE.

Assessing ecosystem condition from remote sensing of vegetation productivity

New methods are being developed for directly assessing the condition of ecosystems using satellite observations of vegetation cover. These can be used to derive indicators of vegetation productivity (the amount of biomass produced each year) and phenology (the timing of seasonal changes in ecosystems, such as the start and end of the growing season), as shown in Box 4.1. Trends, anomalies and inter-annual variations in these indicators can be used to assess ecosystem responses to climate and biogeochemical cycles (Myneni et al., 1997; Schwartz and Reed, 1999; Menzel, 2000; Nemani et al., 2003), disturbances such as fires, climate-related pressures such as drought, and human activities (Wessels et al., 2007, 2010; Ivits et al., 2013a, 2013b). The productivity and phenology metrics may indicate the condition of an ecosystem and its ability to deliver certain ecosystem services such as carbon storage or habitats for species. Thus these metrics could enhance the understanding of the impact of combined environmental and human pressures on ecosystem condition and could help to identify whether ecosystems are resilient or vulnerable.

Changes in vegetation phenology such as the length of the growing season are also useful as indicators because they are easily understood by policymakers and non-technical audiences. Furthermore, they offer quantitative, up-to-date, robust, reliable and harmonised spatially explicit information on ecosystem condition over long time scales and with continuous spatial coverage.

Box 4.1 Ecosystem condition indices derived from earth observation

Growing plants absorb visible light for photosynthesis but reflect infra-red radiation to avoid overheating. The difference between reflectance of visible light and infra-red radiation can be detected by remote sensing and used to derive indicators such as the Normalised Difference Vegetation Index or NDVI, which is correlated to photosynthetic activity in the plant canopy and can be used to derive other indicators such as plant productivity, biomass and leaf area.

Phenology and productivity indices can be derived from regularly spaced (e.g. decadal or monthly) time-series data of vegetation indices such as the NDVI. Most vegetation cover follows a phenological cycle during the growing season, i.e. greening up, reaching a peak and senescence (ageing), and these changes will be apparent from NDVI values. Integrating the NDVI over the whole vegetation growth cycle then indicates vegetation productivity. Perennial vegetation cover, such as permanent grasslands, displays a weaker form of this cycle, and other ecosystems may display several phenological cycles or no cycle. The table below summarises the time-series data that are freely available for monitoring vegetation phenology.

Sensor name	Spatial resolution	Temporal scale	Coverage
GIMMS3g AVHRR	8 km	1982–2013	Global
SPOT VEGETATION	1 km	1999–2014	Global
PROBA-V	1 km and 300 m	Replaces SPOT VEGETATION	Global

4.2.2 Methodology

The available data on the status of habitats and species from the Habitats and Birds Directives provides information on habitat quality that can be used to map the condition of ecosystems using a cross-walk table to link species to their preferred habitat types and to the ecosystems where the different habitats occur. This is relatively simple for terrestrial habitats, where 94 % can be allocated to a single ecosystem, but is more complicated for species, as only 25 % of mammal species and 13 % of bird species can be allocated to a single ecosystem (EEA, 2015d), since species require more than one ecosystem type for feeding and reproduction or they are migratory species. Nevertheless, the EEA has developed a cross-walk table (ETC/BD, 2014b; ETC/ICM, 2015a) and this has been used to map the conservation status of species and habitats for the ecosystems assessed in Chapter 5. The habitat quality indicates condition for species but not necessarily for other ecosystem functions.

Assessment can also make use of ecosystem-specific indicators for pressures that may affect ecosystem condition, such as livestock density, mineral fertiliser use, forest fragmentation, fish harvesting and soil sealing. Forthcoming EEA reports on forest and urban ecosystem assessments will provide complementary information (EEA, 2015a). Indicators are also being implemented for specific coastal and marine situations (EEA, 2015c), although other researchers are working on this using different data and approaches (e.g. Rappot and Hilden, 2013; Tang et al., 2015).

It should be noted that indicators for the 'health' of an ecosystem may be determined based on a range of different criteria that do not always fully address the multifunctionality of ecosystems, especially when considered in isolation. For terrestrial ecosystems, most of the condition indicators are targeted to biodiversity by either directly referring to habitat quality and biodiversity, as described in Section 4.2.1, or, as in the case of forest and woodlands, describing habitat quality by addressing the structural components of ecosystems such as age class distribution or amount of dead wood. Information about the physico-chemical conditions of the terrestrial ecosystems is often lacking, but it is indicated by the presence and absence of certain species, which then can be linked to the respective pressures and their change over time. The chemical conditions of freshwater and marine ecosystems and the physical conditions of river- and seabeds are also important indicators for habitat quality and biodiversity and also address other important ecosystem functions, for example carbon sequestration.

4.3 Knowledge gaps and next steps

Sections 4.1 and 4.2 showed how ecosystem condition can be assessed by mapping the pressures on ecosystems and by using available data on the status of habitats, species and environmental quality to show how these pressures have affected ecosystem condition. This information can be very useful to policymakers, for example by helping them to identify areas where high anthropogenic pressure coincides with vulnerable ecosystems, and demonstrating the cumulative impact of pressures on the conservation status of species and habitats. However, the next steps that would be required for a full ecosystem assessment are currently constrained by lack of accurate, detailed and comparable information across countries. These steps are:

1. mapping and assessing the cumulative effect of multiple pressures;
2. detailed spatial mapping of condition indicators;
3. assessment of the impact of condition on biodiversity and ecosystem service delivery;
4. mapping supply and, especially, demand of ecosystem services.

This section considers the current progress and knowledge gaps for each of these steps and discusses options for extending the assessment as more information becomes available.

4.3.1 Mapping and assessing multiple pressures

Pressures can interact with each other (ECNC, 2013). For example, land take for intensive agriculture can result in greater use of fertilisers and pesticides, leading to pollution of freshwater ecosystems. Similarly climate change could increase the spread of invasive alien species or the growth of algal blooms in response to nitrogen pollution. Climate change impacts such as droughts and heatwaves could affect the health of certain species, making them more vulnerable to the effects of pollution or invasive alien species and pests, and similarly pollution or pests could make species more vulnerable to the impacts of climate change. Overexploitation can reduce species populations to critically low levels, at which further pressure from pollution, climate change or invasive alien species could force local extinction. The combined effect of multiple pressures can therefore be greater than the sum of the separate effects, and can push the ecosystem beyond a threshold or tipping point at which losses become severe or irreversible. Spatially explicit information about cumulative pressures and how these affect ecosystem functioning is crucial for decision-making to secure the sustainability of our natural resources.

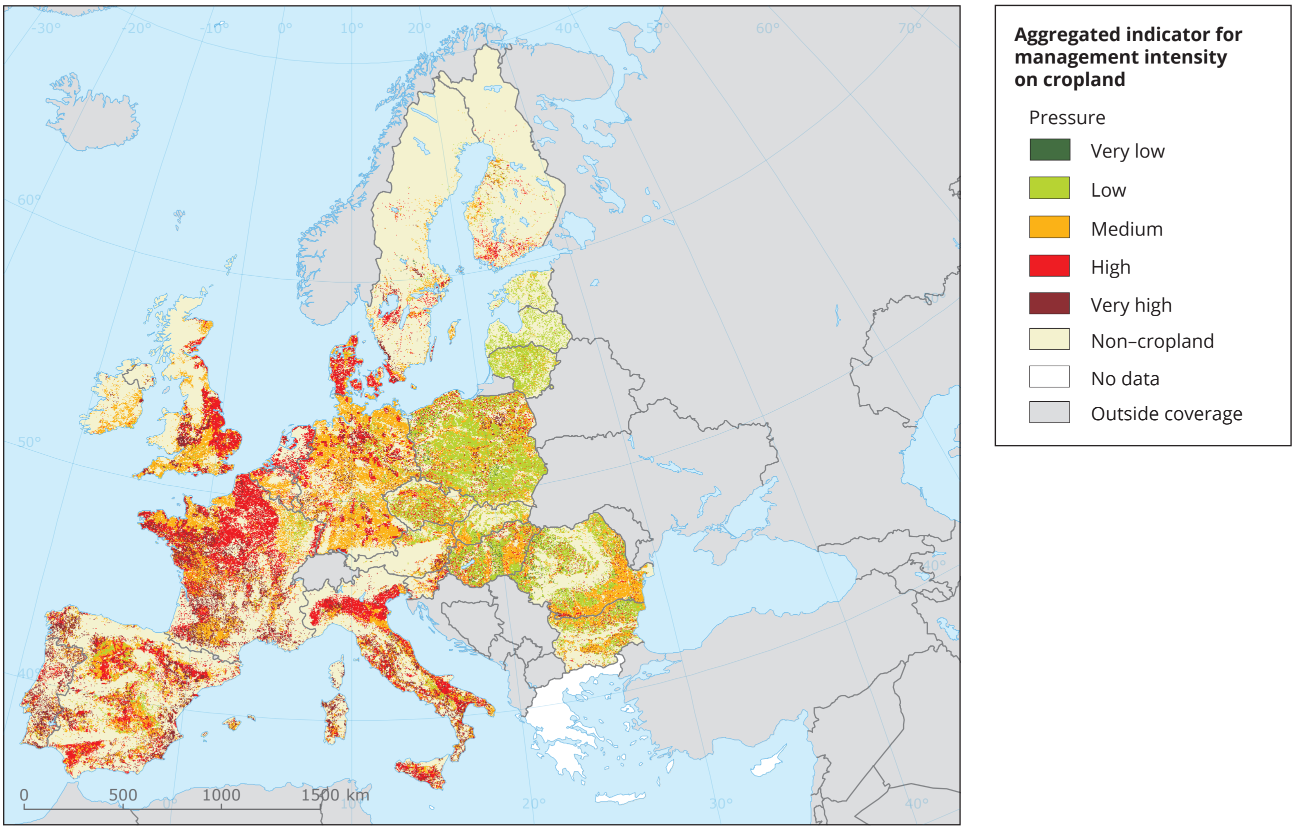
Where pressures are in the same units, they can be added together, such as in the case of nitrogen input from different sources (air pollution, manure from grazing livestock and fertiliser application; see e.g. Map 5.8). However, in most cases multiple pressures can be assessed only by the use of composite indicators, whereby each pressure is normalised on a scale of 0–1 and then weighted and summed. The weighting usually relies on expert opinion, as quantitative data on relative impacts is not available. An example has been developed to indicate the impact of multiple pressures on cropland, based on fertiliser application, crop diversity, irrigation and crop yield (Map 4.8).

4.3.2 Spatial mapping of condition

Mapping of ecosystem condition across Europe requires information that is uniform across national borders, accurate and at the right level of spatial detail. The information on habitat and species condition discussed in Section 4.2 does not always meet these criteria. Map 4.9 illustrates these problems, using the proportion of habitats or species assessed as 'favourable' as an example. This is based on Member State reports under the Habitats Directive: both the conservation status and the GIS files showing the distribution of the species and habitats of interest. The data were collected on a coarse grid (10 km × 10 km), and the maps reveal data gaps for some countries and sudden changes between adjacent countries that may be due more to the methodological approach than to genuine differences in biodiversity. Furthermore, the conservation status is the average for the Member States and the whole biogeographical regions, and it does not illustrate the actual status of each grid cell (see bottom part of figure).

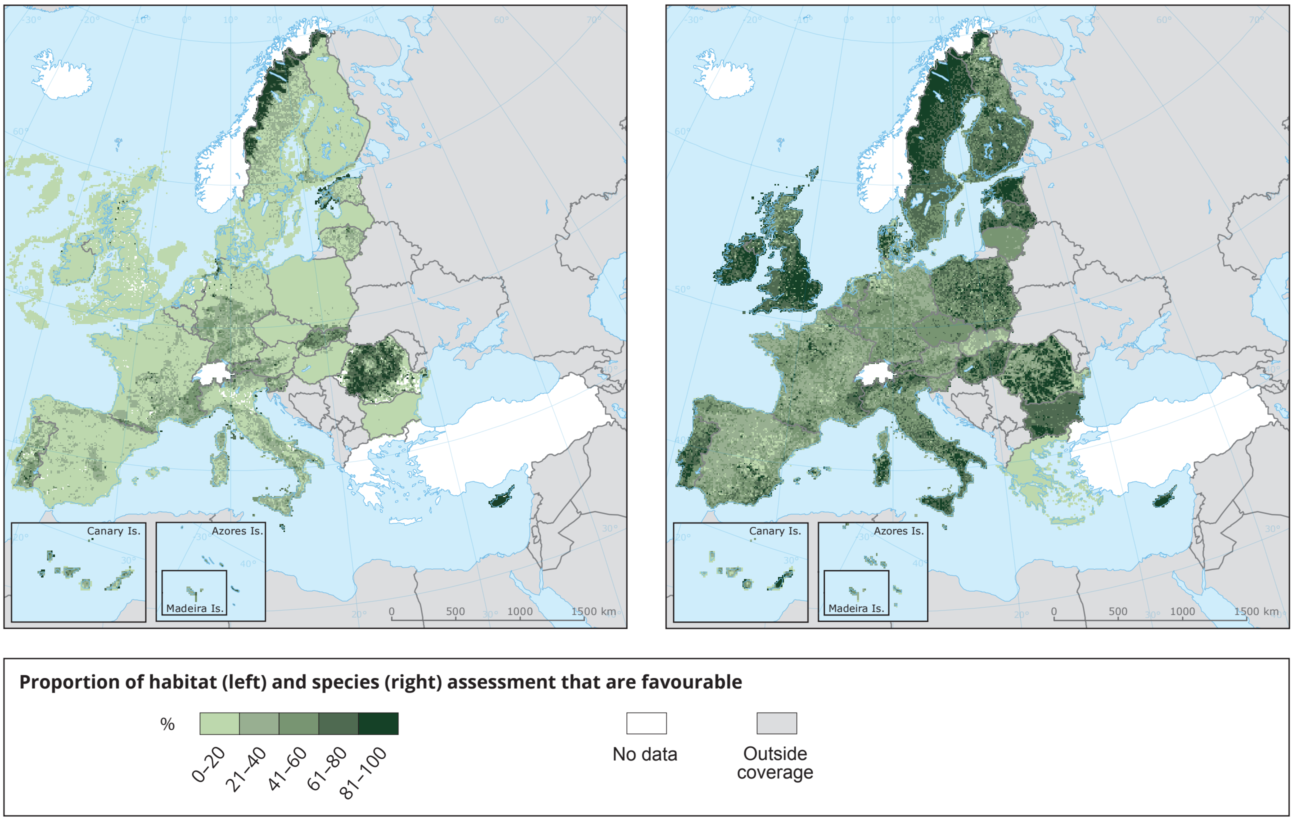
A few examples of condition maps have been produced based on biophysical information and other data sources, including Maps 4.6 and 4.7, which show exceedance of critical loads for acidification and eutrophication. It is also possible to use maps of combined pressures as a proxy for ecosystem condition, although this does not take account of actual

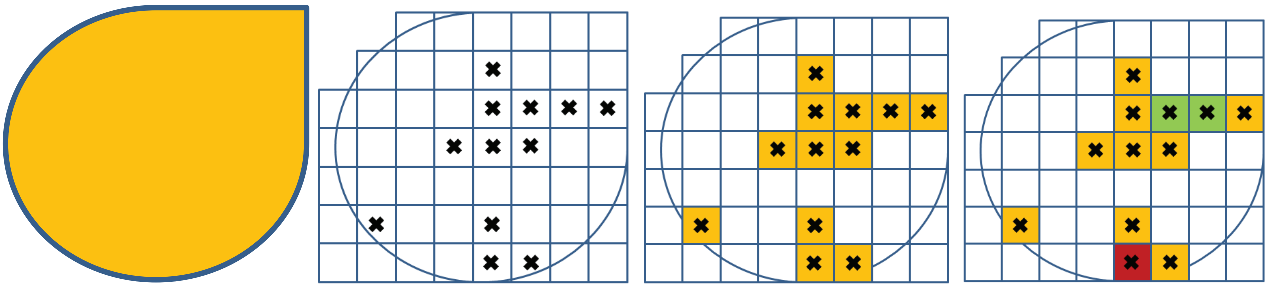
Map 4.8 Aggregated indicator for management intensity on cropland as combination of land management and crop yield



Source: EEA, 2015a.

Map 4.9 **Proportion of habitat (left) and species (right) assessments that are favourable, for 10 km × 10 km grid cells (top) showing problems with lack of spatial detail (bottom)**





a) Biographic Conservation Status (CS) assessment of species A

b) Distribution of species A in that region

c) Downscaling artificiallly biographic CS to species A distribution grids

d) Possible reality of the CS of species A in the region

Source: EEA, 2015d, based on Article 17 reporting under the Habitats Directive and ETC/BD, 2013.

condition, or of the possibility of time lags between the application of the pressure and the response of the ecosystem because of its the buffering capacity. Map 5.9 (cropland condition) uses this 'combined pressure' approach but also incorporates some actual condition data based on the presence of indicator species (species whose presence indicates good environmental condition).

The use of remote sensing techniques and earth observation technology for biodiversity monitoring provides strong tools to account for ecosystem loss, and it may help to address some of the gaps in spatial data on ecosystem condition. In particular, the Copernicus programme (Copernicus, 2015 ([5])) recently provided updated CLC data for 2012 with a resolution of 100 m × 100 m (still not fully validated).

([5]) An overview of land- and freshwater-related data is available on the Copernicus land services website: http://land.copernicus.eu, accessed 12 December 2015.

This will be supplemented by five high-resolution layers that are produced from 20 m resolution satellite imagery (aggregated into 100 m × 100 m grid cells for final products) through a combination of automatic processing and interactive rule-based classification. These layers can be used to improve the spatial definition of sealed soil (imperviousness), tree cover density and forest type, permanent grasslands, wetlands and water bodies. Additionally very high-resolution layers for urban areas (Urban Atlas) and riparian zones will provide detailed information about land cover and land use in sensitive areas of Europe at 2.5 m × 2.5 m spatial resolution.

4.3.3 Assessing impact of condition on biodiversity and ecosystem service delivery

There is a lack of detailed information on how ecosystem condition affects ecosystem service delivery. The delivery of ecosystem services depends on different combinations of processes, traits and structures that are supported by biodiversity (de Groot et al., 2010; Maes et al., 2013), but there are few quantitative data to model how these processes and traits are affected by pressures such as pollution or climate change. However, ongoing EU-funded research programmes including BESAFE (BESAFE, 2015), OpenNESS (OPENNESS, 2015), OPERAs (OPERAS, 2015) and ESMERALDA (ESMERALDA, 2015) are starting to provide more information in these areas (e.g. Menzel et al., 2013; see also Harrison et al., 2014, for a review of links between biodiversity and ecosystem services).

4.3.4 Mapping supply and demand of ecosystem services

Although there is a lack of quantitative data linking ecosystem condition to the potential capacity of ecosystems to deliver services, ecosystem service supply has been mapped using various methods. These include mapping indicators such as carbon storage capacity, crop yield or soil water infiltration (Layke et al., 2012); using expert opinion on the ability of different land cover types to deliver specific services; or using process-based models (see Science for Environment Policy, 2015, for an overview). Indicators of ecosystem service supply are being further developed (e.g. Burkhard et al., 2012; Haines-Young et al., 2012; Maes et al., 2014) and can form part of the process of natural capital accounting (see Chapter 7). Their application will form the next stage of the EEA's work in support of the MAES process in cooperation with the JRC. However, they are not yet widely available for all ecosystems across Europe.

4.3.5 Summary of knowledge and data gaps

ETC/SIA has evaluated the availability of data sets and indicators (ETC/SIA, 2013a) and methodology (ETC/SIA, 2014c), and some of this information was integrated into the second MAES report (Maes et al., 2014). The EEA report *European ecosystem assessment: concept, data, and implementation* provides further details on the main data sets and indicators for mapping and assessing both natural and human-induced ecosystem conditions and trends (EEA, 2015a). All these suggest the need for further clarification and research into the assessment of ecosystem condition, as most countries reported that there is very limited information. The key gaps are given in Box 4.2.

Work is ongoing to address these issues, and improvements are expected owing to the forthcoming availability of higher resolution satellite data (see Section 4.3.2) and improvements in the quality and consistency of data from EU directives.

Work is also being undertaken, as part of the EU BON project (EU-BON, 2015), on the gaps between the biodiversity objectives stated in global and European policy instruments, the indicators used to develop the related policy reports and the data that are actually available to quantify indicators and proxies, using the essential biodiversity variables (EBVs) framework for detecting biodiversity change (Pereira et al., 2013). The study included how reporting requirements of the EU Birds, Habitats, Water Framework and Marine Strategy Framework Directives could contribute to essential biodiversity variable classes, such as species populations, species traits, community composition, ecosystem function and ecosystem structure (Geijzendorffer et al., 2015).

Box 4.2 Key gaps for mapping and assessing ecosystem condition

Knowledge gaps

- Functional relationships between pressures and ecosystem condition (habitat quality and biodiversity).
- Functional relationships between ecosystem condition and ecosystem service supply.
- How to map combined pressures and their impact on ecosystem condition and service supply.
- Whether comparing EUNIS species presence/absence data with observed biodiversity information e.g. European Vegetation Survey (EVS) data could provide additional information about ecosystem condition for terrestrial ecosystems.

Data gaps

- Gaps in the European data sets on the state, trends and spatial distribution of species (e.g. Nature Directives), for example only non-bird species and habitats of 'conservation interest' are covered; there are missing data for some countries (including all non-EU countries); 26 % of terrestrial and 50 % of marine species are reported as unknown conservation status under the Habitats Directive; and the status of 13 % of terrestrial habitats, 80 % of marine biodiversity assessments and 100 % of ecosystem assessments under the Marine Strategy Framework Directive Initial Assessment is unknown (EEA, 2015c).
- Inconsistent quality and comparability of available data sets and indicators across Europe, with challenges related to monitoring, for example the proportion of habitats reported as favourable varies from 4 to 95 %.
- Poor availability of indicators for the impacts of some of the pressures on biodiversity, such as pollution, climate change and invasive alien species.
- Lack of coverage of features too small to be detected by satellite land cover mapping, for example green and blue linear features (hedgerows, streams).
- Lack of time series data due to infrequent (6-yearly) reporting of CLC data, EU Nature Directives, the Water Framework Directive and the Marine Strategy Framework Directive.
- Lack of quantitative data for meeting the targets of the EU Biodiversity Strategy to 2020 especially the No Net Loss and Restoration Prioritization Framework.

Source: Based on information in EEA, 2015a, 2015c, 2015d, and ETC/SIA, 2013a.

5 Short assessments of the main ecosystem types

This chapter presents assessments of the main ecosystem types in Europe. The available data did not permit a full assessment for each of the 12 ecosystem types identified in Chapter 3 (Table 3.1), so these have been aggregated into eight broad classes by reporting on heathland and shrub in the same chapter as sparsely vegetated land and combining the four marine ecosystems into a single group resulting in the following classifications:

- urban ecosystems
- cropland ecosystems
- grassland ecosystems
- woodland and forest ecosystems
- heathland, shrub and sparsely vegetated land ecosystems
- wetland ecosystems
- freshwater (rivers and lakes) ecosystems
- marine ecosystems (marine inlets/transitional, coastal, shelf and open ocean combined).

These ecosystems are assessed in Sections 5.1 to 5.8, with each section including:

- **key messages** summarised in a box;
- **characteristics** — key features and relevance of the ecosystem for providing useful services;
- **drivers and pressures** that are significant for that ecosystem at the European level (as reviewed in Chapter 4.1);
- **condition (state and impact)** — the overall impact of environmental pressures on the ecosystem condition, as indicated by current conservation status and trends in species and habitats, and other factors such as water quality that might affect biodiversity and the delivery of ecosystem services;
- **policy response** — a review of the current policies and what future action might be required to maintain and protect the ecosystem and ensure long-term delivery of ecosystem services and to maximise synergies and minimise trade-offs or conflicts between ecosystem services and other policy drivers;
- **case studies** — examples of good practice from EU Member States demonstrating initiatives that work towards healthy ecosystems.

Section 5.9 is an overview of all ecosystems. It considers future trends in pressures, summarises synergies and trade-offs between ecosystem services, identifies knowledge gaps and presents a strategic outlook on progress towards sustainability.

5.1 Urban ecosystems

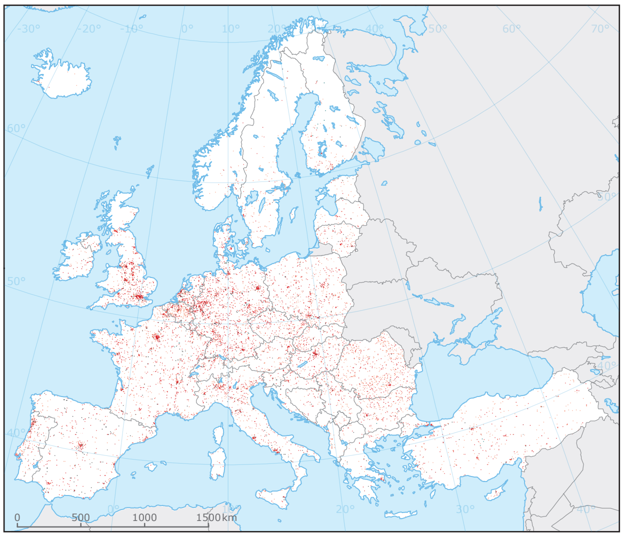
5.1.1 Characteristics

Urban areas cover around 5 % of the EU (see Map 5.1). They include a mix of 'grey' infrastructure such as residential, industrial, commercial and transport infrastructure, mines, waste and construction sites, and 'green' and 'blue' infrastructure, comprising green roofs and walls, parks, canals, rivers and lakes. Core urban areas are densely built up, but the outskirts tend to become less dense as they merge with the surrounding rural areas, where land use becomes more heterogeneous.

In this report we distinguish between 'urban ecosystems' and 'urban areas'. By 'urban ecosystem', we mean the species that inhabit urban areas and the mix of natural, semi-natural and man-made habitats that they occupy. Urban green and blue spaces, including parks, gardens, urban trees, river banks, roadside verges and other areas of rough ground, are home to a variety of species and can help to deliver a range of ecosystem services, including green space for recreation, air quality regulation, flood protection and aesthetic value. Urban ecosystems may include small patches of habitats that could be classified as other ecosystem types, such as grassland, woodland, shrub land and freshwater bodies, though these are usually small, not connected, heavily modified and far from their natural state.

'Urban areas', on the other hand, are viewed not just as areas dominated by man-made infrastructure,

Map 5.1 Urban ecosystems in Europe



Urban ecosystems in Europe

- Low density buildings
- Buildings of cities, towns and villages
- Extractive industrial sites
- Highly artificial man-made waters and associated structures
- Waste deposits
- Transport networks and other constructed hard-surfaced areas
- Areas not covered by urban ecosystems
- Outside coverage

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html accessed, 13 January 2015.

but also as home to 72 % of Europe's population and therefore a source of human activities that have damaging impacts on ecosystems both within and outside the urban area. Expansion of urban and industrial areas causes direct local impacts such as habitat fragmentation, soil sealing and pollution, and is frequently reported by Member States as an important pressure on other ecosystems (EEA, 2015d). In addition, people who live in urban areas depend heavily on other ecosystems to provide resources, such as drinking water, clean air, food and energy, and services, such as flood protection, recreation and waste disposal, as well as land for development. Some of these services may be met locally, but others, such as food, energy and tourism, can have a global impact. In the EU-28 the ecological footprint increased from 3.4 to 4.5 global hectares (gha) per person from 1960 to 2010, whereas the region's biocapacity rose from 2.1 to 2.2 gha per person (EEA, 2015r). However, people who live in urban areas do not necessarily have greater impacts on other ecosystems per capita than those who live in rural areas — indeed, urban lifestyles on average can, for example, be associated with lower levels of car use and a lower demand for heating fuel. Policymakers therefore have opportunities to alleviate these problems through urban planning and the use of green infrastructure while also enhancing biodiversity and natural capital and ensuring the continued delivery of vital ecosystem services (see Section 5.1.4).

5.1.2 Drivers and pressures

Urban ecosystems typically comprise a highly fragmented network of parks, gardens, water features and often brownfield sites; the species in these areas are affected by habitat change (land take and landscape fragmentation), pollution and nutrient enrichment, invasive alien species and climate change

Box 5.1 Key messages for urban ecosystems

- The trend towards urbanisation and urban sprawl, and the highly concentrated demand for resources such as food and water from people in urban areas, drives land take processes, landscape fragmentation, soil sealing, resource extraction, climate change and pollution emission. Urban ecosystems can also act as an entry point for alien species, which can flourish in warm urban microclimates and in urban ecosystems that have been disturbed, outcompeting native species. These pressures damage habitats and affect biodiversity and human quality of life, both in (peri-) urban areas and in surrounding and more distant ecosystems.

- Climatic pressures are projected to further increase, affecting the health and well-being of city residents (e.g. through heat stress and the spread of disease) and causing environmental and structural damage through natural disasters and extreme events.

- Sustainable city planning is urgently needed to tackle these problems. This implies utilising green infrastructure and increasing resource efficiency and can provide multiple benefits, thus protecting the health and well-being of city residents, conserving biodiversity and improving the quality of both urban and surrounding ecosystems.

(causing flooding and heatwaves) (Table 5.1). European cities are very diverse in size, structure and density and the availability of comparable data at city level is still limited. We therefore focus on overall trends for the whole of Europe, e.g. urbanisation.

Habitat change

The trend towards urbanisation over the past few decades has led to the expansion of urban areas and transport infrastructure and an increase in land take for housing, commerce, recreation and other amenities. It is estimated that between 2000 and 2006, approximately 1 000 km^2 per year was converted to artificial surfaces (EEA, 2015b, *Urban systems*), mostly taken from arable land (see Section 5.2.2). This pressure is projected to continue, as it is estimated that by 2050, 82 % of Europe's population will live in cities, resulting in over 36 million new urban citizens (UN, 2014).

Typically, European cities are densely built up and highly populated, with decreasing density around their peripheries. These gradients are changing as 'peri-urbanisation' is increasing, as residents move to locations with a rural character on the outskirts of cities, while still commuting into the city to work (Kovats et al., 2014). This is associated with increased urban sprawl, land take, habitat change and transport emissions (EEA, 2015b, *Urban systems*). On the other hand, within the United Kingdom and some other parts of Europe there is a tendency to densify existing urban areas at the expense of green space, including domestic gardens; this represents a phenomenon commonly referred to as 'backland development' or 'garden grabbing' (Goode, 2006). These problems could be offset by the restoration and subsequent use of previously developed land (e.g. brownfields such as previous industrial sites or contaminated land) to reduce pressures for development on natural or semi-natural land, urban green space and gardens. New methodologies in urban planning are being developed to simultaneously integrate the restoration of brownfields, to answer the demand for new housing within the urban perimeter and to enhance the quality of urban green areas. However, it is estimated that between 1990 and 2000 only 2.5 % of the increase in artificial surfaces created came about through the re-use of previously developed land (EEA, 2015b, *Urban systems*).

Both densification and peri-urbanisation can contribute to habitat and biodiversity loss, land degradation and landscape fragmentation, and a change in the aesthetic quality of landscapes (ECNC, 2013; ETC/SIA, 2014d). Problems include the loss of soil resources through soil sealing, which is the permanent covering of land by impermeable artificial material such as asphalt and concrete (Gardia et al., 2014; JRC, 2014). This affects food production (Gardi et al., 2014), water absorption and filtration (EEA, 2015b, *Urban systems*) and other soil functions. Map 5.2 illustrates the pressures from urbanisation expressed as permeation, a measure for urban sprawl into natural and semi-natural areas in Europe. Pressure from urban sprawl appears to be generally greater in north-western and central Europe, with highest intensity (darkest colour) around major cities but affecting almost the complete territory of the countries. Major areas not affected by urban sprawl can be found in more remote parts of northern, eastern,

Table 5.1 Major pressures on urban ecosystems, and their impacts on biodiversity in Europe

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Land take Landscape fragmentation due to urban sprawl and roads around cities Channelling of streams and rivers in urban areas	Extreme events: droughts, floods, fires, heatwaves Rise in sea level for coastal cities	Gravel extraction around cities Overexploitation of groundwater and freshwater	Expansion of alien species Introduction of exotic species in gardens	Soil contamination by heavy metals due to industrial activities Air pollution and critical level of ozone Water pollution caused by poor wastewater management Sludge Waste

Key: Observed impact on biodiversity to date: Low (yellow) – Habitat changes: very high; Climate change: moderate; Overexploitation: low; Invasive alien species: high; Pollution and nutrient enrichment: very high.

Low	Moderate	High	Very high

Source: Adapted from EEA, 2015a.

and southern European countries and in mountainous regions of central Europe. The pressure on species and habitats from urbanisation and residential and commercial development has been reported as being nearly three times higher than the European average in the Black Sea and some of the Mediterranean regions (EEA, 2015d).

Climate change

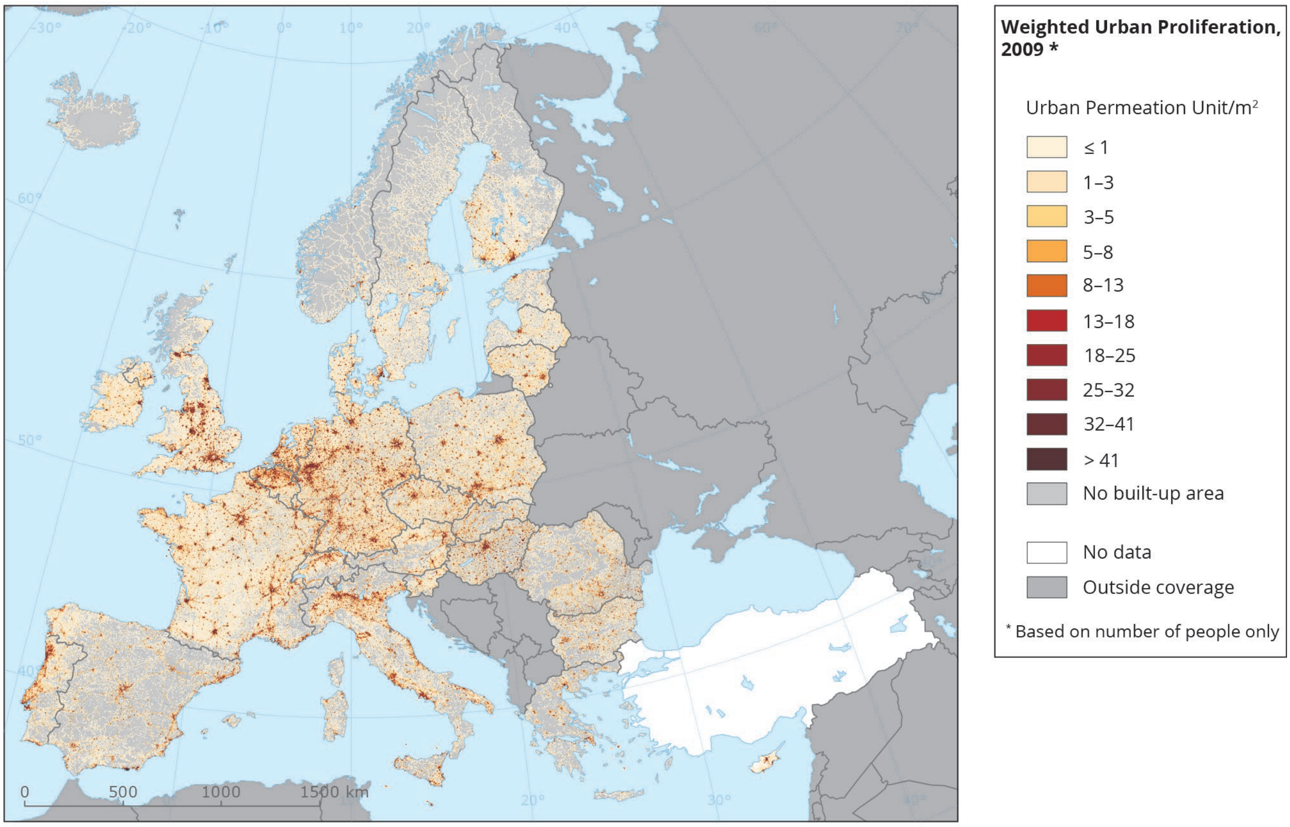
Climate change impacts on humans in Europe are most easily observed in urban areas. The high concentration of people and socio-economic activities, as well as the high proportion of impervious surfaces, magnifies the exposure of cities to impacts such as more frequent and prolonged heatwaves, urban floods and water scarcity (EEA, 2012b). The degree of vulnerability and the magnitude of the impacts of climate change depend on the composition, management and design of urban areas (EEA, 2012e; EEA, 2016a).

Soil sealing in urban areas restricts the natural drainage and absorption of water into the ground, leading to higher run-off into the sewerage system and thereby, potentially to urban flooding. The number of cities with high soil sealing and an increasing number of intensive rainfall events are concentrated in north-western and northern Europe (EEA, 2012b).

A rise in the sea level increases the risk of coastal flooding, and Map 5.3 reveals that the rise is greater along the coastline of north-western Europe, where there is also pressure on semi-natural areas from urbanisation (Map 5.2). The high concentration of cities, transport infrastructure and people in these coastal regions means that flood damage can be very significant.

Climate change, coupled with the urban heat island effect (the increased temperature of urban air compared with that of the rural surroundings), intensifies the risk of heatwaves in cities, especially in southern Europe (EEA, 2012b). The temperature difference between urban and rural areas can be 10 °C or more, and is particularly strong at night

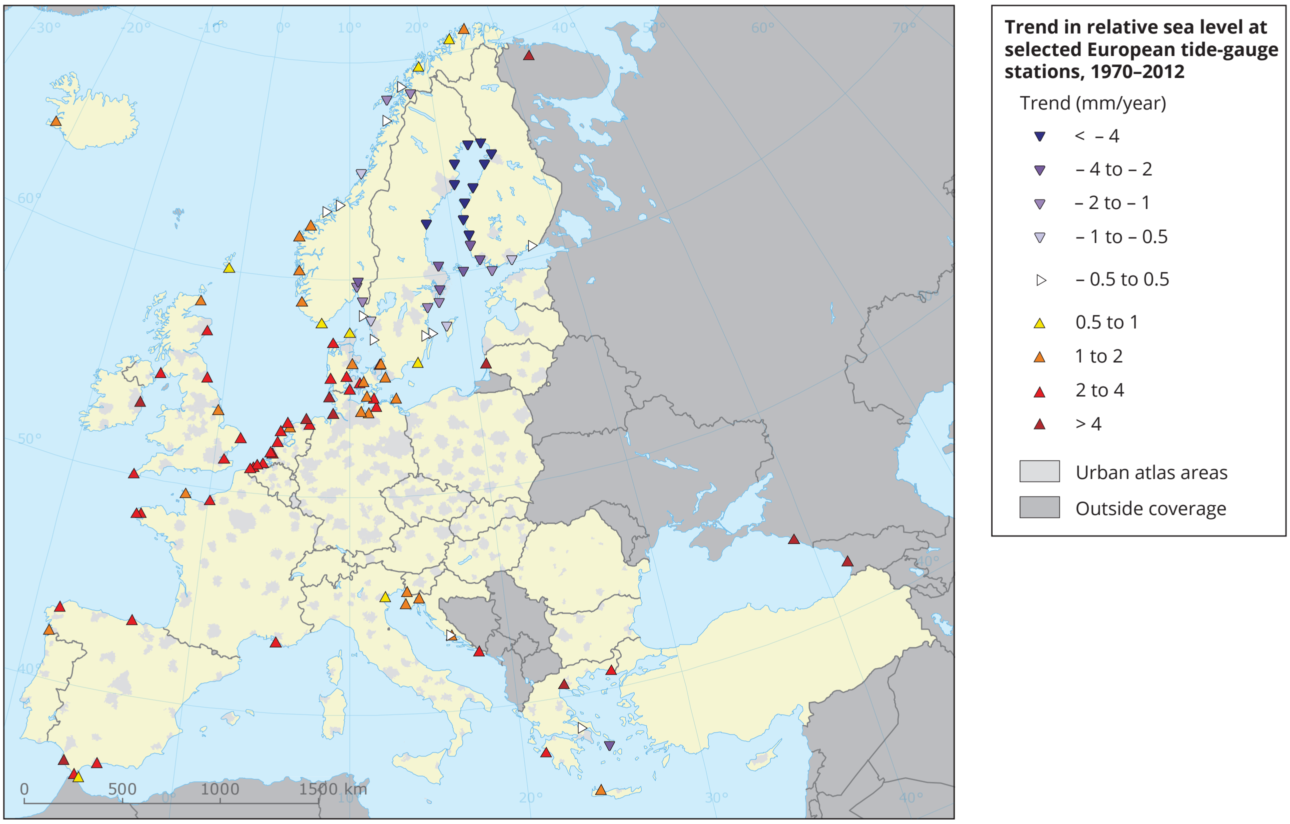
Map 5.2 Urban sprawl in Europe (calculated as Weighted Urban Proliferation, WUP), 2009



Note: Weighted Urban Proliferation (WUP) is the metric to quantify urban sprawl in any given reporting unit. It is the product of the dispersion of the built-up area and its weighting, the percentage of built-up areas in the reporting unit, and a weighting of the land uptake per person. It is measured in urban permeation units per square metre of landscape (UPU/m²).

Source: EEA, 2016d.

Map 5.3 Trend in relative sea level at selected European tide-gauge stations, 1970–2012



Source: EEA, 2014c.

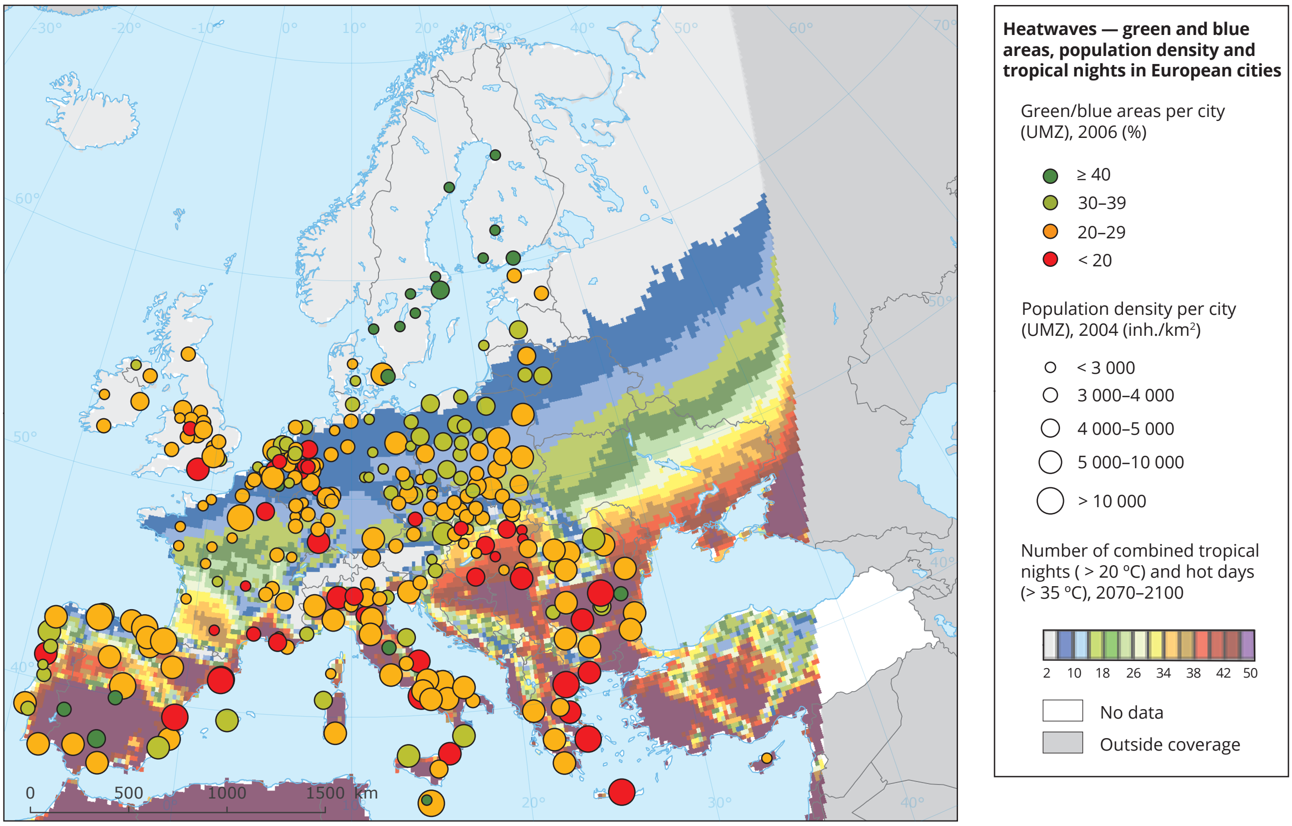
(Oke, 1982). Heatwaves in Europe have been associated with decreases of the population's well-being and increased mortality and morbidity, especially in vulnerable population groups. During the summer of 2003 the heatwave in central and western Europe was estimated to have caused up to 70 000 excess deaths over a 4-month period — more human fatalities than any other natural disaster in recent decades (Robine et al., 2008). Green urban areas, and to a certain extent also water features (blue areas), contribute to the cooling of city environments. For example, the surface temperature of concrete is 17 °C higher than peak air temperature in direct sunlight and 4 °C higher in shade; for grass the maximum temperatures are 1 °C and 4 °C below the peak air temperature (Armson et al., 2012). Map 5.4 maps the risk of heatwaves in urban ecosystems across Europe based on existing data on population density and the presence of green and blue urban areas.

Overexploitation

Urban ecosystems depend on their territorial hinterland to satisfy the food, water and material needs of a highly concentrated population, as well as on the worldwide market for global trade to cover the demands that cannot be provided by the surrounding areas. Surrounding rural areas provide valuable ecosystems services to urban areas (e.g. recreational areas, flood protection) for the supply of resources (e.g. water, food, renewable energy production) and the space for an interconnected infrastructure (e.g. road, power grid), but they also serve as deposits (e.g. waste and waste water). This interdependence between urban areas and their rural surroundings, far beyond the limits of the cities' jurisdiction, poses a major problem for resource management and governance.

Exploitation mostly affects ecosystems in surrounding areas and sometimes those far beyond the limits of the city. The challenge is to develop urban planning that will contribute to the preservation of ecosystem services reduce the exploitation of resources and implement compensation measures. Impacts on the urban ecosystem itself include different pressures. Soil sealing as an element of habitat change (see Map 5.2) destroys resources necessary for the production of food, reduces the infiltration of water and accelerates

Map 5.4 **Heatwaves — green and blue areas, population density and tropical nights in European cities**



Note: Heatwaves — high population densities and a low proportion of green and blue urban areas per urban morphological zone (UMZ) can contribute to the urban heat island effect in European cities. The background map presents data for 1971–2000. Although green spaces and population density are good indicators of the urban heat island effect, other variables such wind pattern and the size, distribution and position of the areas may also affect heatwave risks.

Source: Eurostat Urban Audit database, 2004; EEA Urban Atlas, 2006.

run-off and as such leads to increasing pressure on the remaining natural resources. Gravel extraction, due to a high demand from the construction industry, is another pressure inducing habitat loss and increasing the pressure on remaining resources. Generally, drinking water is extracted beyond the city limits from surface or groundwater bodies that are sometimes far beyond the city's nearest watershed (e.g. around 200 km in the case of Athens). Water scarcity results from a combination of natural (specific geographical, hydrological or climatic conditions) and man-made factors, in particular a lack of governance (e.g. spatial planning, consultation, cooperation, pricing policy, regulation and investment) and management and a poorly adapted infrastructure. The destruction of scenic landscapes by increasing penetration of built-up areas changes the identity of the landscape. Finally, the intensive recreational use of green areas due to the high population density in cities (EEA, 2015a) leads to high pressure on the periphery of cities with negative impacts, including physical (e.g. soil erosion), ecological (e.g. vegetation damage, litter) and aesthetic degradation.

Invasive alien species

Invasive alien plant species are particularly common in urban ecosystems, especially in the temperate zone of western and central Europe (Section 4.1.4). Recent data reveal that among the 1 180 plant groups found in 32 central European cities, 49 % were non-native (Lososová et al., 2012). Alien species are introduced to urban ecosystems via two main routes: the increased trade that takes place in urban centres, and the cultivation of ornamental plants in gardens. Their establishment may also be related to favourable environmental conditions similar to their region of origin, such as higher temperatures (due to the urban heat island effect).

Although alien species are damaging to most ecosystems, some species and habitats have co-adapted to urban ecosystems as urbanisation has occurred (Zisenis, 2015). Particular urban species and habitat types such as spontaneous ruderal flora (plants found on waste or disturbed ground) can have high biodiversity value and are now part of the cultural landscape in Europe. They can provide ecosystem services similar to those of native species, for example by producing oxygen, limiting noise, filtering dust and chemicals, supporting soil fertility, being aesthetically appealing and supporting recreational and relaxation activities (EEA, 2010a; ECNC, 2013), but they may also outcompete native species and trigger allergies and vector-borne diseases.

Pollution and nutrient enrichment

The high population and concentration of socio-economic activities in urban areas result in air, soil, water and noise pollution, affecting the functioning of urban ecosystems and undermining human well-being. Up to one-third of Europeans living in urban environments are exposed to levels of air pollutants exceeding EU air quality standards, in particular for particulate matter and ozone, with road transport being a significant source. According to World Health Organization (WHO) Guidelines for Community Noise (WHO, 1999) more than half of all EU citizens are estimated to live in zones that do not ensure acoustic comfort to residents and more than 30 % are exposed to noise levels that disturb their sleep.

Cities are also estimated to emit 69 % of Europe's CO_2. The emerging trend of peri-urbanisation is contributing to even higher emissions because of car dependency but also because of the characteristics of the buildings. Commuter towns and suburbs are dominated by detached and semi-detached housing with high energy demands (EEA, 2015b, *Urban systems*).

Others sources of pollution affecting urban ecosystems are wastewater and solid waste, which can pose risks to soil and water supplies. Solid waste disposal decreased by 4 % between 2004 and 2012 owing to significant progress made in recycling glass, paper, cardboard, metals and plastic. Emissions from municipal waste also halved from 2001 to 2010 owing to improved municipal waste management (EEA, 2015b, *Urban systems*), and wastewater treatment has helped to reduce pollution of freshwater and groundwater supplies in urban environments and beyond. However, water pollution, including endocrine disruptors mainly originating from households, could be exacerbated in the future by a combination of low water flow and high temperatures as a result of climate change, which also gives rise to changes in patterns of vector-borne diseases (EEA, 2012e).

5.1.3 Condition

Urban ecosystems are often omitted from ecosystem assessments, as their level of 'naturalness' is low and they play only a small role in providing habitats for protected and rare species. Thus the term 'performance', instead of 'condition', is often used to describe the ability of urban ecosystems to provide a range of benefits that contribute to human well-being. Urban green and blue spaces offer critical services in biodiversity conservation, water filtration and regulation, improving the microclimate, sequestering carbon and even providing a small portion of the fresh food consumed by urban populations (e.g. via urban gardens). These areas also encourage recreational activities, increase aesthetic appeal, and provide mental and physical health benefits. The importance of green spaces in urban ecosystems has led to the use of the proportion of green spaces in the total urban area as an indicator of condition (Davies et al., 2013), also available at European level (EEA, 2015b, *Urban systems*).

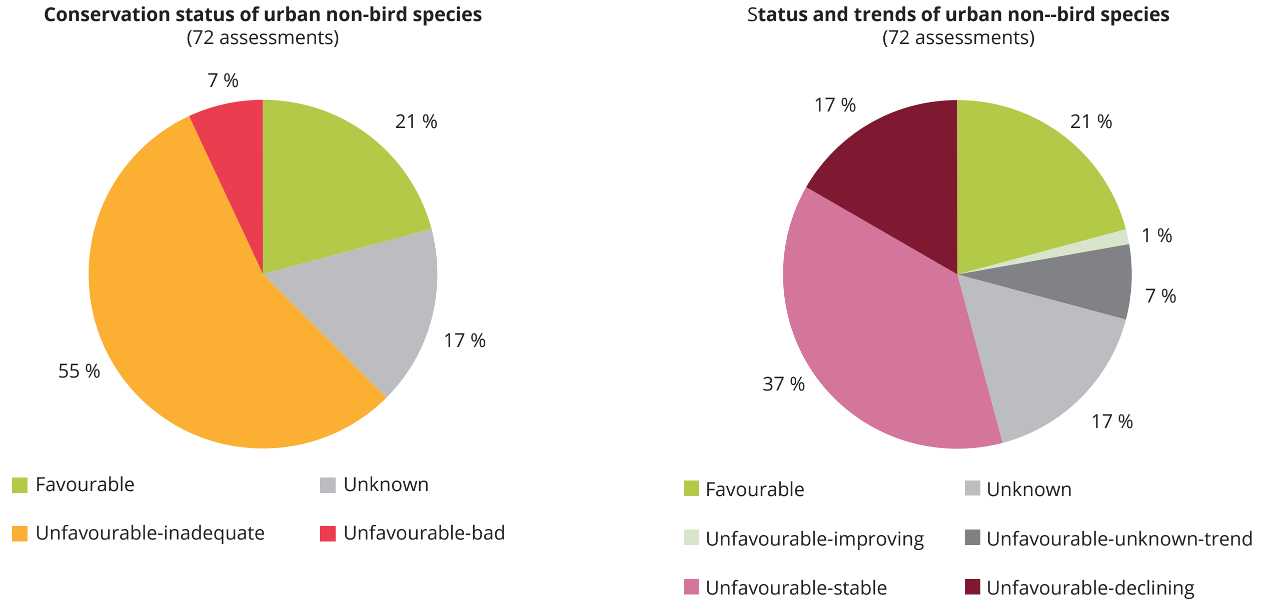
The pressures reviewed in this assessment affect the condition of both habitats and species in urban environments and the capacity of the ecosystem to provide certain services. The condition of urban ecosystems is also linked to the condition of the other ecosystems they depend on for services such as flood regulation, water quality regulation and water provision.

No Annex I habitats, listed in the Habitats Directive, are reported in urban ecosystems. Therefore the role of urban ecosystems for bird species cannot yet be addressed. The available assessments refer only to urban non-bird species and report that more than half (55 %) had an unfavourable-inadequate conservation status, while only 7 % were assessed as unfavourable-bad (Figure 5.1). The main pressure on non-bird species was found to be urban and industrial activities, especially the reconstruction or renovation of buildings.

5.1.4 Policy response

Urban areas are a source of pressures that affect both their own ecosystems and those in surrounding areas, but they can also provide solutions. Urban sprawl and 'grey infrastructure' can have negative impacts on land, soil and biodiversity, especially without appropriate spatial planning. On the other hand, there is a vision for urban planners to work with nature through green infrastructure and 'nature-based solutions' (EC, 2015e) to achieve improved physical and functional habitat connectivity (e.g. through the use of green corridors), healthy ecosystems, a decrease in the loss of biodiversity and more sustainable land use, thus providing social, ecological and economic benefits in parallel. Green infrastructure (see Chapter 6) provides climate adaptation and mitigation benefits (Berry et al., 2015), as well as offering a range of other benefits including improvements in human health

Figure 5.1 Conservation status (left) and trends (right) of urban non-bird species



Source: EU biogeographical assessments, reporting under Article 17 of Habitats Directive, http://www.eea.europa.eu/data-and-maps/data, accessed 12 December 2015.

and amenity value, inward investment, reduced noise and outdoor air pollution, and diverse habitats with high species diversity. Urban green space and green roofs can moderate temperatures and decrease surface rainwater run-off. Despite these benefits, competition between the use of land for green space and building developments is still an issue. For example, an analysis of the Natura 2000 network found that there are only 97 designated sites in 32 major cities (i.e. over 500 000 inhabitants), including 16 capital cities (Sundseth and Raeymaekers, 2006). This low number is thought to be a function of both national planning priorities and political pressures combined with historical and abiotic factors affecting the presence of species and habitats listed under EU directives. New spatial planning approaches tend to combine densification of urban areas with an improvement in the functionality of green urban areas, also taking into account the higher value of real estate investments closely surrounded by green areas.

Policy tools for achieving the vision of sustainable urban ecosystems include Sustainable Urban Development, in Regional Policy (EC, 2015f), the Green Infrastructure Strategy (EC, 2013b) and the EU Biodiversity Strategy to 2020 (EC, 2011a), which look to spatial planning to help protect and safeguard locally valued sites in urban areas and to create new opportunities for biodiversity through the development process. The importance of ecosystems in urban areas is also stressed in the latest EU Horizon 2020 draft work programme on 'Climate action, environment, resource efficiency and raw materials', part of which focuses on 'sustainable cities through nature-based solutions'.

Other policy tools aim to reduce the impact of urban areas on surrounding ecosystems. The Seventh Environment Action Programme, for example, promotes integrated urban policy and aims to ensure that land is managed sustainably by 2020. Strategic objectives in Europe's 2020 Strategy explicitly refer to the importance of a resource-efficient economy. To strengthen the urban dimension in the EU policies, the Urban Agenda was relaunched on 3 March 2015 to bring together the efforts of different levels of governance crossing administrative borders, further supported by the Riga Declaration of 10 June 2015, in which Ministers responsible for territorial cohesion and urban matters across Europe committed to provide political support to the development of the EU Urban Agenda and the significance of Europe's small and medium-sized cities as a common priority. The *Roadmap to a resource efficient Europe* calls for limits on land take and soil sealing, a reduction in soil erosion and an increase in soil organic matter, and, although the EU has withdrawn its Soil Framework Directive (EC, 2015g), it is still committed to the protection of soil. Other EU policies that have had a substantial impact on the development of cities over the past decades include the Thematic Strategy on the Urban Environment, the Communication on Cohesion Policy and Cities, the Green Paper on Urban Mobility, and sectoral policies such as those on water, waste, noise, air and transport (EEA, 2015b, *Urban systems*).

The case study in Box 5.2 demonstrates how knowledge of ecosystem condition can be used to increase biodiversity in cities (in this case bees) by taking advantage of the features of urban areas. Improving habitat for bees not only means creating green areas but also has to take into account the quality of the green areas and their condition and capacity to provide food for bees of sufficient quality and in sufficient quantity. This should also create co-benefits in terms of better living conditions for other species and improve ecosystem service delivery in general, for example air quality and recreation.

5.2 Cropland ecosystems

5.2.1 Characteristics

Cropland includes a mosaic of ecosystems, including areas intensively managed for agriculture, as well as multifunctional areas under lower intensity management that support wild species alongside food production (Maes et al., 2013). It consists of both permanent and annual crops and is one of Europe's most widespread ecosystems, covering around 29 % of the EU-28 area (see Map 5.5).

Box 5.2 Case study: URBANBEES (France)

Bees pollinate nearly 80 % of the wild flora and 70 % of the crops grown in Europe — a service valued at an estimated EUR 14.2 billion for the EU-25 alone in 2005 (Gallai et al., 2009). The absence of insect pollination would cut the production of crops that are partially dependent on insect pollination by around 25–32 % (Zulian et al., 2013). Yet studies have confirmed a decline in the abundance and diversity of European bee populations.

Recent work has shown that urban ecosystems can harbour a large number of wild bee species (Matteson et al., 2008). In fact, urban zones serve as refuges for many animal and plant species, as they are less exposed to agricultural pesticides, while the higher temperatures are also beneficial for species that — like bees — nest in warm environments. Furthermore, flowering occurs throughout most of the year owing to the variety of indigenous and alien and ornamental plants.

The LIFE + Biodiversity project URBANBEES was carried out in the greater urban community of Lyon, France (2009–2014). It promoted measures to conserve and enhance the biodiversity of wild bees in urban habitats, by providing specific nesting devices and appropriate management of green spaces in urban ecosystems. These measures aimed to increase favourable habitats for wild bees and to reduce the genetic isolation of individual populations. The plan included guidance on changing conventional practices in the management of parks and recreation areas to favour the return of indigenous plant and animal species and to control alien species. The project also included extensive awareness campaigns, volunteer training and school visits aiming to reach 200 000 people in urban communities.

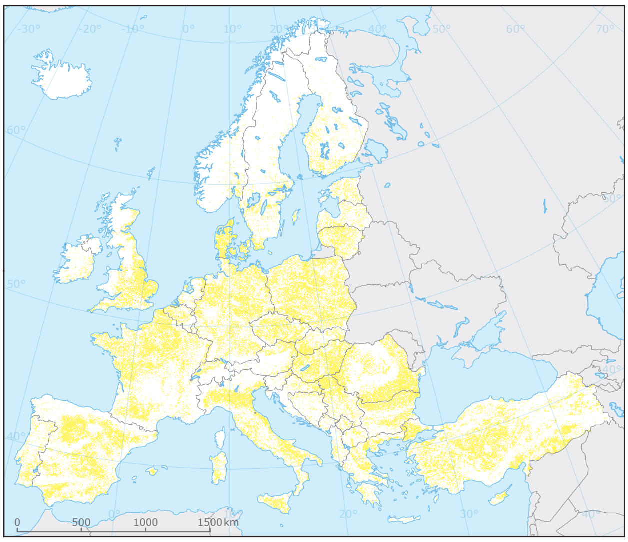
Recommendations were tested in 10 urban zones in the Greater Lyon area to validate the action plan, which aims to target 20 cities across Europe by disseminating information and raising awareness. The outcomes will be essential to pin-point the approaches and the methods that should be taken to restore populations and conserve wild bees in urban ecosystems.

Source: http://www.urbanbees.eu accessed 12 December 2015

Box 5.3 Key messages for cropland ecosystems

- The long-term sustainability of cropland ecosystems is being undermined by harmful farming practices, causing soil degradation and water contamination, as well as a decline in pollinators, the loss of natural biological pest controls and a loss of plant and animal genetic diversity.
- 70 % of cropland non-bird species assessed under the EU Habitats Directive are in 'unfavourable' status, while 39 % of cropland bird populations are decreasing.
- The policy challenge lies in achieving sustainable cropland management that will allow cropland ecosystems to respond to the globally increasing demand for food and agricultural products, while at the same time minimising the pressures exerted from these activities on the environment.

Map 5.5 Cropland ecosystems in Europe



Cropland ecosystems in Europe

- Arable land and market gardens
- Cultivated areas of gardens and parks
- Areas not covered by cropland ecosystems
- Outside coverage

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015.

In the literature, there is potential confusion between the terms 'cropland' and 'agro-ecosystems'. Some sources use 'agro-ecosystems' interchangeably with the terms 'cropland' or 'arable land', while others use 'agro-ecosystems' to indicate a combination of grasslands and croplands or mosaics of various types of croplands, grasslands (and forests) with their linked functionality. In this report, agro-ecosystems are taken as croplands and other cultivated areas, and cropland and grassland are reviewed separately, although data on combined cropland–grassland agro-ecosystems have been used where separate data are unavailable, following the MAES typology.

Although cropland delivers the vital service of food production, agriculture also has major negative environmental impacts. The widespread industrialisation and intensification of cropland management since the 1950s has led to a significant decline in biodiversity across European cropland ecosystems (EEA, 2015b). Arable farming systems with high ecological quality are now rare in Europe (see Section 5.2.3); those that remain are mainly land under lower intensity management in southern and eastern Europe (ETC/SIA, 2014a). This is reflected in the relatively low proportion (7.7 %) of all cropland ecosystems that is protected by Natura 2000, although this is still a large area, and represents 12.2 % of the total area of all Natura 2000 sites in Europe (Figure 3.5). However, cropland in Europe has been shrinking since the 1990s, mainly as a result of urban and industrial development (see section 'Habitat change').

5.2.2 Drivers and pressures

The drive towards agricultural intensification and eventual overexploitation in European croplands is related to a number of major pressures on cropland and associated semi-natural habitats, including land take, landscape fragmentation, pollution and nutrient enrichment, loss of soil quality and cropland productivity, and invasive alien species (Table 5.2). Other pressures on cropland ecosystems arise from climate change and ozone pollution, which can damage crops and natural vegetation. Reporting by Member States showed that modification of cultivation practices (agricultural intensification and

Table 5.2 Major pressures on croplands, and their impacts on biodiversity in Europe

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Land take Landscape fragmentation Agricultural specialisation: intensification and abandonment	Changes in temperature and precipitation Extreme events (floods, droughts, heatwaves) Fires	Agricultural intensification: intensive cultivation and overharvesting Groundwater overextraction	Expansion of invasive alien species	Pesticide use Critical levels of ozone Nutrient enrichment Soil salinisation

Key: Observed impact on biodiversity to date: Low, Moderate, High, Very high

Source: Adapted from EEA, 2015a, and ETC/SIA, 2014c.

crop change), pesticide use and urban development were the most frequently reported pressures on cropland species (EEA, 2015d).

Habitat change

Significant amounts of cropland have been lost to development, with arable land and permanent crops contributing almost 46 % of the land developed from 2000 to 2006, and pasture and mosaic farming accounting for 32 % (Figure 5.2). Tóth (2012) highlighted the fact that the conversion rate of croplands to artificial surfaces is correlated with population growth and is faster in countries with more developed economies, although it is negatively correlated with annual economic growth. As, for historical reasons, most urban areas are located in areas of high soil fertility for growing food, highly productive soils are especially affected by urban sprawl. The consequences include soil sealing and fragmentation of cropland ecosystems, with impacts such as the decline in and endangering of cropland species and a reduction in water infiltration (EEA, 2015b, *Land systems*).

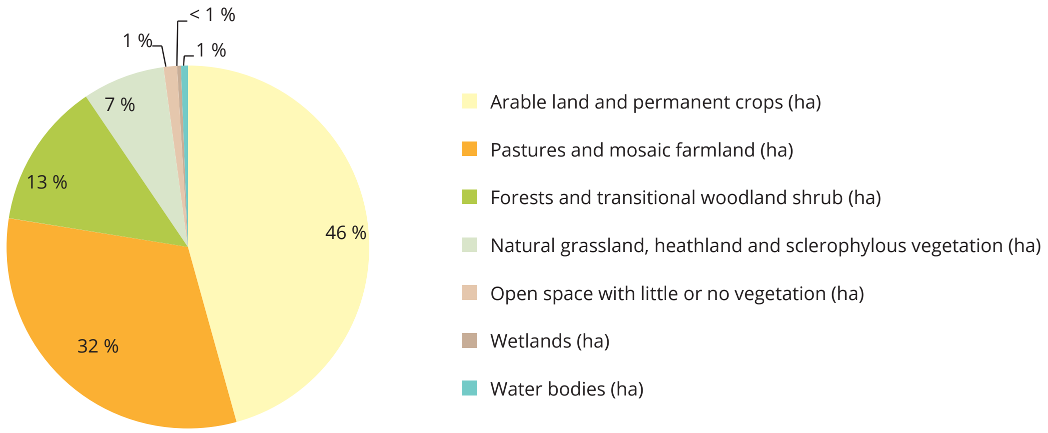
Further habitat changes have resulted from structural changes in agriculture over the past decades, including the increased use of machinery, specialisation in crop production, increasing biofuel production, a halving of the number of farmers in Europe between 1990 and 2010, and an increase in the average farm and field size (although Europe is still regarded as a continent with mainly small agricultural holdings) (EEA, 2015b). These trends are associated with the establishment of uniform landscapes combined with depletion of genetic diversity of crops and loss of habitats for species because of fields being consolidated, leading to loss of landscape elements such as hedges, ponds, stone walls and fallow land, a decreased area of field margins, increased ground- and surface water pollution, soil compaction and a reduction in natural soil fertility, as well as increased vulnerability to climate change (ECNC, 2013).

Another important trend is the marginalisation and abandonment of cropland. As small-scale and extensive farming systems become less viable, especially in remote areas or those with low soil fertility, farmers are sometimes forced to give up land management. This can eventually lead to the growth of shrubs and forests through natural succession, which might create new wilderness areas but can also threaten farmland biodiversity and increase the risk of wildfires (ETC/SIA, 2014a). The area of agricultural land abandoned between 2000 and 2006 was less than the area of forest and other natural or semi-natural ecosystems that were converted to continuous agriculture (permanently managed cropland including permanent crops, grassland), but it was still significant (Figure 5.3) Regardless of the cause — land take or abandonment — the loss of cropland results in additional pressure on the remaining land to satisfy the growing demand for food and biomass.

Climate change

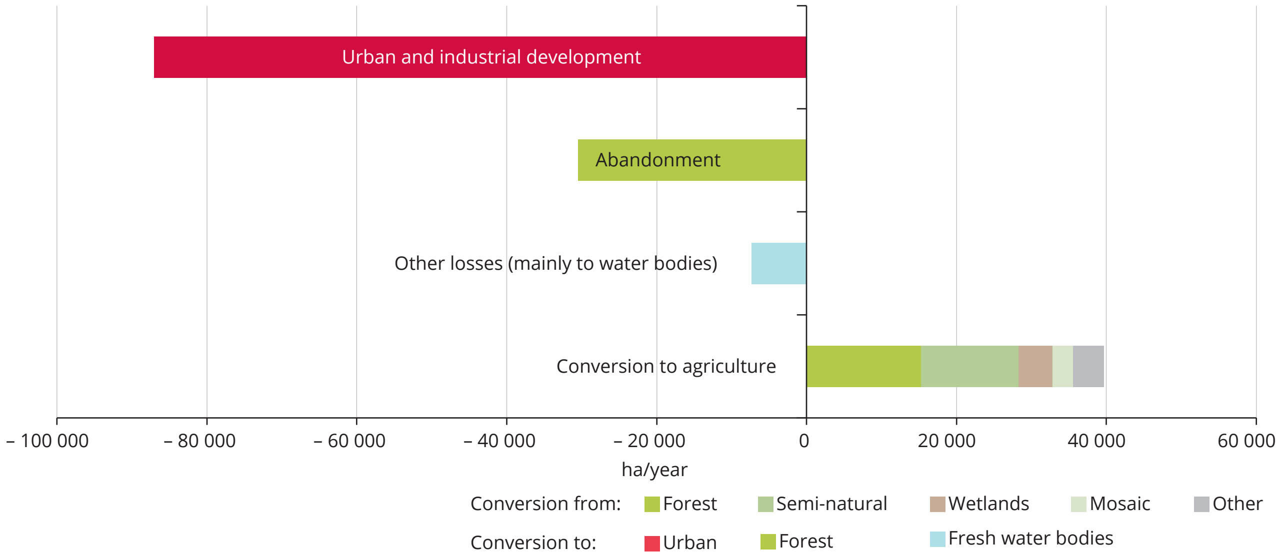
Climate change is already affecting cropland ecosystems, although the regional distribution of the impacts on crop suitability and agricultural production varies widely. Climate change is expected to have the highest impacts in the south and north of Europe, resulting in losses and gains, respectively (ESPON Climate, 2011), as shown in Map 5.6. In the Mediterranean, the drier and hotter climate has increased evaporation, leading

Figure 5.2 Relative contribution of land cover categories to land take by urban and other artificial land development, 2000–2006 (EEA-38)



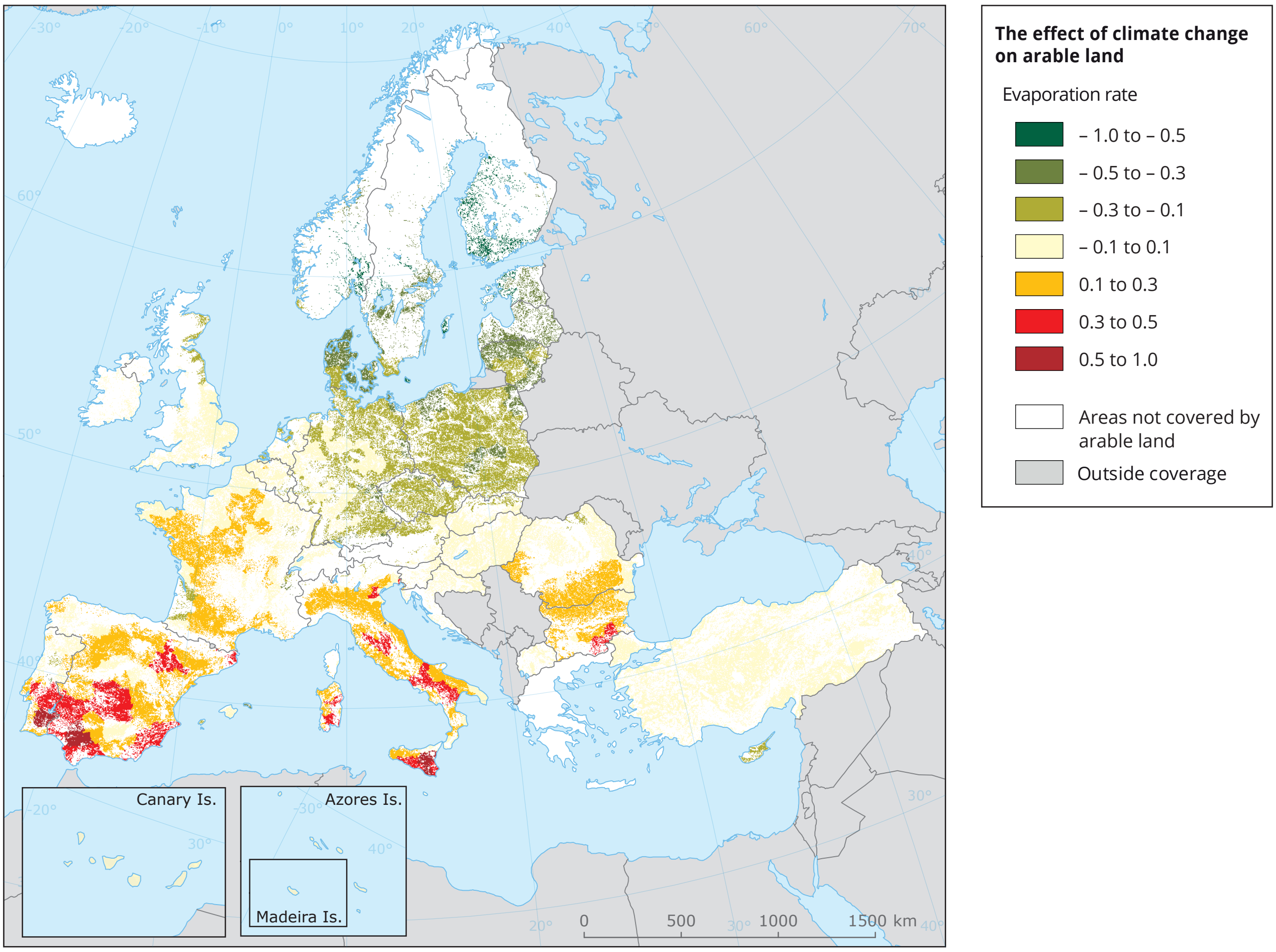
Source: http://www.eea.europa.eu/data-and-maps/indicators/land-take-2/assessment-2, accessed 12 December 2015. EEA-38 includes EEA-39 countries except Greece. Preliminary results from analysis of CLC data for 2006–2012 indicate a general reduction in the conversion of cropland but an ongoing trend of cropland contributing most to urban land take.

Figure 5.3 Average area of agricultural land lost and created, 2000–2006 (ha/year)



Source: Analysis by the University of Oxford for the EEA, based on CLC data.

Map 5.6 The effect of climate change on arable land (non-permanent crops)



Source: ETC/SIA, 2014a. Projection of climate change risks for arable land (non-permanent crops) based on predicted changes in evaporation from ESPON Climate, 2011. The indicator is scaled from – 1.0 (high negative impact) to + 1.0 (high positive impact).

to reduced water availability from river abstraction and groundwater resources, while at the same time it is projected that increased temperatures and drought will increase the need for irrigation and increase soil erosion and the risk of fire (ETC/SIA, 2014a). A reduction in the areas climatically suitable for traditional crops is thus expected in southern European regions. In contrast, milder temperatures and increased precipitation are projected for northern Europe, resulting in increased productivity (Iglesias et al., 2012; ETC/SIA, 2014a). Therefore, climate change will impose a different geographic distribution of crop types, especially for those that have a high water demand (e.g. cotton) (IPCC, 2014). It will also affect organic soil carbon storage, with projected increases in northern and central parts of Europe but decreases in southern and Eastern Europe (Lugato et al., 2014). Extreme events, including droughts, floods and heatwaves, will also have an impact.

Overexploitation

Since the 1950s, traditional farm management, which favoured a diverse range of landscapes, habitats and plant and animal species, has been progressively replaced by intensive farming methods. This intensification and specialisation has significantly increased the productivity of European agriculture, despite the decrease in total area (EEA, 2015b).

Intensification of land use is the most important reason for the decline in biodiversity in arable croplands. Increased application of fertilisers and pesticides, drainage and irrigation, mechanical cultivation, simplification of cropping systems, loss of non-crop habitats and other measures aimed at increasing land productivity have had a severe effect on species richness (ETC/SIA, 2014a) and can contribute to soil erosion and loss of soil fertility and cropland productivity in the long term. The pressure of this overexploitation has increased in the past decades and is projected to continue, driven, for example, by population and economic growth, leading to an increasing demand for both food and energy (Haberl et al., 2009). Land management intensity can be mapped using a combined indicator based on crop yields and the application of nitrogen fertilisers, as shown in Map 4.8 in Chapter 4 (EEA, 2015a).

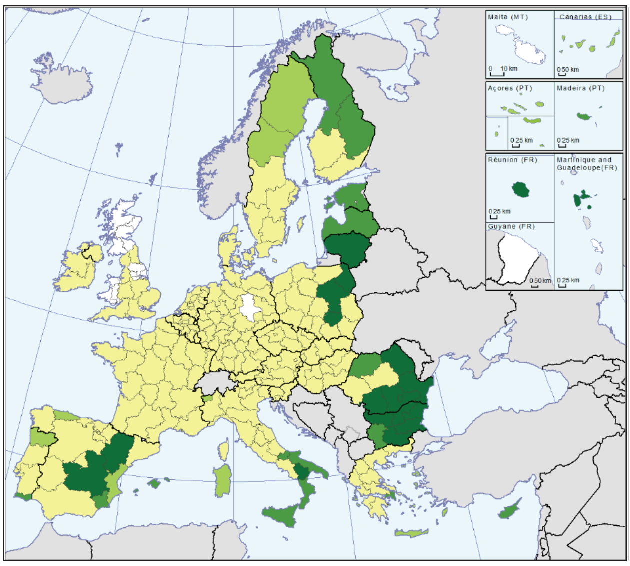
Another indicator of agricultural intensity is the proportion of extensive farming, defined as cropland areas with a cereal yield below 60 % of the EU average of 4.9 tonnes/ha, or grassland with a stocking density not exceeding 1 livestock unit per hectare of forage area. This is influenced both by the choice of management method and by the natural productivity of the land (determined by factors such as soil type and climate). Only 12 % of the utilised agricultural area in the EU-27 is devoted to extensive crop production (EC, 2012b). Extensive crop production is most common along the eastern and southern part of the EU, especially among newer Member States (e.g. Bulgaria with 83 %) (Map 5.7).

Invasive alien species

Invasive alien species can be both a threat to and an advantage for agriculture in Europe. In cropland ecosystems, invasive plant and animal pests can impede crop development and affect the quantity and quality of production, with high costs for the agricultural industry. For instance, species such as the Spanish slug (*Arion vulgaris*), now found in most European countries, are devastating to crops. Other impacts are indirect, by interfering with fundamental functions such as pollination. For example, European honeybees (*Apis melifera*) are badly affected by the mite *Varroa destructor*, a parasite originating in Asia.

On the other hand, many non-native tree and crop species have been introduced to Europe intentionally. Such species are more productive or better adapted to

Map 5.7 Share of utilised agriculture land for extensive arable crop



Share of utilised agriculture land for extensive arable crop

Percentage
- 0
- 0–25
- 25–50
- > 50
- No data
- Outside coverage

European Commission | Agriculture and Rural Development

Source: EC, 2012b.

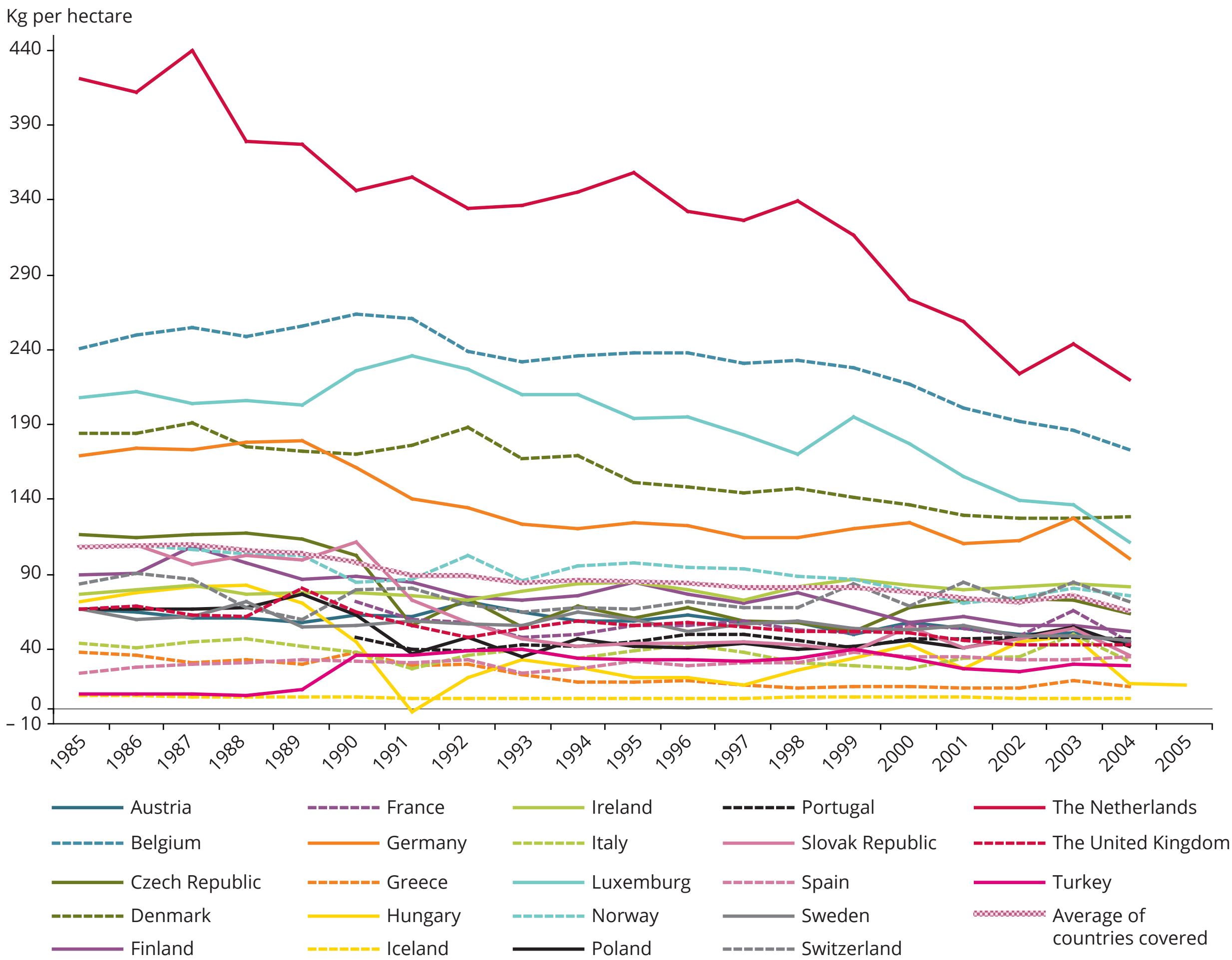
the local climatic conditions. However, they have often spread or been released into the environment with negative impacts for multiple ecosystems (EC, 2014e).

Pollution and nutrient enrichment

The agricultural sector is a significant contributor to nutrient enrichment and pollution in Europe, owing to the widespread input of organic and inorganic fertilisers in intensive production. The amount of nitrogen and phosphorus originating from chemical fertilisers, manure and atmospheric deposition still exceeds the amount taken up by crops and grazed biomass (ETC/SIA, 2013b; EEA, 2015b). Figure 5.4 shows the evolution of the nitrogen balance per hectare of agricultural land in Europe over time, with each country showing a surplus. Although the nitrogen surplus is generally declining, the absolute values remain high in some countries, such as Belgium and the Netherlands, indicating a pressure on the environment and biodiversity that is higher than the carrying capacity of the ecosystems. Nitrogen input rates across the EU are shown in Map 5.8, which is derived from nutrient accounts developed by the ETC/SIA (2014e).

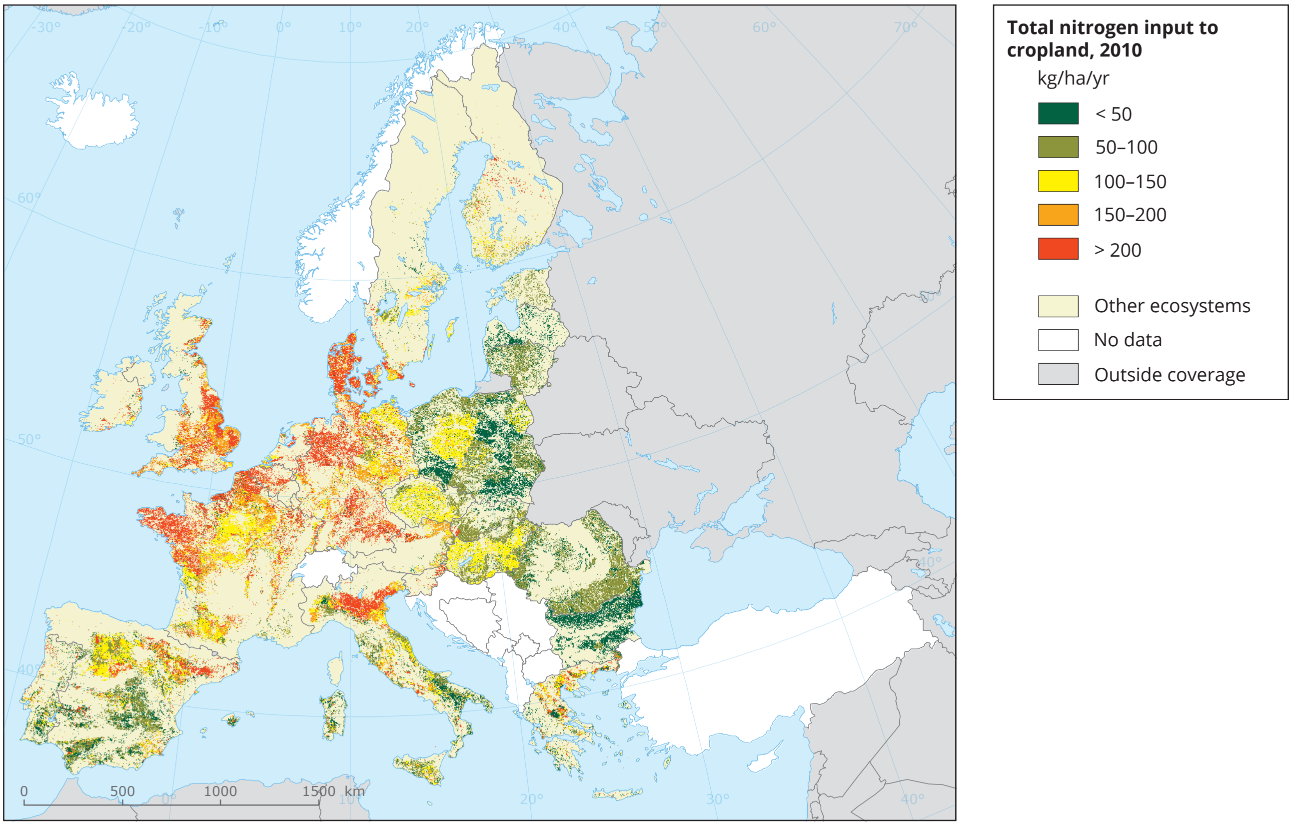
The intensive use of fertilisers can result in diffuse pollution through the loss of nutrients to water bodies, which has led to a decrease in river and groundwater quality and an increase in eutrophication in most parts of Europe (EC, 2012b; ECNC, 2013) impacting, for example, human health and increasing the costs of physical and chemical treatment, which could outweigh the benefits arising from higher yields. Species used in extensive agriculture, mainly endemic arable plants, are more severely affected by high nutrient contents (ECNC, 2013). Surplus nitrogen originating from manure and agricultural soils can also be lost to air as ammonia and nitrous oxide emissions, contributing to air pollution, acidification and climate change. Intensive cultivation of soil can reduce the organic matter and soil organism biodiversity, which can eventually lead to less productive land (EEA, 2015b, *Soil*).

Figure 5.4 Nitrogen balance per hectare of agricultural land, 1985–2004



Source: EEA, 2010c.

Map 5.8 Total nitrogen input to cropland, 2010



Source: EEA, 2015a. For agro-ecosystems (cropland and grassland combined) the nitrogen inputs comprise mineral fertiliser (49 %), manure (43 %), atmospheric deposition (6 %) and biological fixation (2 %).

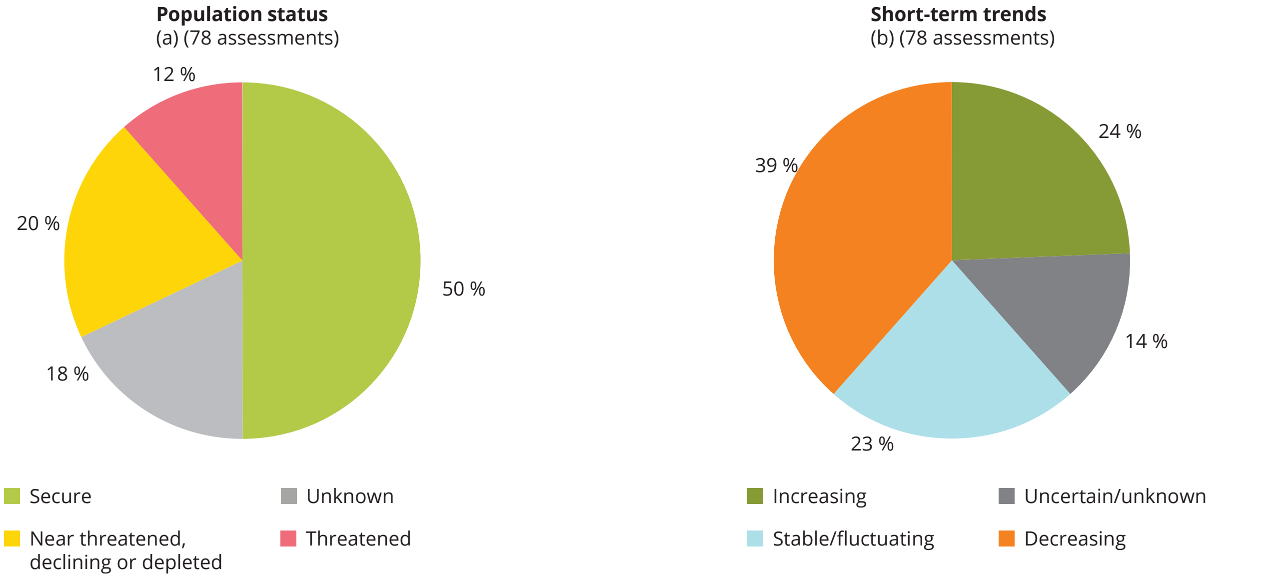
There has also been a significant decline in the recorded volume of pesticide use across the EU in the past two decades, although there are considerable national differences. Nevertheless, the use of new pesticides with more concentrated active ingredients means that there has not been a corresponding decline in environmental impact (EEA, 2015b, *Agriculture)*. The use of neonicotinoid pesticides in particular has been shown to result in concentrations in pollen, soil and water that are lethal to many invertebrates (Goulson, 2013). The wide-ranging effects of agrochemical use on biodiversity include a significant decline in pollinator populations and natural predators of pests leading to lower yields of pollinator-dependent crops and higher costs for pest control also in other ecosystems.

5.2.3 Condition

The pressures described above have affected cropland birds, with 12 % of species being threatened and a further 20 % near-threatened, declining or depleted. Around 39 % of bird populations are decreasing (Figure 5.5). Only 20 % of the cropland non-bird species protected by the Habitats Directive are assessed as having a favourable conservation status, with 50 % assessed as 'unfavourable-inadequate' and 20 % as 'unfavourable-bad', and for 30 % of the assessments the trend was 'unfavourable-declining' (Figure 5.6). This is less favourable than the assessments for birds, because the Habitats Directive assesses only rare, threatened or declining species or habitats. Note that no cropland habitats are assessed under the directive because of their low conservation importance.

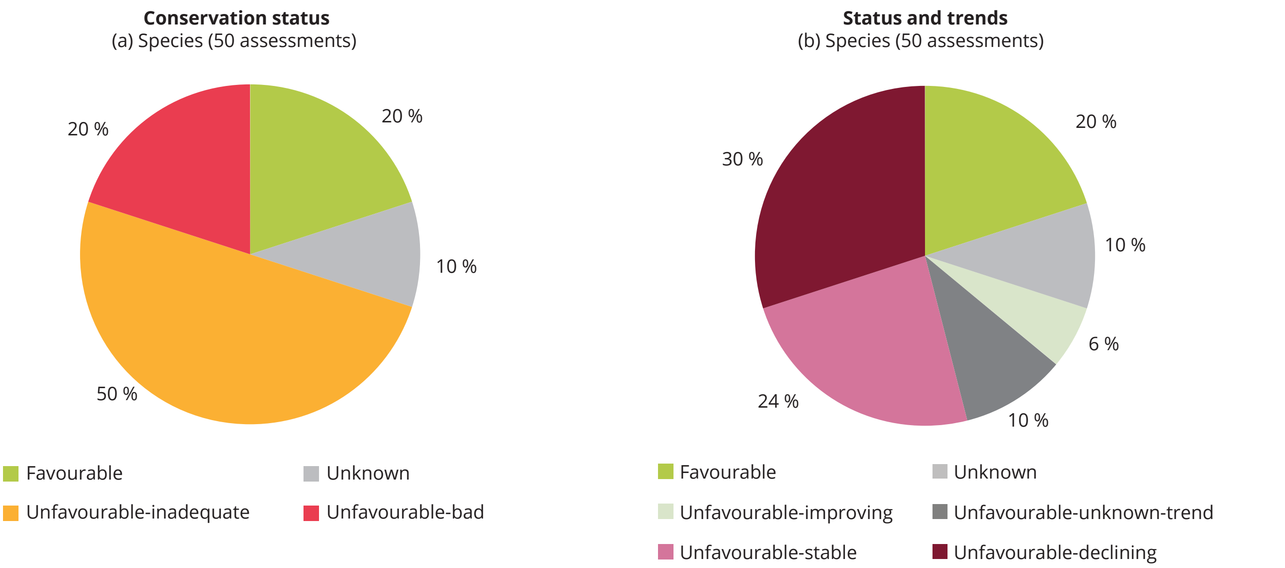
Condition can also be assessed through mapping high nature value (HNV) farmland, which indicates areas that have historically been managed at low intensity and therefore represent high biodiversity. A map of HNV cropland (farmland, excluding pastures) has been combined with information on agro-environmental species and habitat condition to produce a map of cropland condition (Map 5.9).

Figure 5.5 Population status and short-term trends in birds associated with cropland ecosystems



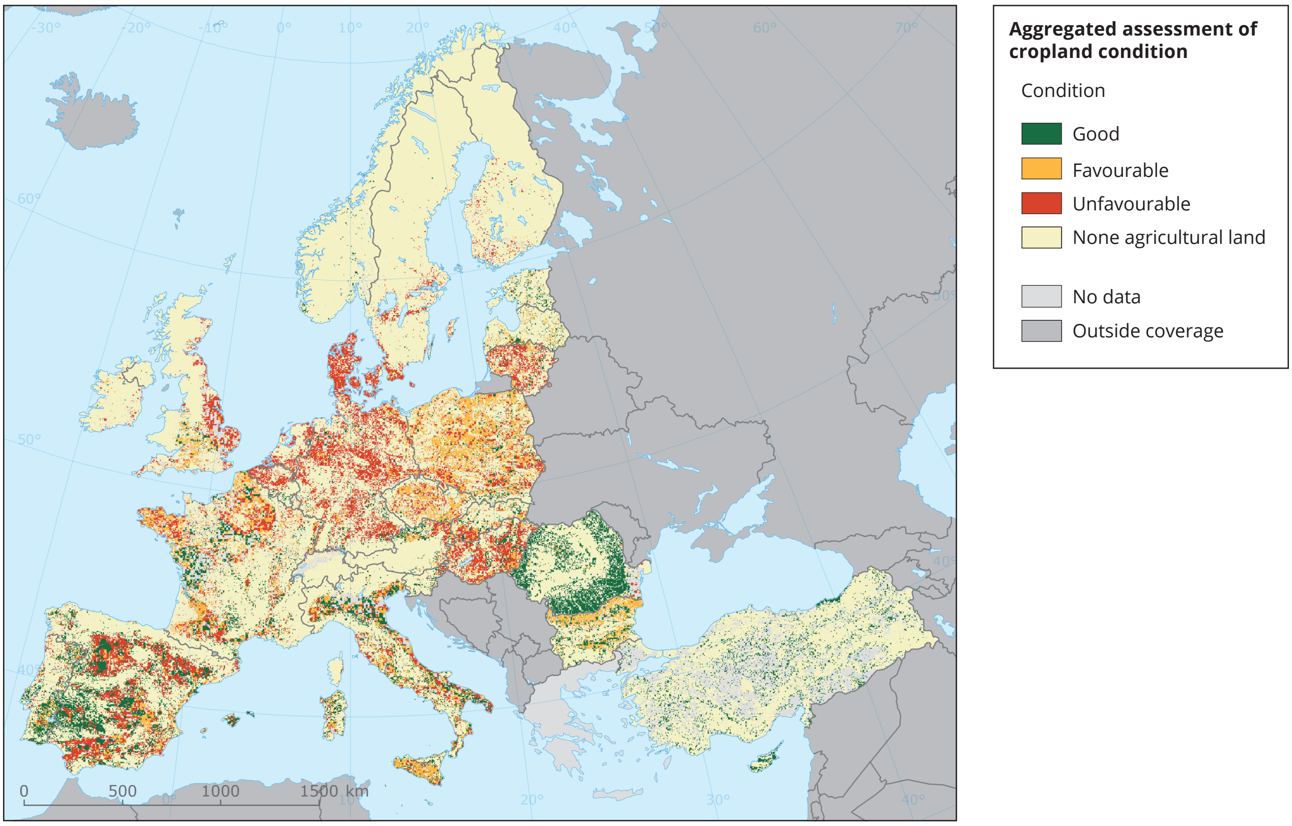
Source: EEA, 2015d.

Figure 5.6 Conservation status and trends in non-bird species associated with cropland ecosystems that are protected under the Habitats Directive



Source: EEA, 2015d.

Map 5.9 Aggregated assessment of cropland condition



Note: Cropland condition, based on aggregated assessment of multiple pressures and species or habitat conservation status, based on 2006 CLC data for farmed pastures and arable land with HNV. Pastures were excluded to avoid overlap with the grassland ecosystem. This was combined with information on habitat and species condition from the Habitats Directive reporting. The units are re-scaled (classified from unfavourable to good) because the input consists of information in different units.

Source: EEA, 2015a.

5.2.4 Policy response

Cropland in Europe serves multiple purposes and societal needs. Although food provision is the primary function, it is also a source of feed, fibre and fuel. Crop production has a negative impact on many regulating services such as water purification and carbon sequestration, although in some cases the situation is improving (e.g. as found by the United Kingdom National Ecosystem Assessment; Firbank and Bradbury, 2011). The long-term sustainability of cropland ecosystem services is being undermined by harmful farming practices, causing soil degradation and water contamination, as well as a decline in pollinators, the loss of natural biological pest control, and the loss of plant and animal genetic diversity (EEA, 2015b, *Agriculture*). There are also trade-offs between the use of cropland for food and for biofuel crops, which raises potential concerns about food security, especially as Europe already imports much of its food (ECNC, 2013).

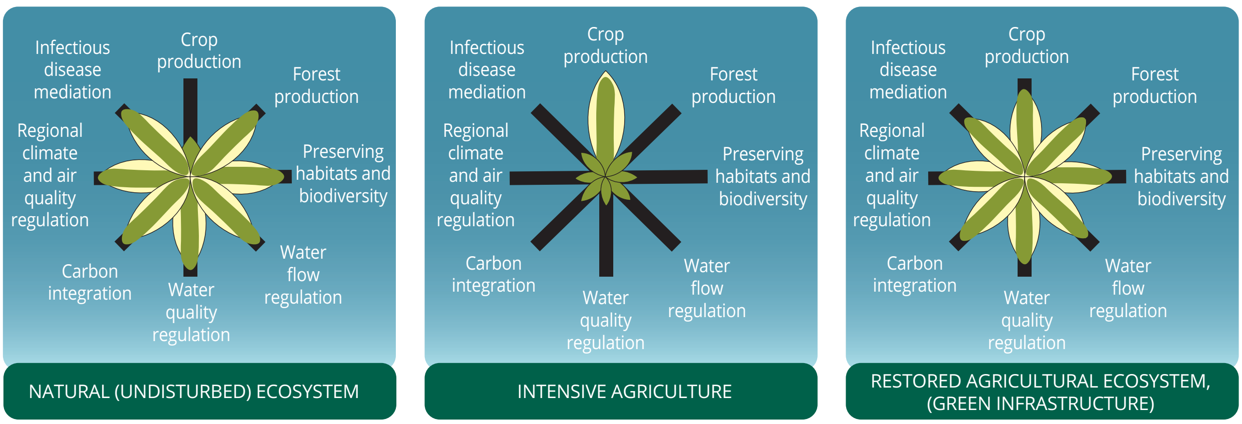
The challenge for policymakers is to reconcile these conflicts and trade-offs, balancing the increasing demand for food and biofuels with the need to reduce pressures on the environment, as well as adapting to a changing climate. The good agricultural and environmental condition criteria, part of the 2003 CAP reform, recognised the link between agricultural activities and the management of land and landscape and sought to ensure a minimum level of sustainability in farming practices. This also underlies Target 3 of the EU Biodiversity Strategy, on sustainable agriculture and forestry. Debates on sustainable agriculture include those around the choice between intensive or extensive use of land (EEA, 2013b), and between 'land sharing', whereby agricultural production takes place within complex multifunctional landscapes, or 'land sparing', whereby agricultural production on already cultivated or marginal land is maximised, so that other areas are set aside for the conservation of biodiversity. While intensive crop production is still ongoing in Europe, it is widely accepted that further reductions in nutrient pollution from agriculture are necessary. Organic farming (which does not use pesticides or inorganic fertilisers) is estimated to yield roughly 20 % less than intensive agriculture, but at the same time it improves the capacity of cropland ecosystems to provide more or better services with higher biodiversity and reduced costs in other sectors (e.g. water purification). In the first instance, such land management measures may call for more land to be allocated to agriculture to keep production on the same level, but other policy targets, such as reducing food waste by improving resource efficiency, have the potential to cope with a reduced harvest. In terms of land sparing versus land sharing, Herzog and Schüepp (2013) conclude that land sparing is not appropriate for Europe for either productive or marginal land.

One of the main policy tools is the CAP, which has supported agriculture in Europe since 1962, pushing cropland ecosystems towards intensive production at the cost of all other services including preserving habitats and biodiversity, water purification and flow regulation, carbon sequestration, regional climate and air quality regulation, etc., as illustrated in Figure 5.7. This support has evolved over time, spurred by the growing recognition of agriculture's impacts on the environment and increased interest in the EU's policy agenda for food security, that is, stable access to an affordable food supply of sufficient quality. The recent CAP reform (2014–2020) aims to guarantee food security and improve environmental performance in rural areas that are faced with large-scale competition for land. It recognises that farmers should be rewarded for the services they provide to the public, even though these might not have a direct market value (EEA, 2015b). Likewise, the Rural Development Policy focuses on improvements in employment, growth and innovation in rural areas, as well as the provision of support in land management and the fight against climate change. Projects range from preserving water quality to sustainable land management or planting trees to prevent erosion (ETC/SIA, 2014c).

Cropland ecosystems and agricultural production are also regulated under the Birds and Habitats Directives, the Water Framework Directive, and environmental measures for limiting greenhouse gas emissions. Despite progress in enacting and implementing these policies, Europe's biodiversity continues to decline, especially birds in farmland (EEA, 2015d), nutrient pollution is still exceeding critical limits and the agriculture sector still contributes about 10 % of the total anthropogenic greenhouse gas emissions in Europe (EEA, 2014e), although emissions have declined by 22 % since 1990 (EEA, 2015b, *Agriculture*).

If cropland ecosystems are properly managed, they can become a reservoir of biodiversity (ETC/SIA, 2014c). Emerging sustainable farming practices, such as organic farming, are now recognised through market prices that take into account the direct and indirect benefits of agricultural biodiversity. Organic farming is now regulated under clear farmland management criteria through EU legislation and has gained a label and increasing popularity with consumers (ECNC, 2013). Nevertheless, in 2012 only 5.7 % of agricultural land in the EU was estimated to be farmed organically (Eurostat, 2015). It also calls for the application of new innovative cropland management methods such as mixed cropping or agro-forestry systems.

Figure 5.7 Capacity of cropland ecosystems to provide services under natural conditions, intensive and balanced management



Source: EC, 2010a; adapted from Foley et al., 2005.

Box 5.4 Case study: demonstrating the benefits of precision agriculture in Greece

A Greek LIFE project set out to optimise crop yields, while at the same time protecting the soil and reducing water and energy use. Employing site-specific management and advanced proximal remote sensing, it was able to improve efficiency in the use of water, fertilisers and pesticides in the production of cotton.

Precision agriculture (or site-specific management) is an emerging approach that promises to develop more sustainable management systems. It recognises that agricultural fields have varying soil fertility and water availability, and thus different fertiliser and irrigation requirements. Sustainable farming is particularly relevant for Greece and other Mediterranean countries, where water can become scarce as a result of heavy consumption by agriculture and the use of pesticides and chemical fertilisers is often high.

The project was carried out on the Thessaly Plain, one of Greece's main agricultural areas. The plain is well-known for the production of cotton and wheat, which are crops with a high water demand. However, surface water and groundwater resources are minimal and support only limited irrigation that is mainly achieved by pumping water from declining groundwater aquifers.

The transition to precision agriculture included 'mapping' the field's water and nutrient needs. Different types of electronic sensors were used to construct two electronic maps to show the points in the field that needed water, and those that had fertiliser requirements. These maps were passed on to the farmer and training sessions were held for stakeholders.

The project also carried out plant protection by installing special traps for insect pests and a device that scans the rows of crops and sprays herbicide only on those areas where weeds are growing.

The project established a 'Smart Crop' system for managing fields, which achieved on average an 18 % decrease in water use, a 35 % decrease in nitrogen fertiliser use and a 62 % reduction in herbicide use. Varying the rate of irrigation also reduced energy use by 20 %.

Source: EC, 2014a.

5.3 Grassland ecosystems

5.3.1 Characteristics

Semi-natural temperate grasslands are among the most species-rich vegetation types in Europe (Wilson et al., 2012). There are two main grassland ecosystem types: managed pastures and natural or semi-natural (extensively managed) grasslands (Maes et al., 2013). Most European grasslands are considered to be semi-natural ecosystems because they have developed over long periods of grazing, cutting or deliberate light burning regimes and therefore are modified, created or maintained by agricultural activities providing habitats

Box 5.5 Key messages for grassland ecosystems

- Grasslands, which have traditionally been managed through grazing or cutting, include some of the most species-rich habitats in Europe, and they have the richest soil biodiversity. They are the source of a wide range of ecosystem services, ranging from meat and dairy products to recreational and tourism opportunities, and they also act as carbon sinks.
- Over the last century, more than 90 % of semi-natural grasslands have been lost in most European countries owing to intensification or abandonment, and populations of a large number of grassland species have declined or become extinct. Almost half (49 %) of the grassland habitats assessed under the Habitats Directive are in 'unfavourable-bad' condition.
- It is therefore imperative for EU rural development policies to reconcile agricultural development and conservation through measures such as agri-environment schemes.

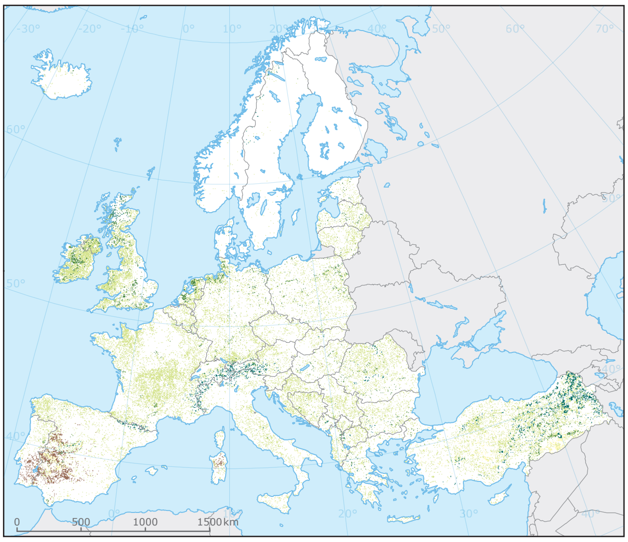
for species that would not survive without grassland management measures (ETC/SIA, 2014d). There are also some more natural 'permanent grasslands' in Europe, such as alpine and subalpine or chalk grasslands, the distribution of which is determined by natural conditions including climate, topography and soil structure (EC, 2008c). Grasslands are very variable, ranging from dry grasslands and steppes to humid grasslands and meadows and from lowland to montane grasslands (Map 5.10).

Grassland ecosystems are the third most dominant ecosystem within the EU (after cropland and woodland), representing approximately 16 % of the area of EU ecosystems, although only 15 % of their total area is designated as Natura 2000 sites (see Figure 3.2 and Figure 3.5). Over the last century, more than 90 % of semi-natural grasslands have been lost owing to intensification or abandonment in most European countries, and a large number of grassland species have declined or become extinct (Gustavsson et al., 2011).

Only 21 % of the utilised agricultural area in the EU-27 is devoted to extensive grazing with a stock density not exceeding 1 livestock unit per hectare of forage area (EC, 2012b). Compared with extensive crop production, extensive grazing is more widespread, especially in the south-western part of the EU, and the proportion is particularly high in Portugal (59 %), Latvia (58 %), Estonia (55 %) and Sweden (52 %) (see Map 5.11). In areas with a high proportion of both extensive cropland and grazing, such as in parts of Scandinavia and eastern Europe, the reduced pressures could lead to better ecosystem condition.

As noted in Section 5.2, there is some potential overlap between cropland and grassland ecosystems in reports referring to agro-ecosystems. Nevertheless, there are very specific pressures and impacts on grasslands that do not apply to croplands, while the services provided are also quite distinct. Grasslands, and in particular natural grasslands, are generally more important for biodiversity than croplands.

Map 5.10 Grassland ecosystems in Europe

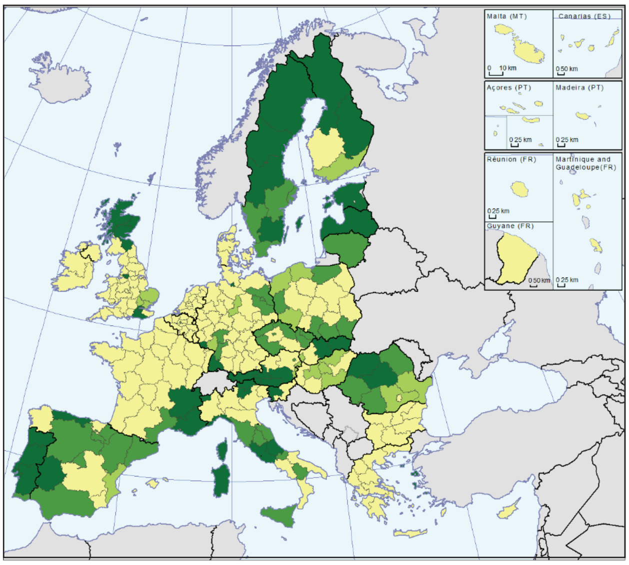


Grassland ecosystems in Europe

- Dry grasslands
- Mesic grasslands
- Seasonally wet and wet grasslands
- Alpine and subalpine grasslands
- Inland salt steppes
- Sparsely wooded grasslands
- Areas not covered by grassland ecosystems
- Outside coverage

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015.

Map 5.11 Share of utilised agriculture land for extensive grazing



Share of utilised agriculture land for extensive grazing

Percentage

- 0
- 0–25
- 25–50
- > 50
- Outside coverage

European Commission | Agriculture and Rural Development

Source: EC, 2012b.

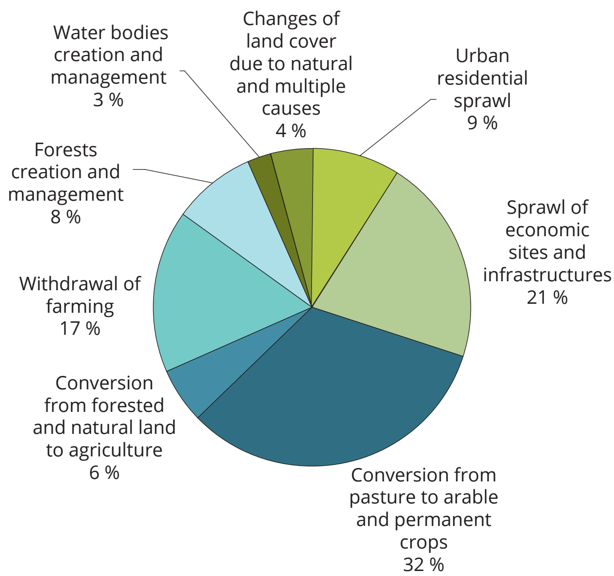
5.3.2 *Drivers and pressures*

The main pressure on grassland ecosystems is habitat change, both from land take, e.g. for cropland or urban development (Figure 5.8) and from land abandonment (Table 5.3). The most frequently reported pressures by Member States were the modification of cultivation practices, including agricultural intensification and conversion of grasslands to arable land, as well as the abandonment of mowing or grazing, leading to replacement of grassland by shrubs or forests (EEA, 2015d).

Habitat change

The main reasons for the loss of grassland habitats in Europe are urban sprawl and development, conversion of pastures and (semi-natural) grasslands to arable land (in areas where agriculture is profitable), and land abandonment, causing grassland to revert to shrub land or forest (in areas where socio-economic conditions are unfavourable for farming). There are regional differences. For example, grassland areas in western Europe were, to a large extent, converted to fodder maize and cash crops from 1975 to 1990, whereas in eastern European countries (e.g. Bulgaria and Romania) more than 30 % of grassland areas were abandoned (Peeters, 2009) As shown in Figure 5.8, these processes are still ongoing (EEA, 2015g), most likely further enhanced by increasing production of biofuels and the subsequent conversion of grassland into cropland. Examples from Spain also show how hay meadows have been abandoned and traditional grazing with sheep and goats has declined, accompanied by the loss of farmers and massive depopulation of rural areas (Dover et al., 2011). Map 5.12 shows the regional differences in grassland abandonment across Europe.

Figure 5.8 Causes of loss of grasslands, 2000–2006



Source: EEA, 2015g. Preliminary results from CLC 2006–2012 analysis indicate a reduction in conversion of grasslands but a slight increase in the contribution of urban land take relative to other land cover classes.

Natural succession resulting from land abandonment can transform semi-natural ecosystems, which are often dependent on low inputs of fertilisers, grazing and mowing, into scrubland and forest vegetation types. This results in species changes and structural changes from tall herbs and grasses to shrubs, and then to woodland (Prévosto et al., 2011). Species adapted to these extensive management regimes are losing their habitats, and landscapes become less attractive for tourism if open grassland with forest

Table 5.3 Major pressures on grasslands, and their impacts on biodiversity in Europe

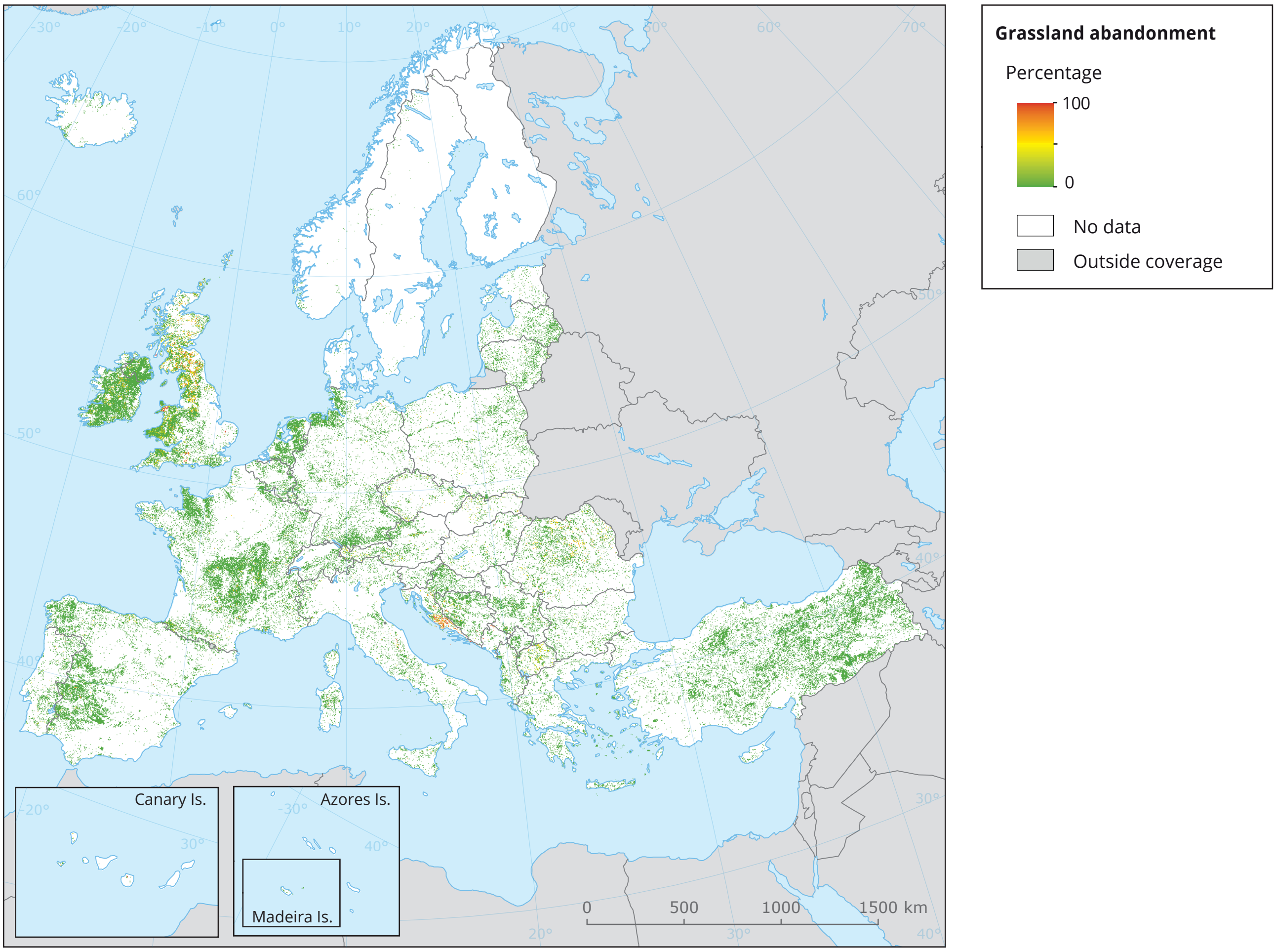
Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Landscape fragmentation Abandonment of grazing or mowing Land take Habitat loss	Changes in temperature and precipitation Extreme events Fires	Agriculture intensification Overgrazing Groundwater extraction	Expansion of invasive alien species	Fertilisers Nutrient run-off Critical levels of ozone Heavy metals

Key: Observed impact on biodiversity to date

Low	Moderate	High	Very high

Source: Adapted from EEA, 2015a, and ETC/SIA, 2014c.

Map 5.12 Grassland abandonment



Source: ETC/SIA, 2014a.

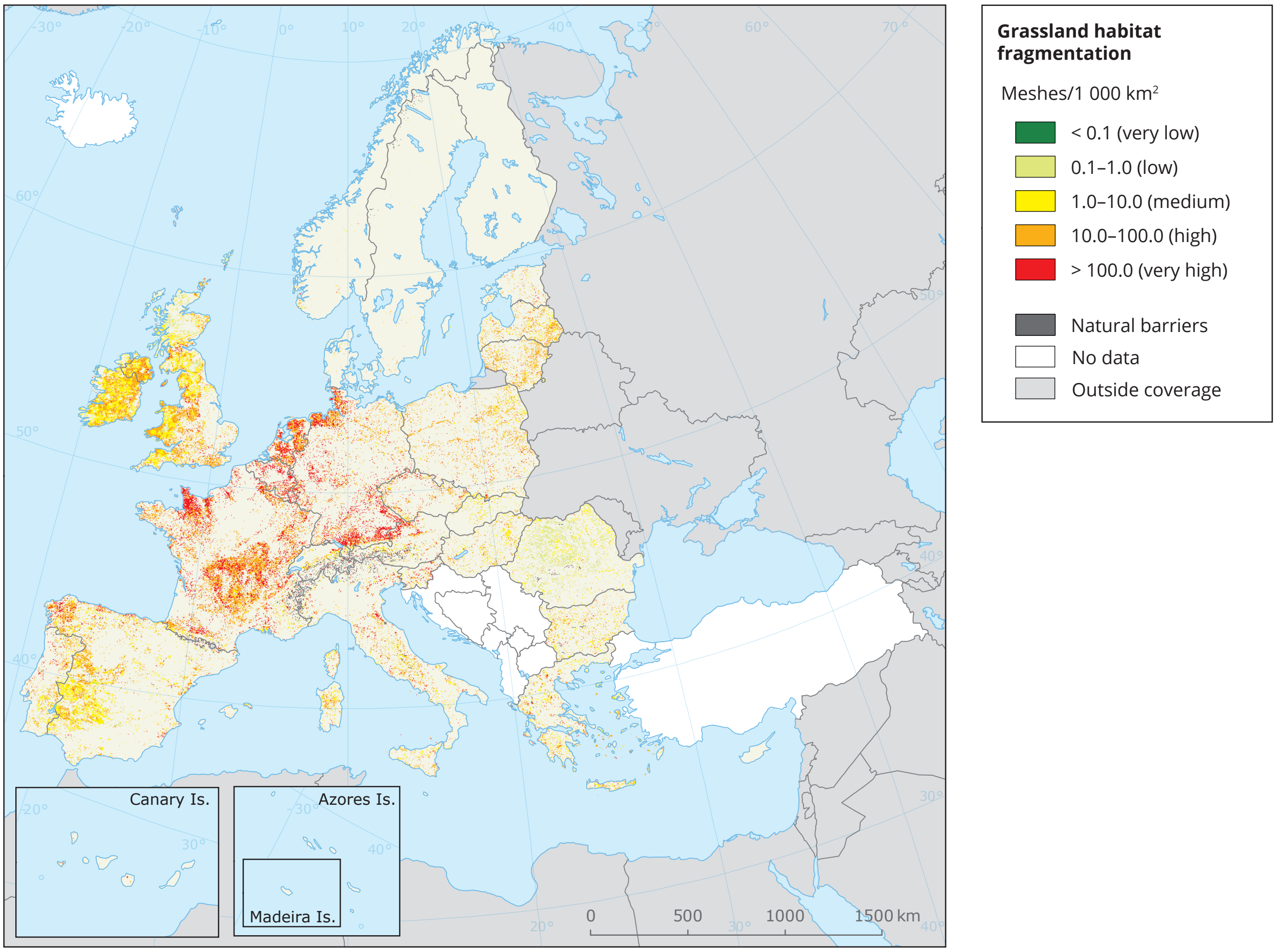
mosaics turn into more homogeneous scrubland and forests. This could be beneficial in increasing the area and connectivity of shrub and forest ecosystems, but it is also possible that abandoned land may be more prone to urban sprawl and economic development (although abandonment is more prevalent in remote rural areas where development is less of a threat).

Agricultural intensification, grassland conversion and land abandonment are resulting in habitat loss and fragmentation, and an associated loss of grassland biodiversity (ETC/SIA, 2014d). Map 5.13 illustrates the pressure of fragmentation on Europe's grasslands, using as a proxy the effective mesh density (meshes per 1 000 km^2) (EEA, 2011b). The mesh density indicator is a measure of the probability that two randomly chosen points are within the same patch of ecosystem. A high effective mesh density indicates that there are more barriers fragmenting the landscape, therefore the pressure on habitats is greater (ETC/SIA, 2014d). Central and north-western European grasslands are more fragmented than other regions. However, if grassland is replaced by shrub or forests, then the fragmentation of these habitats may be reduced.

Climate change

Although environmental variability is an integral part of the dynamics of grassland ecosystems, climate change alters the habitats of species favouring more thermophilic and xerophytic conditions at the cost of species adapted to a colder and wetter climate and intensifies seasonal disturbances and the frequency of extreme events such as fires. Changes in soil temperature and moisture levels can affect the abundance and composition of soil organisms, thus influencing plant physiology and community structure and potentially reducing productivity (ETC/SIA, 2014b). This can affect the amount of carbon stored in grassland soils, although there is a high level of uncertainty attached to the rate of carbon sequestration (EEA, 2012b). As with cropland, climate change could lead to increased sequestration of soil organic carbon in

Map 5.13 Grassland habitat fragmentation



Source: ETC/SIA, 2014a.

northern and central parts of Europe but decreases in southern and eastern Europe (Lugato et al., 2014). However, carbon storage may increase if abandoned grassland reverts to shrubs or forest land.

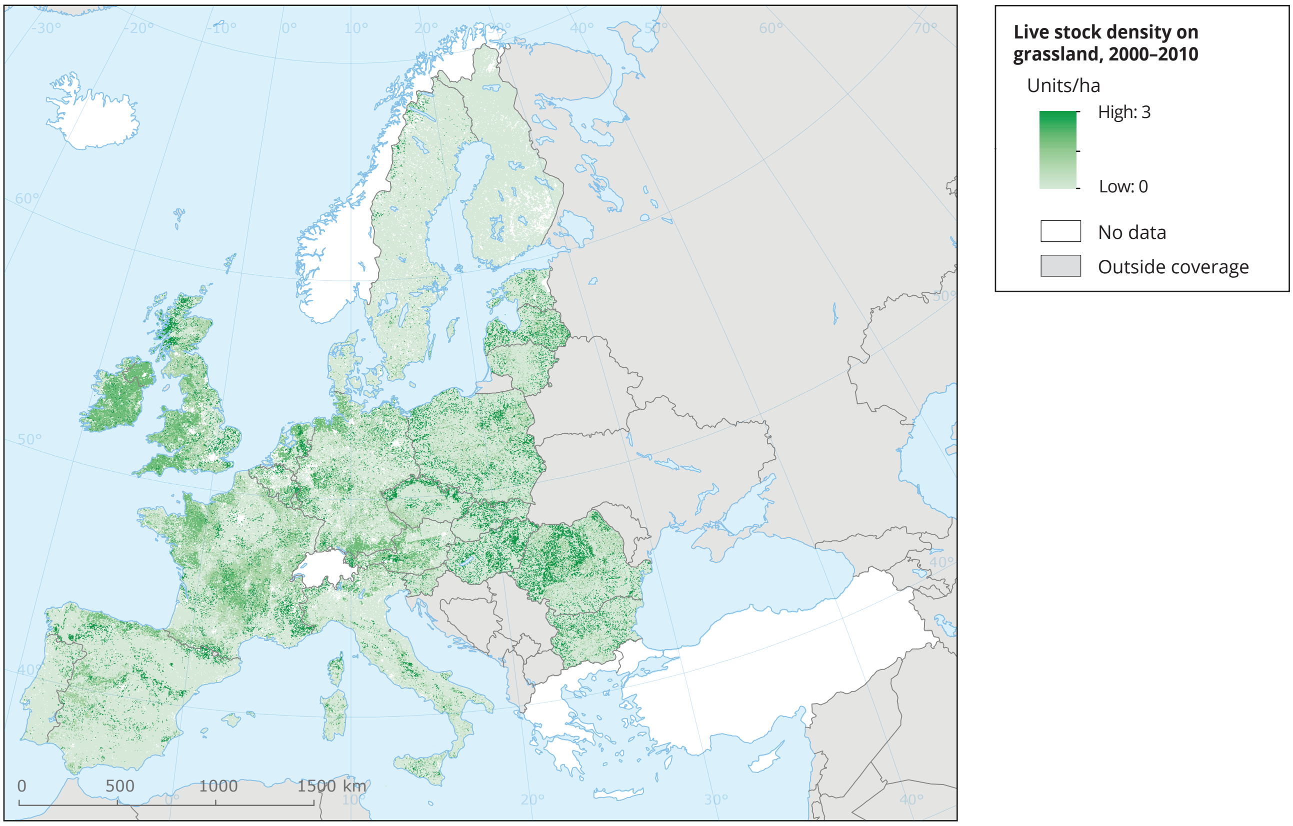
Overexploitation

The main overexploitation pressures on grassland are agricultural intensification and overgrazing. Socio-economic changes have resulted in varying trends and management intensities across Europe. For instance, whereas data from Greece suggest that traditional shepherded grazing of sheep and goats on mountain pastures is in decline, in other places grazing has intensified (ECNC, 2013). In addition, consumer demand influences grasslands in contrasting ways. Although the demand for food is increasing because of the growing population, the preferences of European citizens are shifting towards meat from pigs and poultry rather than beef and lamb (ETC/SIA, 2014c). The resulting changes in the number and distribution of livestock can profoundly affect grasslands and their value for wildlife (EC, 2008c), mainly by intensification of grassland management leading to shorter mowing intervals, higher inputs of fertiliser and pesticides or even regular ploughing and seeding of a small number of highly productive grass species, turning grasslands into monocultures.

Overall trends in the grazing activity in grassland ecosystems can be assessed using data from agricultural statistics and relating them to the land cover class grassland (Map 5.14). This indicates (among other factors) the pressure of grazing on grassland ecosystems, including other pressures such as nutrient enrichment by manure (ETC/SIA, 2014a).

Intensification of grassland management leads to a number of pressures, such as the use of fertilisers and pesticides, as well as the introduction of alien plants and mechanical mowing techniques. This change in management may increase plant density and biomass, but it also reduces the structural and floristic diversity of

Map 5.14 Live stock density on grassland, 2000–2010



Source: ETC/SIA, 2014a.

grasslands (EC, 2008c) and can decrease soil organism biomass (de Vries et al., 2011). Because of this, the prevalence of extensive grazing can be used as an indicator of good grassland condition (see Figure 5.9).

Invasive alien species

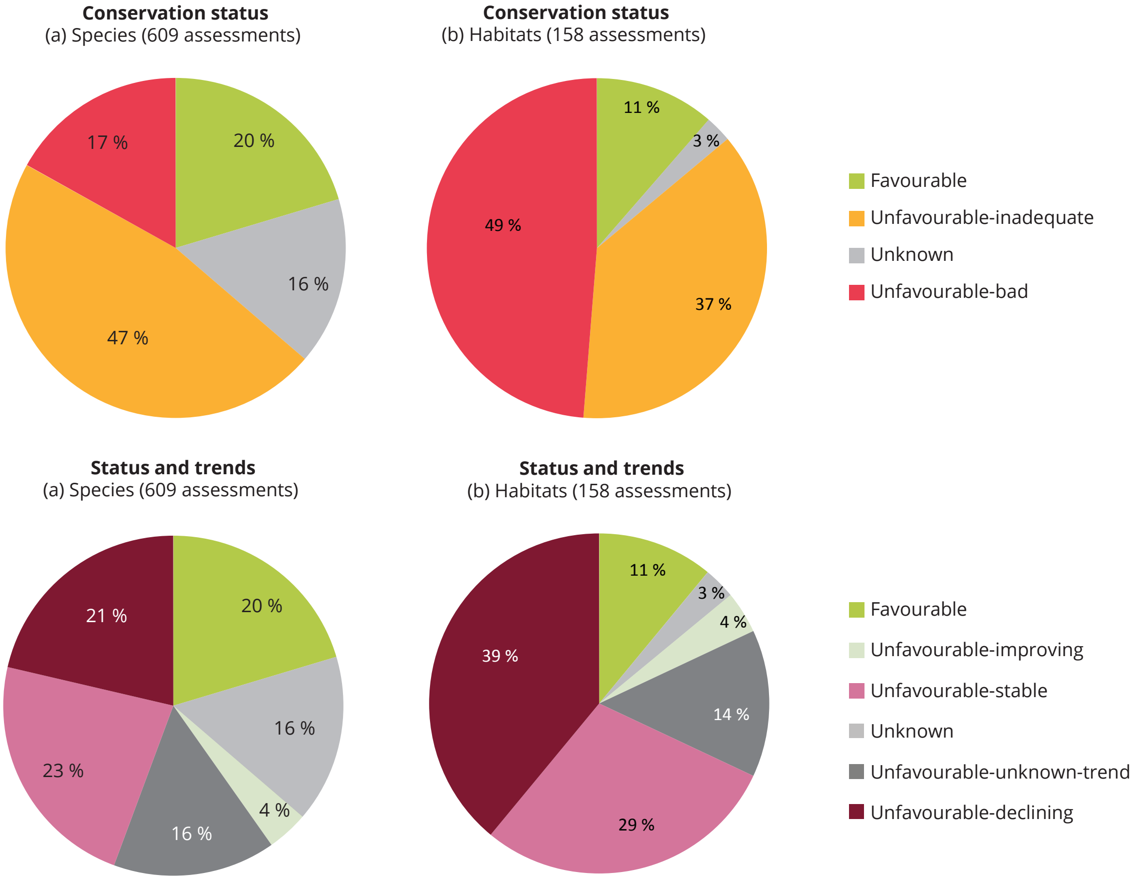
Intensive grassland management can include reseeding with improved or alien grass varieties (EC, 2008c). In addition, changing climatic and soil conditions may favour non-native species. When regular management through traditional cutting or extensive grazing is abandoned, increased nitrogen fertiliser applications can allow a small number of more competitive taller grassland species to establish and become invasive, although these are often native, rather than alien, species.

Increasing competition with alien species threatens the less competitive European dry grassland species. It can reduce the populations of specialised species to below viable levels, so that they can be wiped out by negative events such as fluctuating climatic conditions (e.g. hard winters or dry summers), predators, genetic diversity loss in small populations, or disease. In these cases, local or regional extinction is probable, though it may not be immediately visible because of the time-lag between introduction of invasive alien species and disappearance of native grassland species (ECNC, 2013).

Pollution and nutrient enrichment

Intensification of farming practices through the use of pesticides and fertilisers has degraded grassland soil quality, biodiversity and soil organism biomass (de Vries et al., 2011), either directly or through agricultural run-off. The key pollution pressure on grasslands is excessive nitrogen inputs to the soil from organic and inorganic fertiliser application, further enriched by the atmospheric deposition of nitrogen (Map 5.15). Most grassland communities in Europe are dominated by species with low nutrient requirements, which are, therefore, very sensitive to elevated nitrogen levels. Nitrogen enrichment can encourage the growth of competitive plant species, reducing the structural diversity of grasslands, in terms of both species composition and abundance (EEA, 2015a). Another pressure is acidification from the atmospheric deposition of sulphur and nitrogen oxides from fossil fuel

Figure 5.9 Conservation status and trends in non-bird species and habitats associated with grassland ecosystems that are protected under the Habitats Directive



Source: EEA, 2015d.

combustion. Grasslands on acidic, nutrient-poor soils are particularly vulnerable to acidification, because they have limited buffering capacity. Calcareous grasslands, in contrast, are affected more by eutrophication than by acidification (Horswill et al., 2008).

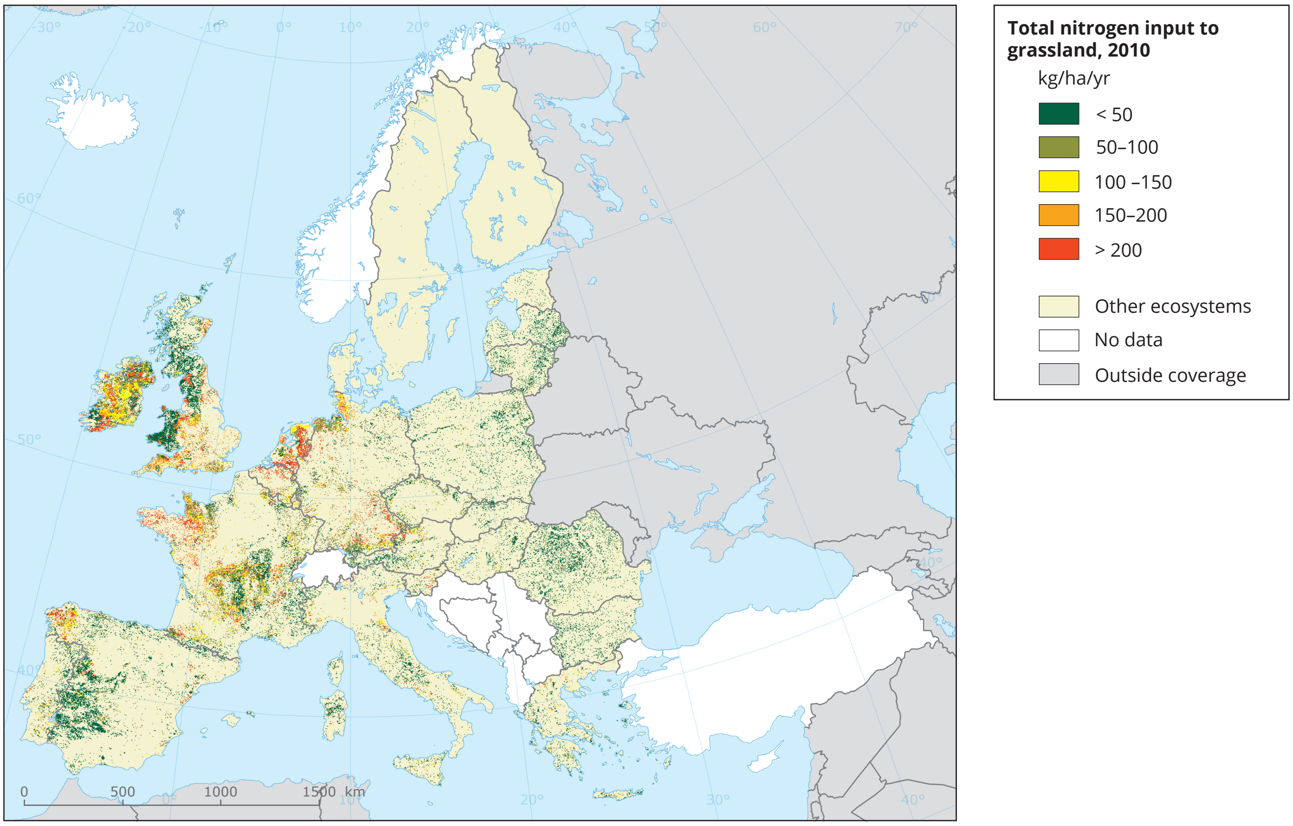
5.3.3 Condition

Grasslands include some of the most species-rich habitats in Europe, at least for vascular plants. Indeed calcareous (chalky) grasslands are Europe's most species-rich plant communities, hosting up to 80 plant species per square metre (Wilson et al., 2012). This extremely high plant diversity gives rise to high arthropod diversity (e.g. butterflies) and can support grassland-adapted birds and other species such as rodents (EC, 2008c). These grassland habitats, therefore, offer ideal conditions for a vast diversity of habitats and species, and provide vital breeding grounds for birds and invertebrates.

However, habitat and land use changes have resulted in a continued decline in grasslands since the 1990s and — as a consequence — a decline in biodiversity (ETC/SIA, 2014c). The conservation status of 49 % of grassland habitats assessed under the EU Habitats Directive was reported as 'unfavourable-bad', while 37 % were 'unfavourable-inadequate' and only 11 % were 'favourable' (EEA, 2015d). Similarly, for non-bird species only 20 % of those assessed were reported to be in favourable condition, with 47 % inadequate and 17 % bad (Figure 5.9).

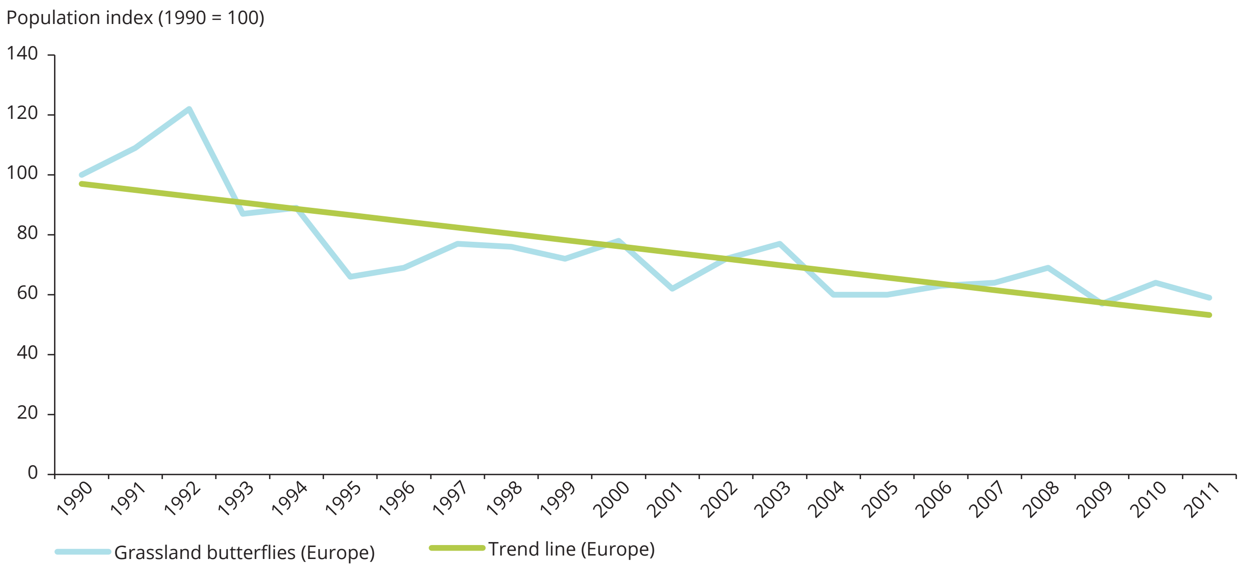
Another indicator of the decreasing condition of grassland ecosystems is the decline in the populations of grassland butterflies of almost 50 % between 1990 and 2011 (Figure 5.10).

Map 5.15 Total nitrogen input to grassland, 2010



Source: ETC/SIA, 2014e. For agro-ecosystems (cropland and grassland combination) the nitrogen inputs comprise mineral fertiliser (49 %), manure (43 %), atmospheric deposition (6 %) and biological fixation (2 %).

Figure 5.10 Grassland butterfly indicator for 17 species in Europe



Note: Annual change (%) in grassland butterfly population (green line) and trend (blue line). Year 1990 = 100 %.

Source: http://www.eea.europa.eu/data-and-maps/daviz/european-grassland-butterfly-indicator#tab-chart_1, accessed 12 December 2015.

5.3.4 Policy response

Grasslands provide multiple ecosystem services. For example, extensively managed permanent grassland provides food, regulates water flows and soil erosion, acts as a carbon sink, supports nutrient cycling, offers recreational and tourism opportunities and has high biodiversity value. The link between agriculture and grassland habitats is very important, with most European grasslands being managed through grazing or cutting. However, changes in agricultural practices and land use pressures have caused grasslands to disappear at an alarming rate, rendering them among Europe's most threatened ecosystems. The declining condition of the remaining grasslands has an impact on their delivery of ecosystem services and biodiversity, reducing, for example, the pollination service and the attractiveness of the landscape (Maes et al., 2013).

The EU Biodiversity Strategy, together with the reform of the CAP, attempts to halt these losses and maximise the potential synergies between food production and other services by rewarding farmers for the maintenance of permanent grassland (EEA, 2016e). The Habitats and Birds Directives also address the protection of Europe's grasslands, and the EU Rural Development Policy aims to reconcile agriculture with the objectives of EU nature conservation policy. This goal includes agri-environmental measures that have a direct impact on the conservation of European grasslands, through the maintenance of permanent grassland and support through Natura 2000 designated sites (EC, 2012b). Copernicus high-resolution layer grassland and very high resolution layer riparian areas will help to measure progress in grassland maintenance across Europe by monitoring the changes (see Copernicus, 2015).

Box 5.6 Case study: National Grassland Inventory (Slovakia)

The grassland inventory of Slovakia was organised by the non-governmental organisation (NGO) DAPHNE — the Center for Applied Ecology — and it ran from 1998 to 2006. Later phases of the inventory were also funded by the Global Environmental Facility and the Slovak Ministry of the Environment.

Field mapping of grasslands with a natural species composition was carried out covering the whole country. Surveyors recorded the vascular plant composition, estimated the cover using a standardised methodology and recorded other important data (e.g. habitat type, cover of trees and shrubs and management). More than 100 surveyors were involved, and they recorded an area of 323 000 ha, representing more than 96 % of the preselected grassland area in Slovakia. The project database contains nearly 1 million records of species occurrence.

Data from the inventory were used for several purposes. They served as a basis for the identification of the best grassland sites for the Natura 2000 network. The information system was also widely used to certify the natural species composition of sites receiving agri-environmental payments under the programme for the conservation of semi-natural and natural grasslands. Finally, it is expected that the data will be used for the recently initiated official monitoring of Natura 2000 habitats. In 2012, they were used in the monitoring study focusing on the implementation of the agri-environmental programme. As most of the data were obtained before Slovakia joined the EU, comparison with the current state of its grasslands will allow an evaluation of the impact of EU subsidies on grassland biodiversity.

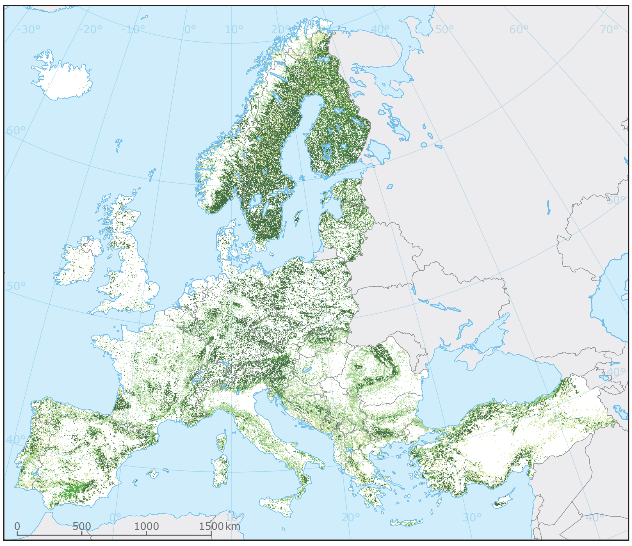
Source: EEA and MNHN, 2014.

5.4 Woodland and forest ecosystems

5.4.1 Characteristics

Woodland ([6]) and forest ([7]) is the most widespread ecosystem type in Europe, covering approximately 40 % of the EU-28 area (see Map 5.16), although the definition can vary across countries. Forest cover ranges from more than 60 % of the land area in northern Europe to around 10 % in western regions of Europe. The EUNIS classification lists 36 forest habitats, of which the boreal and temperate forests, including the large forest areas in the Scandinavian and Baltic countries, are the most prevalent in Europe. Most of Europe's forests (87 %) are semi-natural. These forests are the result of natural and planted regeneration but have kept their characteristics regarding stand composition and structure. Around 9 % of forests are commercial plantations, whereas only 4 % are natural forests, almost close to undisturbed by human activities (EEA, 2016c). More than 40 out of 180 million hectares (22.9 %) of total forest area is protected by Natura 2000. This is a relatively small proportion compared with some other ecosystems. However, woodland and forest ecosystems make up 50.5 % of the area protected by Natura 2000 sites (Figure 3.5). This reflects the importance of forests and woodlands for biodiversity and for providing multiple ecosystem services (see Section 5.4.4).

Map 5.16 Woodland and forest ecosystems in Europe



Woodland and forest ecosystems in Europe

- Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice
- Broadleaved deciduous woodland
- Broadleaved evergreen woodland
- Mixed deciduous and coniferous woodland
- Coniferous woodland
- Areas not covered by woodland and forest ecosystems
- Outside coverage

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015.

Box 5.7 Key messages for woodland and forest ecosystems

- Woodland and forest ecosystems have slowly increased in recent years to cover almost 40 % of the EU-28. About 73 % of Europe's forests are even aged and only 5 % have more than six tree species. Growing demand for wood and timber products is expected to intensify the pressure of exploitation and land use change, resulting in slightly unsustainable levels of harvest by 2020.
- Recent assessments of forest and woodland habitats under Annex I of the Habitats Directive reveal that only 15 % are in favourable conservation status while 80 % have unfavourable (inadequate or bad) conservation status.
- The EU Forest Strategy, adopted in 2013, aims to coordinate Member States' efforts in forest protection, biodiversity conservation and the sustainable use and delivery of forest ecosystem services. Thus, there is no common, legally binding forest policy in Europe.

([6]) Woodland is defined as an area with a high density of trees (McRoberts et al., 2009).
([7]) Forest is defined as land spanning more than 0.5 ha with trees higher than 5 metres 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 agricultural or urban. Woodland is the same except that canopy cover is 5–10 % (FAO, 2015).

5.4.2 Drivers and pressures

Increasing demands for land for agriculture, urban expansion and transport infrastructure, coupled with unsustainable exploitation for timber and wood products, climate change, pollution and nutrient enrichment, is driving habitat loss and the fragmentation and degradation of woodland and forest ecosystems (Maes et al., 2014) (Table 5.4). Member States report that the main pressures on species and habitats are forestry practices, especially felling and the removal of dead or dying trees (EEA, 2015d).

Habitat change

Land use change, habitat loss and degradation are key pressures affecting Europe's woodland and forest ecosystems. It is estimated that less than 5 % of forests in Europe remain undisturbed by humans, while 90 % are influenced to some extent by human interventions, although they still maintain their natural functions — hence they are characterised as semi-natural forests. The remaining 5 % are plantations heavily influenced by human intervention. While forest cover in Europe is increasing, the spatial pattern of forests across the landscape is also changing. Forest connectivity, dependent on forest presence and distance between patches of forest, is not always enhanced, with the trend revealing fragmentation at a local scale as a result of multiple habitat gains and losses, driven by land take for agricultural expansion, housing, transport infrastructure or recreation. Two-thirds of European forests are still in a core natural landscape pattern. One-third of forests are embedded in a mixed pattern of natural, agricultural and artificial lands and more than half of them appear very fragmented in a predominantly agricultural or artificial landscape.

Map 5.17 characterises the forest connectivity of each European country and the trends in landscapes with the most connected forests. Landscapes with poorly connected woodlands (below 30 %) represent more than 60 % of the EU. In most countries, the number of landscapes with highly connected forest (> 50 %) either remained stable or decreased from 2000 to 2012, suggesting that distance and landscape permeability between forest areas are not sufficiently accounted for in management and planning.

Efforts are being made across Europe to halt landscape fragmentation and re-connect environments through land and forest management (e.g. via the Natura 2000 Network). The large areas of managed forest land in Europe are considered to be central to Europe's ability to alleviate biodiversity loss (Maes et al., 2014).

Climate change

Climate change is expected to have both positive and negative impacts on forest structure, growth patterns, composition, productivity and functioning, depending on the location and type of forest (EEA, 2016c). For instance, alpine forests are more susceptible to changes in the hydrological cycle that affect precipitation and to reduced snow and glacier cover due to rising temperatures. Temperatures in the Alps increased by around 2 °C between the late 19th and early 21st centuries (EEA, 2010b). Southern European countries are also affected, but by different factors. Soil degradation is already intense in parts of the Mediterranean and central and eastern Europe and, together with prolonged droughts and fires, is already contributing to an increased risk of desertification (EEA, 2012b). In 2013, southern Europe recorded 36 000 fires and a burnt area of 291 000 ha (JRC and DG ENV, 2014).

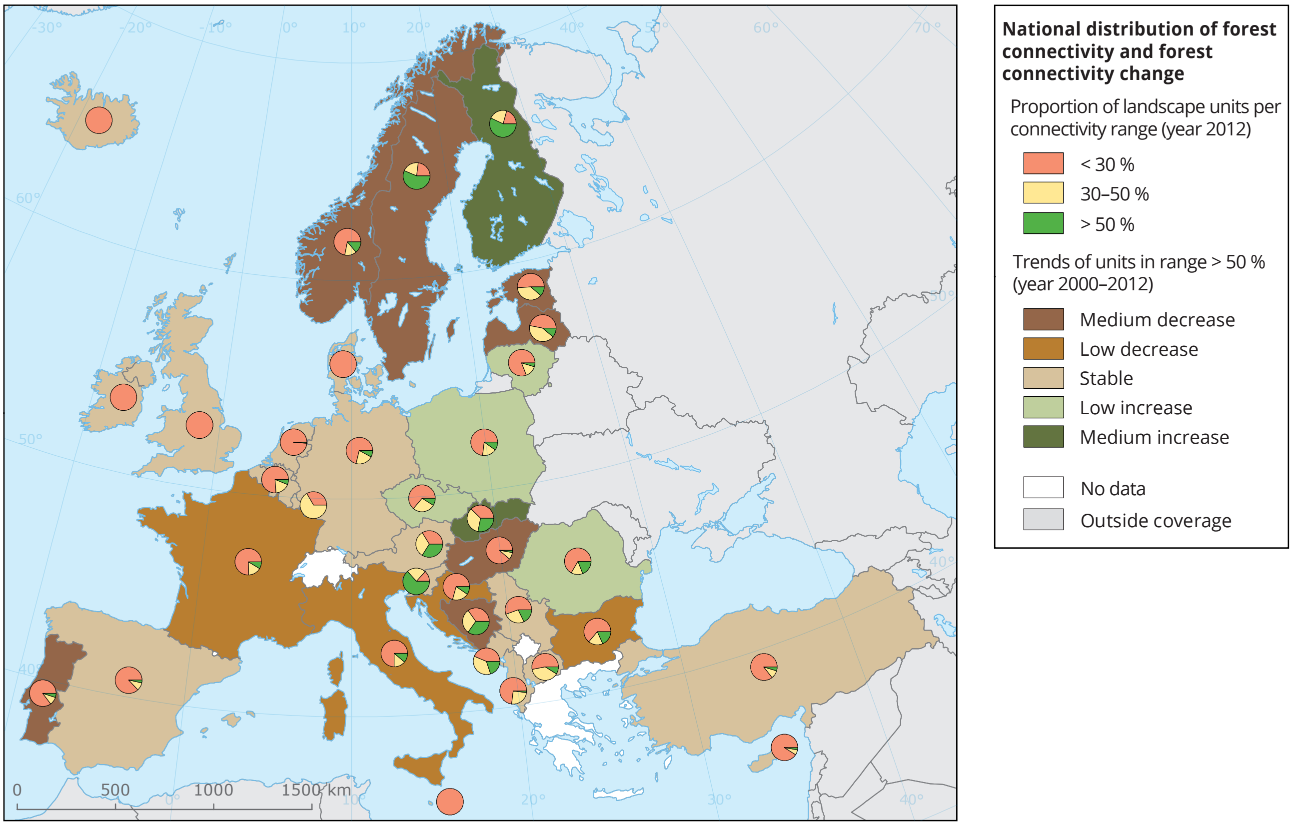
Table 5.4 Major pressures on woodlands and forests and their impacts on biodiversity in Europe

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Land use change: urbanisation, conversion to agriculture Changes in forest pattern Fragmentation due to roads, forest isolation	Changes in temperature and precipitation Fires Extreme events (droughts, frost, floods, storms) Pests and diseases	Unsustainable exploitation of timber and non-wood products Recreation and tourism Game hunting Overgrazing	Fast-growing invasive alien species Pests and disease agents, e.g. *Phytophthora*	Nitrogen enrichment Acidification Heavy metals Air pollution Critical levels of ozone

Key: Observed impact on biodiversity to date: Low, Moderate, High, Very high

Source: Adapted from EEA, 2015a, and ETC/SIA, 2014c.

Map 5.17 **National distribution of forest connectivity and forest connectivity change**



Note: Forest connectivity and trends for forest generalist species dispersing 1 km. The pie-chart shows the proportion of landscape units (25 × 25 km) in three connectivity ranges (poorly connected forests (red), intermediary (yellow), and highly connected forest (green) for the year 2012 in each country). The trend (medium/low increase/decrease or stable) in the proportion of landscape units with highly connected forest (above 50 %) is given for the period 2000–2012 per country. A decreasing trend means that such landscapes have undergone forest fragmentation (loss and/or isolation) processes.

Source: Estreguil et al., 2012, 2013; Forest Europe, 2015.

Changes in the frequency and severity of pest and disease outbreaks are also more likely, and the new conditions may lead to introduced forest species becoming invasive. An increased frequency and severity of summer drought in the southern European countries, and extreme precipitation events in northern European countries, will impact forest growth and phenology and species composition, altering the pattern of forest cover (EEA, 2010b).

It is challenging to distinguish the individual impacts of climate change from other drivers of ecosystem change, and often the impacts are contradictory. However, regardless of the regional variations, there is consensus that climate change already has, and will continue to have, direct and indirect impacts on the decline in forest health (EEA, 2016c).

Overexploitation
Scarcity of land and increasing demand for forest products, as a consequence of population growth and changing lifestyles, are prominent drivers of overexploitation in European forests. This is leading to deforestation and degradation of forests, although in some remote regions farm abandonment is leading to forest expansion (EEA, 2016c). There has been widespread replacement of biodiverse natural forests by plantations over the last century (EEA, 2016c). Today, 73 % of Europe's forests are even aged and 30 % are single species, with a further 51 % having only two to three tree species per forest and only 5 % having six or more tree species (Forest Europe et al., 2011). This results in a loss of biodiversity and ecosystem resilience and compromises the supply of essential climate- and water-regulating services, while also affecting recreational and economic opportunities. The use of (dead-)wood as fuel is another pressure that affects forest biodiversity and service capacity (EEA, 2015s).

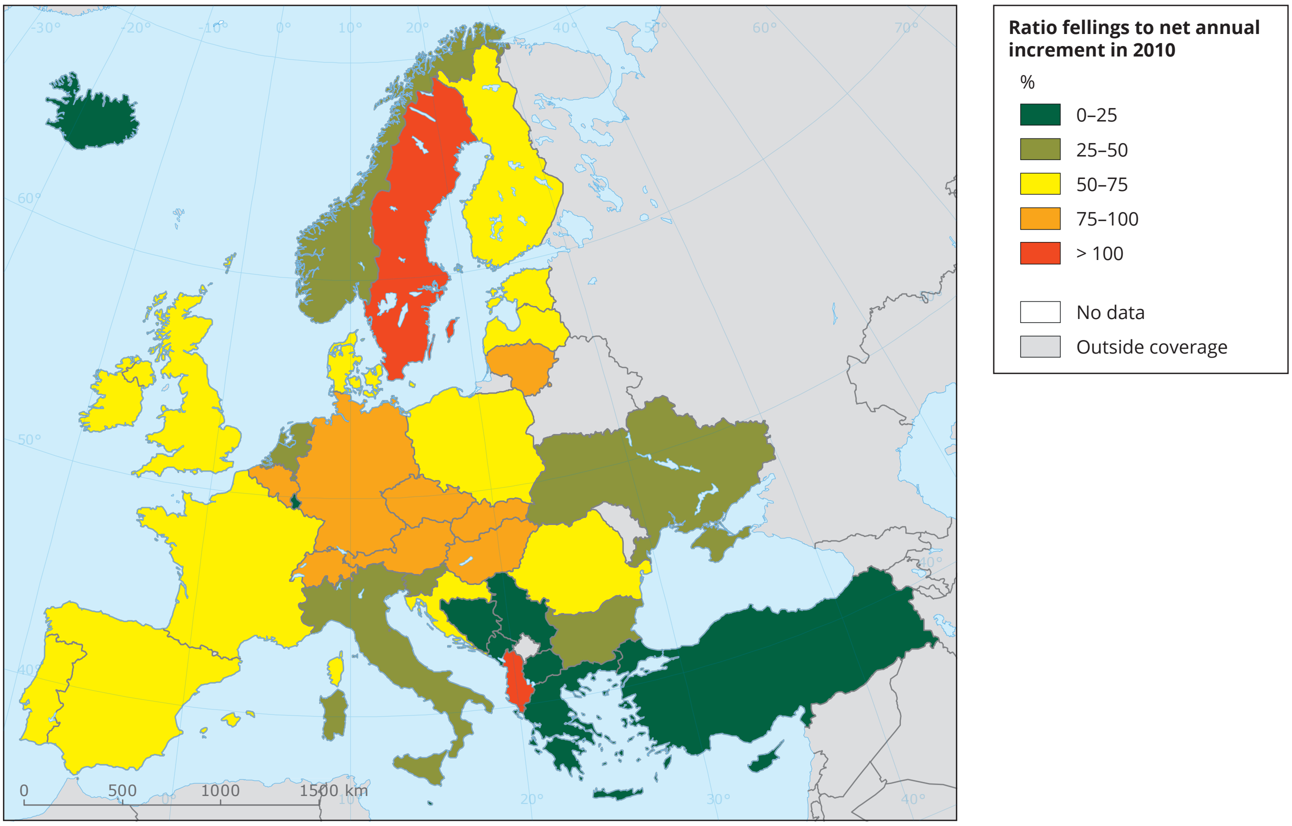
The intensity of forest management affects forest structure, soils, biogeochemical cycles, biodiversity and ecosystem services (EEA, 2016c). Recently, harvest rates for timber in Europe have been estimated at 60–70 % of the annual increment in growing stock, a rate that allows the growing stock to increase. Map 5.18 presents this 'forest utilisation rate' in Europe for 2010, showing that, with the exception of Sweden and Albania, fellings remain below annual increments and consequently below the 'sustainability limit' of 100 %, despite substantial variation between countries. However, according to Member States' projections of Land Use, Land-Use Change and Forestry (LULUCF), harvest rates are expected to increase by around 30 % by 2020 compared with 2010, reaching marginally unsustainable levels (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 the forests are being managed for biodiversity. Understanding the spatial patterns of forest management intensity and its drivers is therefore important for assessing the environmental trade-offs of forestry and for identifying opportunities for sustainable intensification (EEA, 2016c).

Invasive alien species

In the last decades, forest health and productivity have been threatened by insect attacks and fungal infections, which can be devastating when populations reach high levels. Outbreaks can lead to damaging levels of mortality under suitable climatic and site conditions and can change the forest ecosystem structure and species composition. Climate change can exacerbate this threat, by altering native environments and creating conditions that are more favourable for the establishment of invasive alien species at the expense of indigenous species.

Increased global travel, trade and transport have also contributed to an increase in the establishment of new alien pathogens. Some of these invasive alien species are clearly intrusive, being serious pathogens of native forest trees, while others threaten biodiversity. A well-known example is Dutch elm disease, caused by a fungus which arrived in the United Kingdom in 1927 on a shipment of rock elm logs from North America. This was a new strain of a pathogen already present in Europe, which proved

Map 5.18 Forest utilisation rate in 2010 for countries in the Ministerial Conference on the Protection of Forests in Europe (MCPFE)



Source: Forest Europe et al., 2015; EEA, 2016c.

both highly contagious and lethal, causing the death of over 25 million European elms in the United Kingdom alone (DAISIE, 2011; Forestry Commission, 2016). Similar threats also arise from traded plant material. For example the fungus causing root rot has been estimated to cause annual losses in European forest of EUR 790 million. The total costs of damage to forests by invasive alien species in Europe are estimated at EUR 12.5 billion annually (EEA, 2016c).

Pollution and nutrient enrichment

Forests in Europe are affected by deposition of nitrogen and sulphur compounds from the air, causing soil acidification and nutrient imbalances, which can lead to eutrophication, and by ground-level ozone. These pollutants can damage trees and alter the species composition of forests, potentially compromising some of the ecosystem services they deliver. In the 1980s and 1990s, acid deposition caused severe damage to forests in central Europe, and although air pollution has now been significantly reduced (see also Map 4.6 and 4.7), with clear evidence of recovery in many ecosystems, there can be a residual legacy effect on forests.

5.4.3 Condition

Until recently, the assessment of forest condition or forest health has largely been concerned with the physiological health of forests, as a means of assessing potential threats to the forests' commercial value. A more holistic approach involves looking at forest condition in terms of structure, function, disturbance impacts and habitat values. In Europe, the maintenance of forest health and vitality is assessed as part of the reporting on both Criteria and Indicators for Sustainable Forest Management (Forest Europe et al., 2011; Forest Europe, 2015) and Forest Resource Assessment (FAO, 2010). Indicators of habitat quality address structural components such as forest cover, as well as forest fires, native and invasive pests, habitat fragmentation, amount of dead wood, and future risks from climate change impacts (EEA, 2015a).

However, assessing these indicators is challenging, as little information is reported at an ecosystem level. Furthermore, each indicator includes multiple individual components. For instance, forest biodiversity can include functional groups, species populations, habitats and specific biological assemblages, as well as processes and patterns (structure and functioning of food webs) (EEA, 2016c). Therefore the most reliable available information is usually provided by reporting obligations, particularly the Habitats Directive. This reveals that only 15 % of woodland and forest habitats are assessed as having favourable conservation status, and 80 % are assessed as unfavourable-inadequate-bad (Figure 5.11). Trends in the conservation status of forest habitats were largely unfavourable-stable (40 %) and unfavourable-declining (28 %), with only 3 % being unfavourable-improving.

5.4.4 Policy response

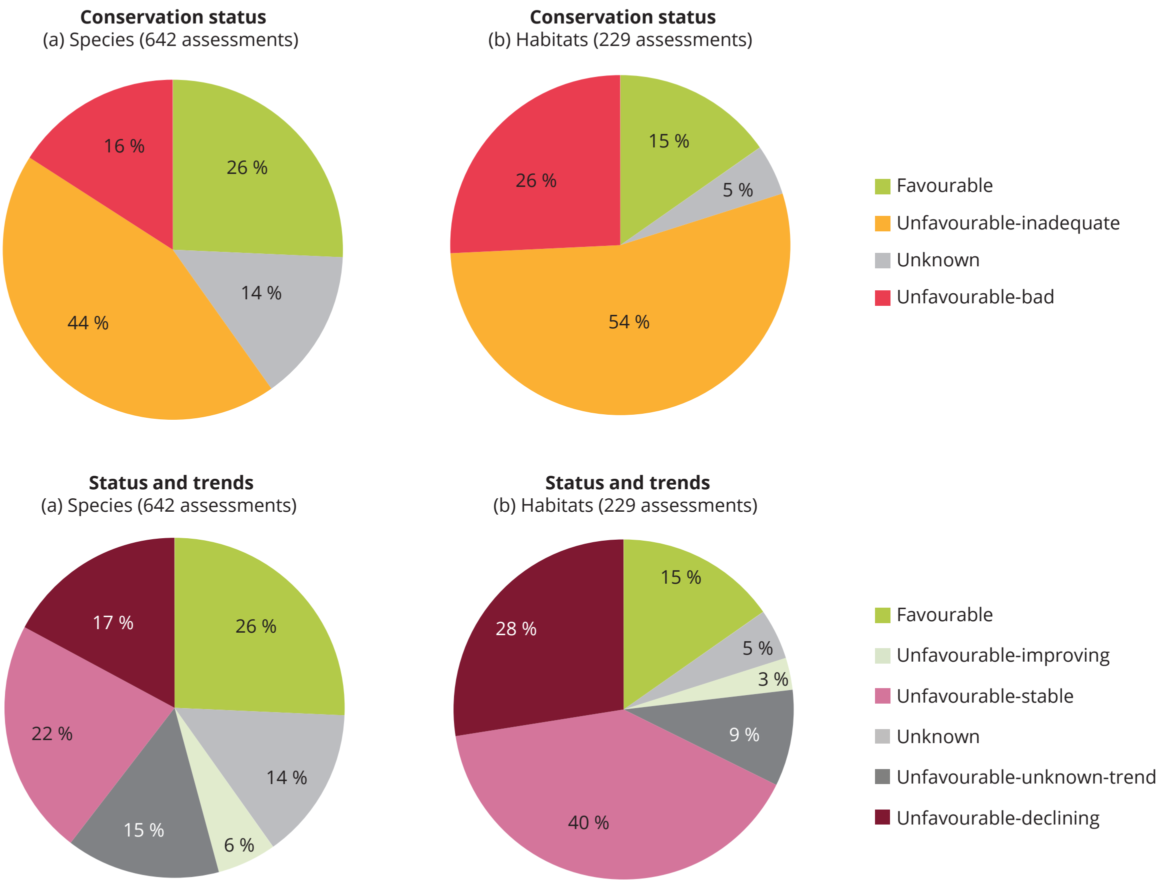
Forests provide multiple ecosystem services, the amount and extent depending on their species composition, age, structure and management, and they can host high levels of biodiversity. Although many forests are managed mainly for wood production, they are vitally important for climate change mitigation and adaptation, flood protection, water filtration, soil stability, recreation and aesthetic value. However, pressures such as habitat fragmentation, spread of invasive alien species and climate change threaten the health and vitality of woodland and forest ecosystems and their ability to provide these services now and in the future.

The challenge for policymakers is to maximise the synergies between the provision of forest ecosystem services while balancing trade-offs with conflicting aims, such as timber production, recreation and biodiversity conservation. One example is the increasing demand for biomass energy that will require trade-offs among levels of deadwood, proportion of old trees and intensity of forest management. There are other trade-offs between water yield and forest growth, as certain types of forest may reduce water availability in water-scarce environments (EEA, 2015a).

At an EU level, coordination with Member States on forest management and relevant policies is developed mainly through the Standing Forestry Committee. However, to date, there is no common forest policy in Europe (EEA, 2015b, *Agriculture*, *Biodiversity*, *Forests*). The EU Forest Strategy (EC, 2013d), however, seeks to fill the lack of coordination and coherence between various relevant policies. More specifically, it aims to coordinate Member States' responses to concerns over forest protection, biodiversity conservation and the sustainable use and delivery of forest ecosystem services. (EEA, 2015b, *Agriculture*, *Biodiversity*, *Forests*). The strategy redefines sustainable forest management (SFM) as:

SFM means using forests and forest land 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.

Figure 5.11 **Conservation status and trends in non-bird species and habitats associated with woodland and forest ecosystems that are protected under the Habitats Directive**



Source: EEA, 2015d.

The EU Forest Strategy, although not legally binding, addresses the drivers of environmental change, the trends in and projections of pressures, and the human influence on adding to these pressures or introducing new ones. Changing pressures and conditions on forest ecosystems require re-thinking and adapting policies so that they remain suitable and up to date to address these challenges (EEA, 2016c).

The ongoing MAES initiative shall offer an integrated and systemic view of pressures and effects that can be valuable in policymaking. National assessments provide good data on forest condition, but the lack of a binding reporting mechanism means that these data sets are not harmonised and may not be accessible for EU-level assessments.

Further measures are provided by Target 3 'sustainable agriculture and forestry' of the EU Biodiversity Strategy on halting biodiversity loss and the related Green Infrastructure Strategy (EC, 2013b), and by the Nature Directives, which offer legislative protection to woodlands and forests that are part of the Natura 2000 network. Europe's 2020 Strategy target for renewable sources to provide 20 % of the EU's primary energy advocates increasing biomass energy from wood and ensuring legal compliance for wood or forest products imported into the EU (EC, 2015b). Other relevant policies and regulations include efforts to combat illegal logging (e.g. the EU Timber Regulation; EC, 2010b), the CAP seeking to manage rural development, and other environmental, energy and industry policies that include components related to forest ecosystems (EEA, 2015b *Agriculture*, *Biodiversity*, *Forests*).

Box 5.8 Case study: green corridors for wildcats (Germany)

The *Netze des Lebens* LIFE project aimed to raise awareness and increase acceptance of the need to connect forest habitats through the creation of green corridors for mobile species such as the wildcat.

EU habitats suffer more from fragmentation than those in other parts of the world. Up to 50 % of protected areas and Natura 2000 sites in Germany are isolated. However, in densely populated countries such as Germany, it is difficult to establish networks of green corridors to connect these areas. Many conflicting interests regarding land use need to be overcome, while the loss of biodiversity is still not considered a major problem for society. This project therefore targeted stakeholders and policymakers in an information and awareness campaign, based around a charismatic endangered species with strong public appeal — the wildcat.

The project's communication campaign addressed authorities and politicians, who are obliged by law to implement the linking of biotopes. It aimed to inform at least 300 policymakers, as well as the general public, especially people living close to the planned corridors, and schoolchildren and teachers. Public appreciation of biological diversity should help persuade politicians to take this subject more seriously. More than 200 million contacts with people were achieved by the project through various campaigns and media activities conducted by the beneficiaries.

The project's coordinating beneficiary BUND (Friends of the Earth Germany) developed a model to link forest habitats optimally. This provided a basis for planning decisions aimed at protecting biodiversity. The majority of federal state and regional spatial plans are due to be adapted in the next few years, offering a unique opportunity to integrate the planning of green corridors to connect forest areas.

Green corridors created during the LIFE project have already been used by wildcats. Following on from the LIFE project, the Wildcat Leap Project, sponsored by the German Federal Environment Ministry, provides the opportunity to protect the wildcat in the long term. Moreover, the Pathway Plan for the Wildcat has been incorporated into the state development plans of Hesse and Thuringia. The right planning conditions have therefore been achieved for the creation of a consistent forest network of more than 1 000 km, and the long term aim is to extend this to 20 000 km.

Source: EC, 2014b.

5.5 Heathland, shrub and sparsely vegetated land ecosystems

5.5.1 Characteristics

Heathland and shrub ecosystems are areas with vegetation dominated by shrubs, which also include hedgerows, moors and sclerophyllous (small, hard-leaved) vegetation (Maes et al., 2013). They cover 5.3 % of the EU-28 area (Figure 3.2). Most of these habitats are in fact natural or semi-natural ecosystems that arise during the succession process between grassland and forest. They have traditionally been managed by cutting, grazing or controlled burning, which prevent succession to woodland and forest ecosystems. Lowland heaths once covered much of north-west Europe, but since the 1950s they have shrunk by 80–90 % (EC, 2012e). CLC data reveal that this loss is continuing: the area of heath and shrub ecosystems fell by almost 3 % from 1990 to 2006. Heathland and shrub habitats are concentrated in the western oceanic fringes of Europe and at higher altitudes, which is related to the specific climatic conditions in those areas. In the past they have been of great importance to coastal settlements and for subsistence agriculture, and they are valued for their cultural landscapes and as key habitats for biodiversity (ECNC, 2013).

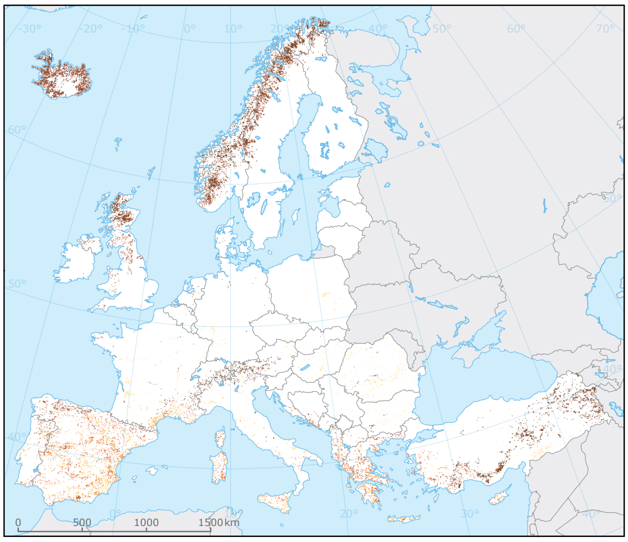
Sparsely vegetated land refers to all unvegetated or sparsely vegetated habitats including bare rocks, glaciers, dunes, beaches and sand plains (EEA, 2015a). Unfortunately, this ecosystem is rarely addressed in reports, as it is often not covered by data sets and so, although it is a separate ecosystem type in the MAES typology, it is reported jointly with heathland and shrub in this chapter. According to CLC data, in 2000 it was estimated that 'Open spaces/bare soil', which largely corresponds to sparsely vegetated land ecosystems, represented 6 % of the total land cover area in Europe. According to more recent data, sparsely vegetated land represents just 1 % (44 576 km^2) of the area of all the ecosystems within the EU (Figure 3.2), but this is a significant underestimate, as it includes only coastal dunes — just one of the habitats listed as sparsely vegetated land. Sparsely vegetated land is estimated to cover 14 % of EU mountainous regions, rising to 34 % in the Scandinavian Mountains and 20 % in mountainous areas of Turkey (EEA, 2015d).

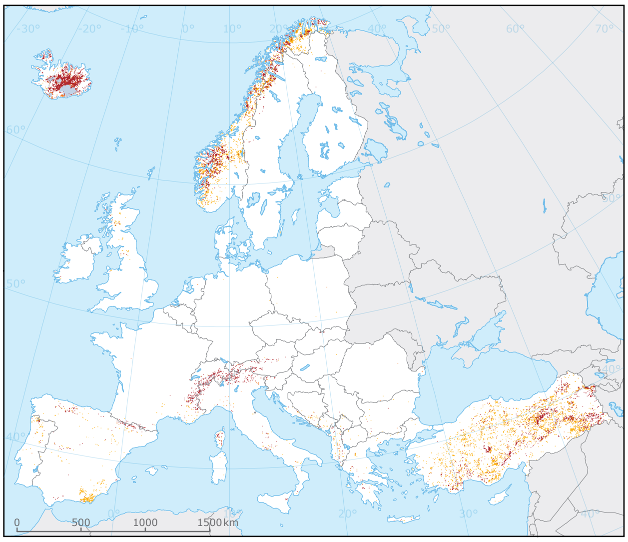
Box 5.9 Key messages for heathland, shrub and sparsely vegetated ecosystems

- Although these ecosystems represent only small parts of the total area of all the ecosystems within the EU, they have undergone losses and the remaining areas are currently heavily protected with many of the core areas included in the Natura 2000 Network: 31 % for heathland and shrub and 54 % for sparsely vegetated land.
- Despite this high level of protection, 74 % of heathland and shrub and 59 % of sparsely vegetated land habitats are in 'unfavourable' condition. Pressures include fragmentation from urban development, overgrazing and the abandonment of traditional grazing leading to an encroachment of trees.
- This threatens the unique biodiversity and cultural value of these landscapes, and can also diminish their ability to provide services such as carbon storage or a reduction in soil erosion (although this may not be the case for succession to forest).

These ecosystem types cover a wide range of habitats, from tundra to Mediterranean maquis and from sand dunes to limestone pavements. They occur in widely different biogeographical regions and range from small niche areas to large expanses. They are found in areas with unfavourable natural conditions, for example low nutrients, or very hot, cold, wet, dry or salty areas, especially in the Alpine and Arctic regions of Europe such as Norway and Iceland (Map 5.19) and often as a consequence of intensive

Map 5.19 Heathland and shrub (left) and sparsely vegetated land (right) in Europe





Heatland and shrub in Europe

- Tundra
- Arctic, alpine and subalpine scrub
- Temperate and mediterranean montane scrub
- Temperate shrub heathland
- Maquis, arborescent matorral and thermo-Mediterranean brushes
- Garrigue
- Spiny Mediterranean heaths (phrygana, hedgehog-heaths and related coastal cliff vegetation)
- Thermo-Atlantic xerophytic scrub
- Riverine and fen scrubs
- Shrub plantations
- Areas not covered by heatland and shrub
- Outside coverage

Sparsely vegetated land in Europe

- Screes
- Inland cliffs, rock pavements and outcrops
- Snow or ice-dominated habitats
- Miscellaneous inland habitats with very sparse or no vegetation
- Areas not covered by heatland and shrub
- Outside coverage

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015.

use (former arable land or grassland). These extreme conditions often support rare species, creating a mix of distinctive ecosystems with very high biodiversity value (ECNC, 2013). Therefore, despite covering only a small area of the EU, over 31 % of the area of heathland and shrub ecosystems is protected under Natura 2000, and for sparsely vegetated land the proportion is 54 %, making them the most highly protected of all EU ecosystems in proportion to their area in recognition of their high value for biodiversity and tourism and the losses suffered (Figure 3.5).

5.5.2 Drivers and pressures

The key pressures causing degradation of heathland, shrub and sparsely vegetated ecosystems in Europe are fragmentation, land abandonment, land use change, fires and pollution from atmospheric nitrogen. Table 5.5 presents the major drivers and pressures for heathland and shrub ecosystems (sparsely vegetated land is not addressed owing to a lack of data). Member States report that the main pressure on heathland birds is from agriculture, with the top threat being intensification followed by land abandonment, with reduced grazing leading to natural succession to forest and thus the loss of heathland habitats. Other reported threats to heathland habitats include invasive alien species, pollution and urban development. For non-bird species, forestry is also reported to be a significant pressure, presumably through planting of forests on open land.

For sparsely vegetated land, Member States report a range of pressures including predation by other species such as domestic animals (the top pressure for birds), sport and leisure activities, urbanisation and industrial development, transport infrastructure, grazing by livestock, mining and quarrying, forestry, and human disturbance such as trampling (EEA, 2015d).

Habitat change

Between 2000 and 2006, 42 % of losses of heathland and shrub were due to conversion to forests (which could include either land abandonment or planting new forests), 22 % were due to multiple causes including fires and 21 % were due to conversion to agriculture (EEA, 2015g). The impact of heathland and shrub loss on biodiversity depends on the previous land cover. For example, heathlands and shrublands created as a result of clear felling, forest fires or abandonment of traditional pastures might be associated with a loss in biodiversity value.

Another pressure on heathland habitats is land fragmentation driven by urban sprawl and the expansion of transport corridors. The landscape fragmentation map of Europe (Map 5.20) illustrates the fragmentation of European heathland using the mesh density indicator.

For sparsely vegetated land, CLC data reveal that there was only a small decline in its area of 0.6 % from 1990 to 2006. From the same data, 65 % of the unvegetated coastal ecosystem losses can be attributed to coastal erosion, partly due to the dynamic nature of coastal ecosystems, and 16 % to the sprawl of industrial sites and infrastructure such as airports (EEA, 2010a). There is a clear interaction with the pressures on marine and coastal ecosystems reviewed in Section 5.8 (ECNC, 2013). The map of European coastal erosion (Map 5.21) indicates that about 15 % of the European coastline is affected by erosion, most of which is concentrated in the Mediterranean and North Seas.

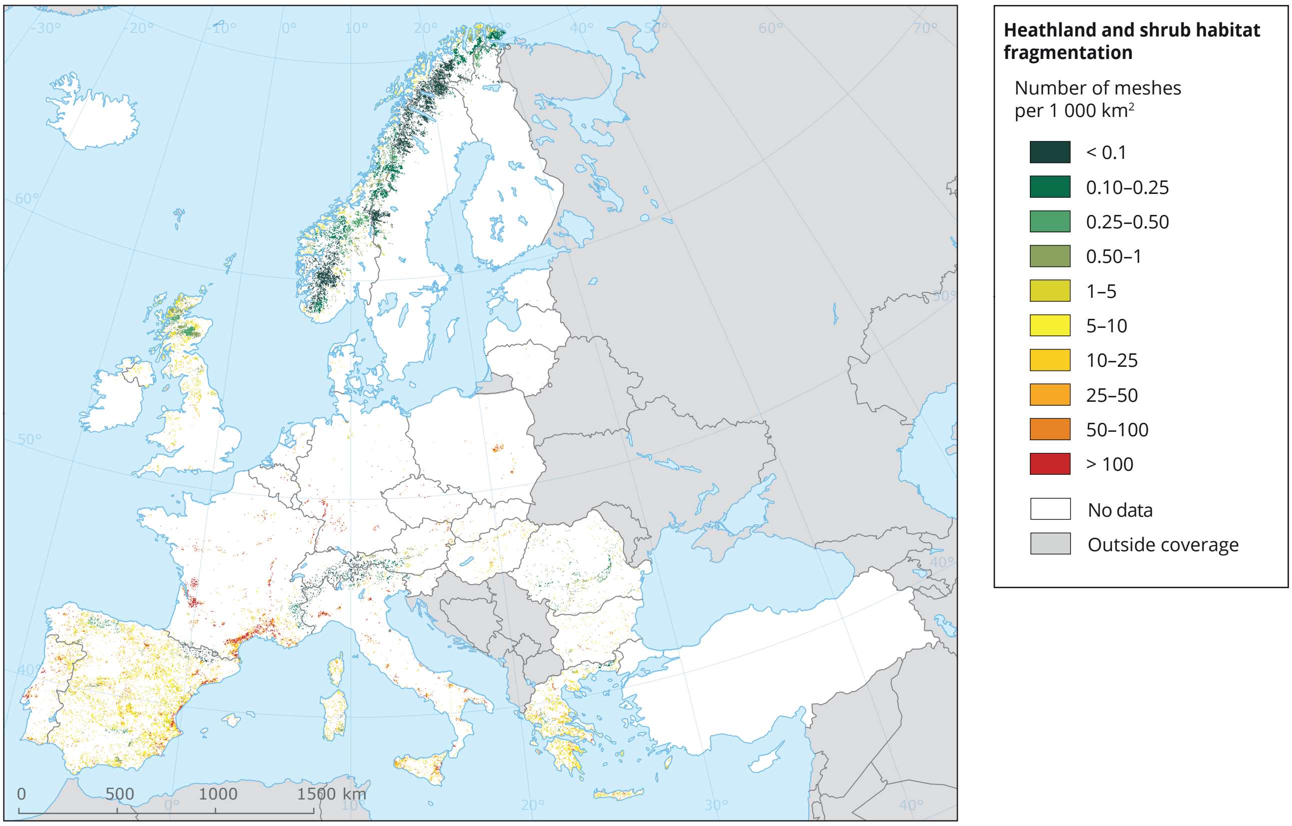
Table 5.5 Major pressures on heathland and shrub and their impacts on biodiversity in Europe

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Land use change Landscape fragmentation Land take Land abandonment	Extreme events Fires	Lack of appropriate site management Recreational and urban disturbance	Invasive plants, e.g. rhododendron, water fungus, and disease agents, e.g. *Phytophthora*	Nitrogen enrichment Critical levels of ozone Heavy metals

Key: Observed impact on biodiversity to date: Low, Moderate, High, Very high

Source: Adapted from EEA, 2015a, and ETC/SIA, 2014c.

Map 5.20 Heathland and shrub habitat fragmentation



Source: Analysis based on EEA, 2011b and http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015. Higher mesh density indicates a greater number of barriers.

Climate change

Both heathlands and sparsely vegetated land are adapted to extreme climatic conditions, but, when these conditions change, the ecosystems can degrade and/or be replaced by other ecosystems. Climate change and increased temperatures, especially during the summer months, increase the occurrence of summer fires, which can have a major detrimental impact on heathland habitats, destroying all above-ground vegetation and burning into the litter and humus layers, thereby substantially reducing the level of nutrients (Barker et al., 2004). Climate change is also creating new sparsely vegetated land habitats as a result of glacial retreat in Europe. This trend has accelerated since the 1980s and is likely to continue (ECNC, 2013) but will not outweigh losses due to the other pressures.

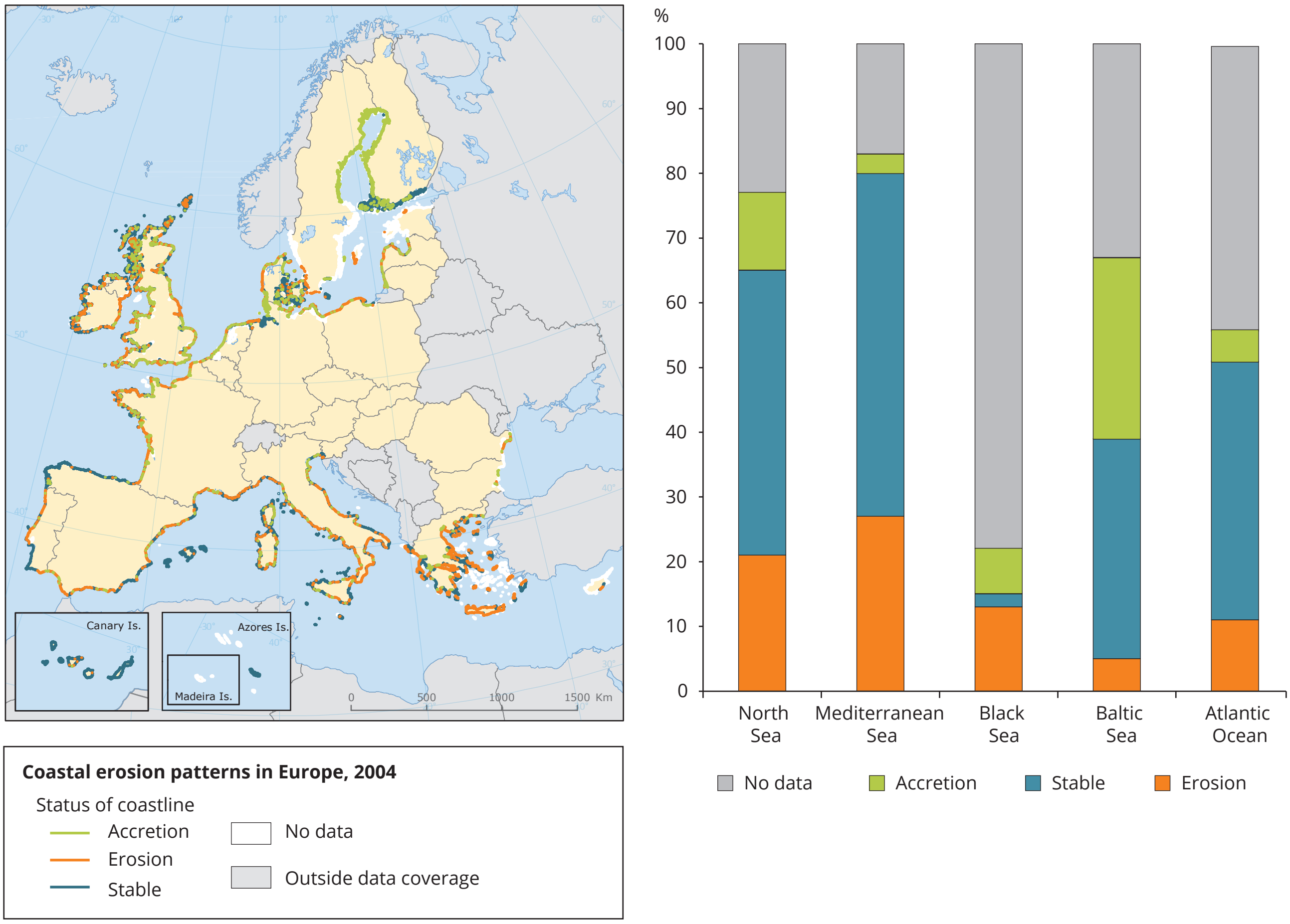
Overexploitation

Loss of heathlands is associated both with overexploitation and underexploitation. One of the traditional uses of heathlands has been extensive grazing by livestock, which helps to restrict scrub invasion, often accompanied by periodic burning to promote the growth of new green shoots with a higher nutritional value. These practices hinder succession to woodland but do not give sufficient economic return in the current European market, leading either to the abandonment of grazing and thus succession to woodland or to intensified grazing pressure and thus conversion to grassland (ECNC, 2013).

Invasive alien species

In the United Kingdom, rhododendron (*Rhododendron ponticum*), a non-indigenous shrub, has proved to be an aggressive coloniser, accounting for 44 % of all cases of shrub invasive alien species mentioned in 2000, and large amounts of money have been spent annually on control and eradication programmes (Mortimer et al., 2000; Forestry Commission, 2006). The species was introduced to the United Kingdom and Ireland in the 18th century and widely cultivated as a flowering plant in gardens, parks and estates (Forestry Commission, 2006) and its invasion is now spreading through continental Europe (NNSS, 2015). Other invasive alien species that can affect heathland

Map 5.21 Coastal erosion patterns in Europe, 2004



Source: http://www.eea.europa.eu/data-and-maps/figures/coastal-erosion-patterns-in-europe-1, accessed 13 January 2016.

and shrub ecosystems include bacteria and organisms such as water moulds that infect and destroy plant roots in water (EEA, 2016c).

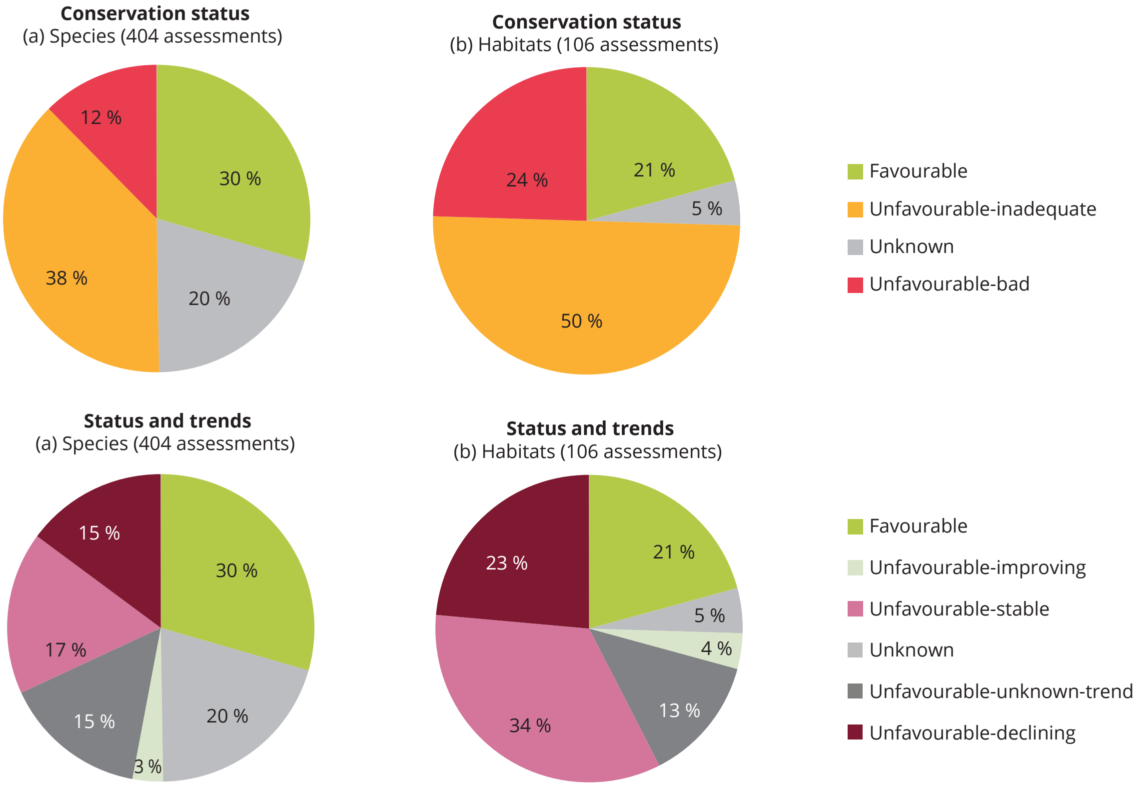
Pollution and nutrient enrichment

As these ecosystems are often found on nutrient-poor mineral soils with a low pH, they are vulnerable to the effects of both eutrophication and acidification caused by the increased atmospheric deposition of nitrogen from fertilisers or fossil fuel combustion (ECNC, 2013). Typical responses to elevated nitrogen levels include changes in plant growth, phenology and chemistry and, in some cases, changes in community composition. Excess nitrogen deposition leads to the damage and loss of communities of nitrogen-sensitive species, coupled with invasion by nitrogen-loving species of lower conservation value, such as the replacement of sensitive shrubs and wild flowers in heathlands by grasses, which also affects protected areas (EEA, 2010a).

5.5.3 Condition

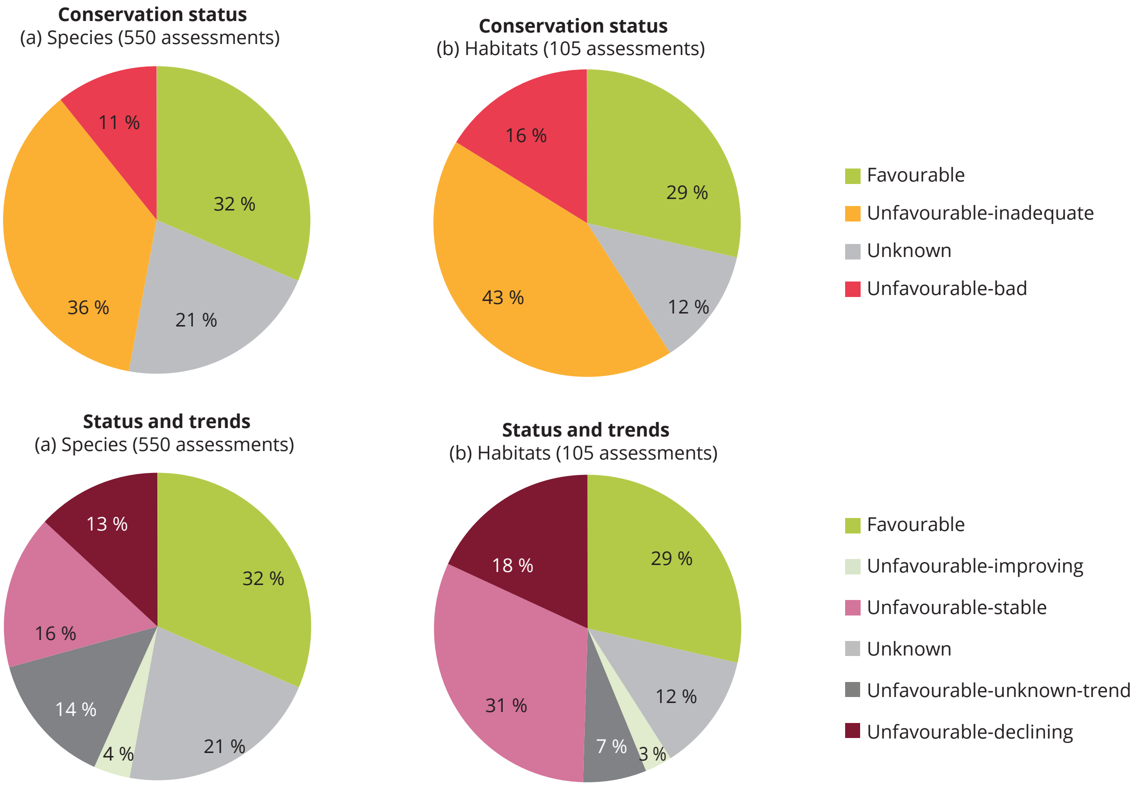
Figure 5.12 shows that the conservation status of half of the heathland and shrub habitats assessed under the Habitats Directive is reported as being unfavourable-inadequate, a quarter as unfavourable-bad and only 21 % as favourable. About one-third of habitats assessed as unfavourable were also assessed as stable and about one-quarter as declining, while only 4 % were found to be improving. The conservation status of non-bird species is slightly better than that of habitats, with 30 % being favourable, 38 % inadequate and only 12 % bad, although 20 % are of unknown status. However, in 15 % of non-bird species assessments, the conservation status was in decline, and only 3 % were improving (EEA, 2015d). The assessments for sparsely vegetated ecosystems were similar but slightly more favourable for both species and habitats compared with heathland and shrub (Figure 5.13).

Figure 5.12 Conservation status and trends in heathland and shrub non-bird species and habitats



Source: EEA, 2015d.

Figure 5.13 Conservation status and trends in sparsely vegetated land non-bird species and habitats



Source: EEA, 2015d.

5.5.4 Policy response

As social preferences and needs have evolved, so has the demand for the goods and services provided by these ecosystems. For example, a study in the Cantabrian Mountains found that the demand for provisioning services such as grazing, food and fuel from heathlands has declined in favour of cultural services related to their natural heritage and their recreational value as a source of inspiration, education, ecotourism and leisure activities such as bird watching and hunting (European Heathland Workshop, 2013).

In the EU, initiatives have been established to encourage countries with heathland and shrub habitats to actively share information on their status, threats and management techniques for their conservation and restoration. For example, the European Heathland Network has been established to enable those involved in research, conservation and policy formulation and implementation to exchange knowledge and ideas on conservation of heathland ecosystems. The HEATH project (HEATH Project, 2015), funded under the EU INTERREG programme, is an example of cross-border cooperation between the United Kingdom, France and the Netherlands. The project has helped to restore over 4 000 ha of prime heathland in these countries and has led to the development of a management model and tool kit that can be applied to heathland management across north-west Europe (EC, 2012e). As knowledge around traditional management practices (cutting, burning and grazing) for these ecosystems grows, a number of strategies have been emerging at national level, namely in Denmark, England, Iceland, Ireland and Norway.

Box 5.10 Case study: restoring a heathland landscape (Belgium)

The valley of the Visbeek in northern Belgium was once part of a vast area of heath, fen and species-rich hay meadows, but by 2010 only 3 ha of highly fragmented heathland were left. Although most of the area had been converted to pine plantations or intensive agriculture, there were relics of a number of endangered Annex I habitats including fen meadows, alluvial forests, European dry heaths, inland dunes and Northern Atlantic wet heaths. The area was also still home to rare and threatened species such as the pool frog (*Rana lessonae*) and the adder (*Vipera berus*).

The project began as a 20-year programme involving volunteers working with Natuurpunt, a Belgian NGO, before it expanded into an ambitious 5-year LIFE project in 2010. The goal was to improve, enlarge and connect the relics to form 37 ha of wet and dry heaths and inland dunes, 14 ha of meadows and 4 ha of standing water. Research on groundwater and soil conditions was used to help select the best locations for restoring each habitat type.

One of the main features of the project was the emphasis on realising socio-economic and cultural benefits through partnerships with local people. Key actions are listed below.

- Municipality workers spent a couple of months every winter restoring heathland, under the supervision of a ranger of the Flemish Agency for Nature and Forests.
- Local farmers mowed or grazed the restored grasslands and established grass–clover mixes to reduce the nutrient levels in the former farmland. This win–win approach ensured a high-quality harvest for the farmers and increased the quality of the restored heathland habitats, which require low nutrient levels.
- Local people were involved in harvesting firewood (associated with clearing trees from areas to be restored to heath), which encouraged public support for nature restoration.
- Local people, tourists and the general public were kept informed of the benefits of the project through leaflets, new information panels, the development of new tracks, the publication of articles and the organisation of public activities.

Sources: European Heathland Workshop, 2013; Natuurpunt, 2015.

5.6 Wetland ecosystems

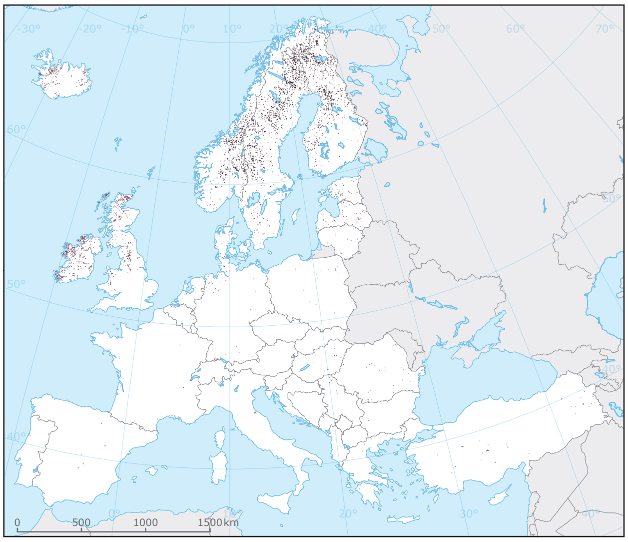
5.6.1 Characteristics

There are several different definitions of wetlands, but generally they are areas where water is the primary factor controlling the environment and the associated habitats (ETC/BD, 2014a). They include both land and water environments. Some wetlands can be seasonally aquatic or terrestrial and typically occur where the water table is at or near the surface of the land, or where the land is covered by shallow water. Wetlands are complex, dynamic systems, often with fluctuating and undefined borders.

The MAES process defines two types of wetlands: inland wetlands, and marine inlets and transitional waters (Maes et al., 2013). Marine inlets and transitional waters are included under the marine ecosystem category (see Section 5.8) and so the focus here is on inland wetlands. These include natural or modified mires, bogs and fens, as well as peat extraction sites. They represent approximately 1.8 % of the EU-28 area (Map 5.22).

While they cover a relatively small area, Europe's wetland ecosystems are a major source of biodiversity, and they are closely linked to terrestrial and marine ecosystems (ECNC, 2013). Wetlands are also crucial in regulating water flows including their function in flood plains and filtering water and carbon storage. Their importance is reflected in the relatively high proportion of all wetland ecosystems, 37.5 %, that is protected by Natura 2000 sites. Wetlands are 3.8 % of the total area of Natura 2000 sites in Europe (Figure 3.5).

Map 5.22 Wetland ecosystems in Europe



Wetland ecosystems in Europe

- Aapa, palsa and polygon mires
- Raised and blanket bogs
- Valley mires, poor fens and transition mires
- Base-rich fens and calcareous spring mires
- Inland saline and brackish marshes and reedbeds
- Sedge and reedbeds, normally without free-standing water
- Areas not covered by wetland ecosystems
- Outside coverage

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015.

5.6.2 Drivers and pressures

The primary drivers of the degradation and loss of wetlands are population growth and increasing economic development (Davidson, 2014), which result in pressures including drainage for agriculture, afforestation, urban and infrastructure development, hydraulic engineering, water abstraction, pollution from agricultural run-off, peat extraction, overexploitation of groundwater resources, climate

Box 5.11 Key messages for wetland ecosystems

- Most of Europe's wetlands exist within a mosaic of heavily managed land and are vulnerable to pressures and threats originating in the surrounding water catchment area. Despite global and national recognition of their importance, Europe's wetlands remain under severe pressure. Two-thirds of wetland-related species and 85 % of all wetland habitats of European interest are in unfavourable status.
- The main causes of wetland loss are conversion to agriculture by planting commercial crops, afforestation by forests being created, or through natural succession due to changes in water regimes, drying out and the colonisation of shrub and tree species. Other pressures include pollution and nutrient enrichment, and peat extraction.
- In recent decades, growing public and political awareness of the decline in wetlands and the importance of the ecosystem services they provide have led to improved commitments, policies and practices for their conservation and sustainable use throughout much of Europe.

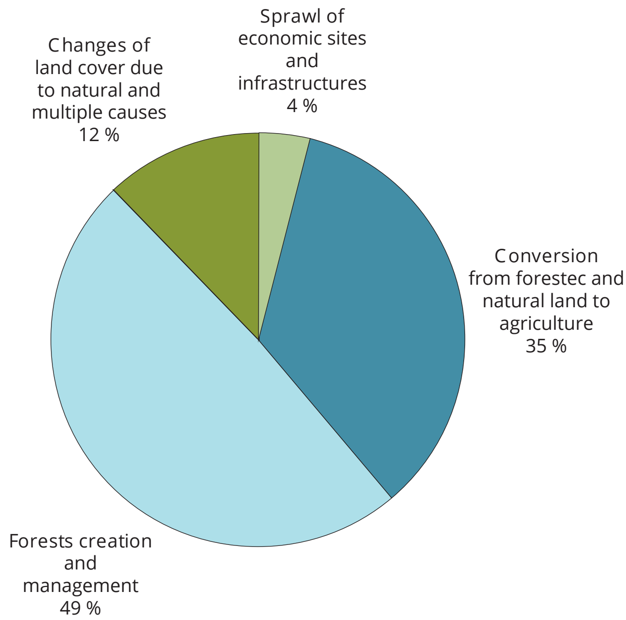
change and the introduction of invasive alien species (MA, 2005; EC, 2007a; Mediterranean Wetlands Observatory, 2012; EEA, 2010a; ETC/BD, 2014a), as shown in Table 5.6. Member States report the main pressure to be modification of water body conditions, such as drainage disconnection from rivers by river regulation and diversion (EEA, 2015d).

Habitat change

Although the drainage of wetlands has been common practice in Europe for centuries, it has increased significantly in the past century and especially in the last 50 years, leading to a substantial decrease in the number, size and quality of wetland areas. Over 60 % of European wetlands had already been lost before the 1990s, and CLC data show that a further 4.8 % were lost between 1990 and 2006, although the rate of loss is slightly declining. A global-level meta-analysis showed that wetland loss has been mainly due to conversion to agriculture driven by population and economic growth (Asselen et al., 2013). In Europe afforestation is the most important driver of wetland loss (Figure 5.14). This habitat loss has led to a high level of fragmentation and a related loss of ecological connectivity between rivers and their floodplains (UK-NEA, 2015), which can lead to further drying and wetland loss and increases vulnerability to pollution, water stress and other pressures. Conversely, many artificial wetlands have been created (e.g. through mineral workings or managed retreat of coastlines), and some now play a significant role in the conservation of certain species but they are far from compensating previous losses (ETC/BD, 2014a).

Wetlands are vulnerable to changes in surrounding ecosystems in the water catchment. Land use activities such as unsustainable forestry practices and intensive agriculture, especially in the upper parts of watersheds, can lead to increased soil erosion and reduced water retention and filtering capacity. Land clearing for agriculture in upland areas and subsequent operations can have a major negative impact on water quality and also lead to significant changes in flood and dry season flows. Lowland agriculture can lead to the drainage or conversion of floodplain wetlands, leading to loss of biodiversity and natural functions and benefits (ETC/BD, 2014a). RBMPs arising from the Water Framework Directive trigger measures to preserve and restore wetland areas in river basins (EC, 2012d).

Figure 5.14 Cause of loss of wetlands, 2000–2006



Source: EEA, 2015g.

Table 5.6 Major pressures on wetlands, and their impacts on biodiversity in Europe

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Land take Fragmentation Drainage for agriculture	Drought Changes in rainfall	Blocking and extraction of the water inflow Overexploitation of groundwater resources Water abstraction Reed harvesting, also for biofuels	Introduction of invasive fish Plant species such as *Hydrocotyle ranunculoides* (floating pennywort) and *Azolla filiculoides* (water fern)	Eutrophication Pesticides Acid rain Litter (e.g. plastic)

Key: Observed impact on biodiversity to date: Low, Moderate, High, Very high

Source: Adapted from EEA, 2015a, and ETC/SIA, 2014c.

Climate change
Changes in rainfall patterns are already being observed throughout Europe, and rainfall is expected to decline further in the coming decades, putting increasing pressure on wetlands (Mediterranean Wetlands Observatory, 2012). The effects will vary in the different regions of Europe. The northwards movement of mobile species has been observed to follow changes in climate (temperature and precipitation), but less mobile species such as amphibians and fish may not be able to keep up with the speed of change (ETC/BD, 2014a).

Overexploitation
Overexploitation of water is especially severe in the Mediterranean, with agriculture being the main consumer (64 %) (Mediterranean Wetlands Observatory, 2012). Inappropriate management also affects the hydroperiod (with permanent water bodies becoming seasonal and vice versa) and this affects the plant and animal communities (Poff et al., 2007).

Peat extraction is also a major driver of habitat degradation. Tourism and outdoor activities present a danger to many wetlands through disturbances, including trampling, which is a particular threat to ground-nesting birds (ETC/BD, 2014a). Unsustainable hunting, fishing and reed harvesting present an additional pressure. Hunting threatens the conservation of many wetland species, especially in some Mediterranean countries. Fishing is less of a threat in freshwater wetlands, but it can affect particular species (Mediterranean Wetlands Observatory, 2012).

Invasive alien species
Invasive alien species are of particular concern to the conservation of wetlands as they may become very dominant, suppressing and outcompeting naturally occurring species. This is particularly the case for introduced plant species, which can become invasive and spread from garden ponds, and predatory fish, which can wipe out native species in a matter of years and can pose a considerable threat to native amphibians (Zedler, 2004). In addition, degraded wetlands are especially vulnerable to invasive plants.

Pollution and nutrient enrichment
Nitrogen pollution is one of the major threats for wetlands, causing both eutrophication and acidification (ETC/SIA, 2014e). The main sources are atmospheric deposition and point and non-point sources from surrounding areas. Other pollution pressures include pesticides from agriculture, heavy metals, polychlorobiphenyls (known as PCBs) and polycyclic aromatic hydrocarbons (known as PAHs) from industry, and phosphates from domestic wastewater (EC, 2007a).

Box 5.12 Case study: LIFE Project — Habitat Management in the Weidemoos Bird Reserve (Austria)

Industrial peat extraction has shaped European landscapes, especially by draining wetland habitats. Following the end of industrial peat extraction many of these wetland habitats, particularly bogs, have become important habitats for bird species. But in order to prevent these habitats from turning into wooded landscapes, because the water regime has been changed by draining, landscape management is needed.

The Weidemoos region, in the bog region north of Salzburg in Austria, is such a habitat, which has been affected by years of peat extraction up to 2000. It is a mosaic of standing water, vegetation-free areas and forested patches, providing an ideal breeding ground for more than 150 species of bird. However, without proper management, this semi-open 132 ha site would rapidly turn into a wooded landscape, losing its special habitat mix, which is important for a range of bird species and other species.

In 2003 a LIFE Nature project was set up to maintain and optimise the birds' breeding, resting and wintering areas. It also aimed to encouraging a more positive attitude towards the area among the local population.

Conservation work in the area focused on the construction of dams and landscape modelling to keep water on site and also to create new areas of standing water. Experimental management of wet meadows, reed beds and bushy areas was introduced to optimise procedures for maintaining the habitats.

To ensure the continued success of the LIFE Nature project, ongoing testing of standing water and maintenance activities, such as mowing of meadows and reeded areas, maintenance of vegetation-free areas and tending of trees, has been carried out.

Sources: http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/wetlands.pdf. accessed 13 January 2016; http://www.weidmoos.at/pdf/laienbericht_en.pdf. accessed 13 January 2016.

5.6.3 Condition

There is only limited information available for mapping and assessing the condition of wetlands, especially for those which do not fall under the scope of the Water Framework Directive (Maes et al., 2014). Under Habitat Directive reporting, more than half (51 %) of the 61 assessments for inland wetland habitats were classified as unfavourable-bad, with 34 % being unfavourable-inadequate and just 13 % favourable (Figure 5.15). Regarding trends in condition, nearly half were unfavourable-stable (26 %) and unfavourable declining (44 %), while only 7 % were reported to be improving (EEA, 2015d).

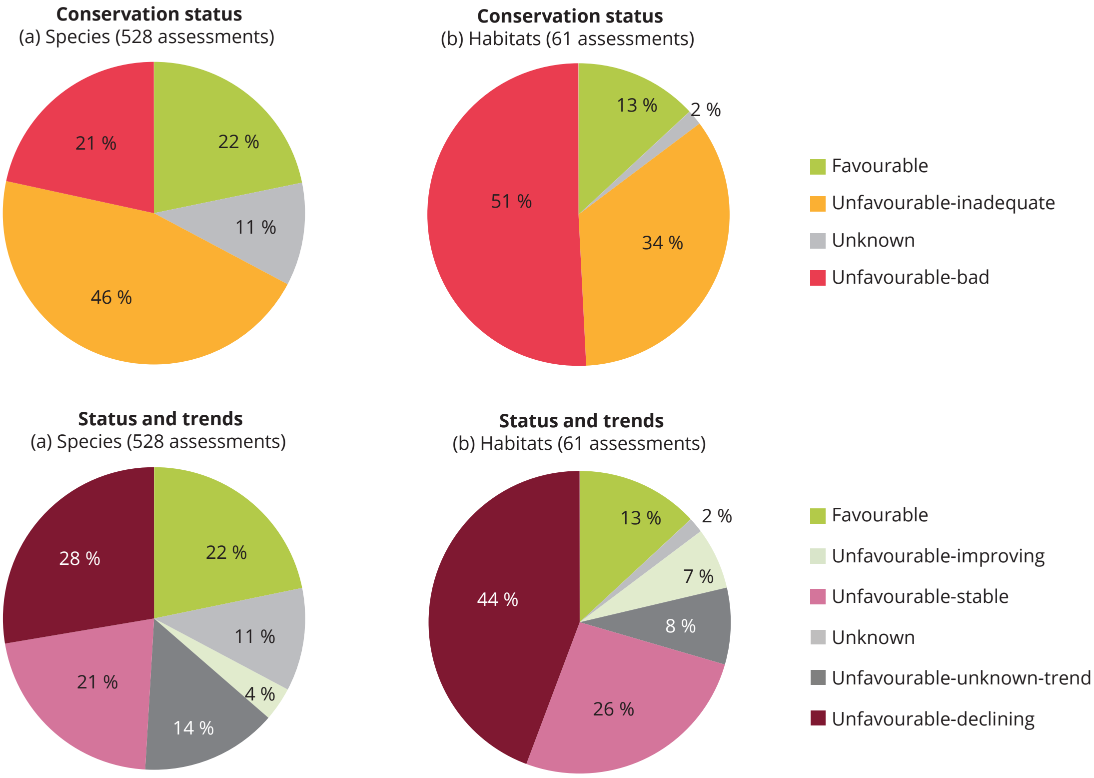
5.6.4 Policy response

Wetlands provide a wide range of ecosystem services such as a water supply, water purification and flood protection, and they offer opportunities for recreation and tourism because of their amenity value in terms of landscape. Depending on their management, they can be either sources or sinks of greenhouse gas emissions (EEA, 2015d). They are particularly vulnerable to conflicts between specific ecosystem services (such as agricultural production) and the maintenance of the ecosystem's integrity and the multiple services it provides. Policymakers therefore need a clear understanding of the trade-offs and the associated true costs (ETC/BD, 2014a; UK-NEA, 2015).

Wetlands are protected by the Ramsar Convention, a global multilateral agreement, as well as by European legislation including the Birds Directive, the Habitats Directive, which lists 40 wetland habitat types in Annex I, and the Convention on the Conservation of European Wildlife and Natural Habitats (Council of Europe, 1979). In addition, most European countries have specific national measures for wetland protection that integrate the provisions of the relevant EU directives (ETC/BD, 2014a).

Water quality is a particularly important issue for wetlands, through its effect on species survival and ecosystem condition. Thus, the EU's Water Framework Directive, which calls on Member States to ensure good chemical and ecological status of all freshwater bodies by 2015, is a key tool to protect and restore wetland biodiversity (EC, 2007a). Other legislation regulating water quality and quantity is also relevant for wetland conservation, including the Nitrates Directive (EC, 1991a), the Directive on Urban Wastewater Treatment (EC, 1991b), the Groundwater Directive (EC, 2006) and

Figure 5.15 Conservation status and trends in wetland non-bird species and habitats



Source: EEA, 2015d.

the Directive on Industrial Emissions (EC, 2010c). The Flood Risks Management Directive (EC, 2007b) is also of direct relevance to wetlands, as wetlands play a vital role in water retention and act as an important buffer zone in the prevention of flooding (ETC/BD, 2014a).

5.7 Freshwater (rivers and lakes) ecosystems

5.7.1 Characteristics

Freshwater ecosystems represent approximately 2.4 % of the EU-28 area (Map 5.23). They include an extensive network of rivers extending to several million kilometres, plus over a million lakes and numerous small streams and ponds. Reporting under the Water Framework Directive covers 1.1 million km of the river network and 19 000 lakes (EEA, 2012c).

While they cover a relatively small area, Europe's freshwater ecosystems are rich in biodiversity, (EEA, 2010e), with diverse habitats including alpine and lowland rivers, floodplains, lakes and ponds of various sizes. Around 250 species of macrophytes (aquatic plants) and a similar number of fish species inhabit European inland surface waters, and a significant number of birds, fish and mammals depend on freshwater and wetlands for breeding or feeding (EEA, 2015t). The importance of freshwater ecosystems to Europe's biodiversity is reflected in the relatively high proportion (36.3 %) of freshwater ecosystems protected as Natura 2000 sites. Freshwater areas form 4.9 % of the total area of Natura 2000 sites in Europe (Figure 3.5).

Around 80 % of the river network in Europe consists of small creeks and streams, and these are very important ecologically, as they support specific hydrological, chemical and biological processes (Kristensen and Globevnik, 2014). Freshwater ecosystems are intrinsically connected with the terrestrial ecosystems within their catchments, including wetlands, and with downstream coastal and marine waters. They constitute a hydrological system that interacts with groundwater levels and which is vulnerable to changes in the water or land further upstream.

Map 5.23 Freshwater ecosystems in Europe

Freshwater ecosystems in Europe
- Surface standing waters
- Surface running waters
- Littoral zone of inland surface waterbodies
- Areas not covered by freshwater ecosystems
- Outside coverage

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015.

Box 5.13 Key messages for freshwater ecosystems

- Intensive agriculture, urbanisation, hydropower production, inland water navigation and flood protection schemes have extensively altered European hydrological systems and freshwater habitats. Climate change adds to these challenges, through increased water temperatures and more severe droughts.
- Although much cleaner than 25 years ago, many water bodies are still affected by pollution or altered habitats. In 2009, only 43 % had good ecological status in Europe. Although this is expected to increase to 53 % in 2015, this is still far from the 2015 target of 100 % good status.
- Freshwater ecosystems must be restored in order to achieve their full potential as habitats for wildlife and for the provision of critical ecosystem services. The EU Biodiversity Strategy to 2020, through its *Blueprint to safeguard Europe's water resources*, seeks to achieve this goal through better implementation of current water legislation, the integration of water policy objectives into other policies, and filling legislative gaps on water quantity and efficiency.

Freshwater ecosystems are important not only for providing drinking water but also for other ecosystem services such as water retention, recreation and the provision of aesthetic landscapes, fishing, agriculture, industrial use and mediation of wastes, thus providing important benefits for Europe's economy.

5.7.2 Drivers and pressures

The major pressures on Europe's freshwater are water pollution, overabstraction of water and modifications to water bodies that affect morphology and water flow (EEA, 2012c) (Table 5.7). This is confirmed by Member State reports, which cite the main pressures to be modifications such as canalisation, diversion, dams, flood defences, irrigation schemes and infilling of ditches and ponds, and the loss of connectivity, as well as pollution (especially from agriculture and forestry) and invasive alien species (EEA, 2015d).

The dominant pressures differ between regions (EEA, 2012c). The Mediterranean region is most affected by water abstraction and water storage, owing to its warmer and drier climate. The Alpine region generally has fewer pressures, but hydropower production and the modification of hydromorphology is significant. Lowland regions with high populations, especially in north-western Europe, are most affected by agriculture and urban development, causing pollution from nutrients and organic matter, as well as changing the shape and flow of water bodies (ETC/ICM, 2014).

Habitat change

Rivers and lakes are often engineered by humans to meet the needs of agriculture and urbanisation, to produce hydropower and to protect against flooding. Rivers are straightened and diverted, flood defence embankments prevent rivers from spilling onto their flood plains, flooded land is reclaimed for agriculture or development, and dams and weirs are built. These activities all affect the morphology (shape) and hydrology (water flow) of the water bodies, that is, their hydromorphology, and they also affect their capacity to retain water during flood events.

There are several hundred thousand barriers such as dams and weirs in European rivers. In many river basins, the continuity of the rivers is interrupted every second kilometre, restricting the movement of migratory fish (EEA, 2015u). Dams and weirs are also used to alter the seasonal or daily flow regimes of rivers, to produce hydropower, and for water storage or irrigation (see also section 'Overexploitation'). This changes freshwater habitats and can have severe impacts on the status of aquatic ecosystems. Hydromorphological pressures and altered habitats are reported in over 40 % of rivers and one-third of lakes, especially in the Atlantic, Continental and Pannonian regions (Map 5.24). For example, only 21 % of German rivers, mainly in less populated areas,

Table 5.7 Major pressures on freshwater ecosystems, and their impacts on biodiversity in Europe

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Modification of watercourses Channelling River regulation Fragmentation (dams) Soil erosion from agriculture leading to sedimentation of gravel riverbed habitats	Changes in temperature, precipitation and average river flows Droughts	Water abstraction Gravel extraction	Invasive plants, fish, mammals (e.g. American mink), molluscs and crustaceans (e.g. merican signal crayfish)	Nutrient intake from diffuse and point sources (agriculture, wastewater, aquaculture) Pesticides Deposition of acid and nitrifying substances Heavy metals; household and industrial chemicals Endocrine disruptors Sediment transport from soil erosion

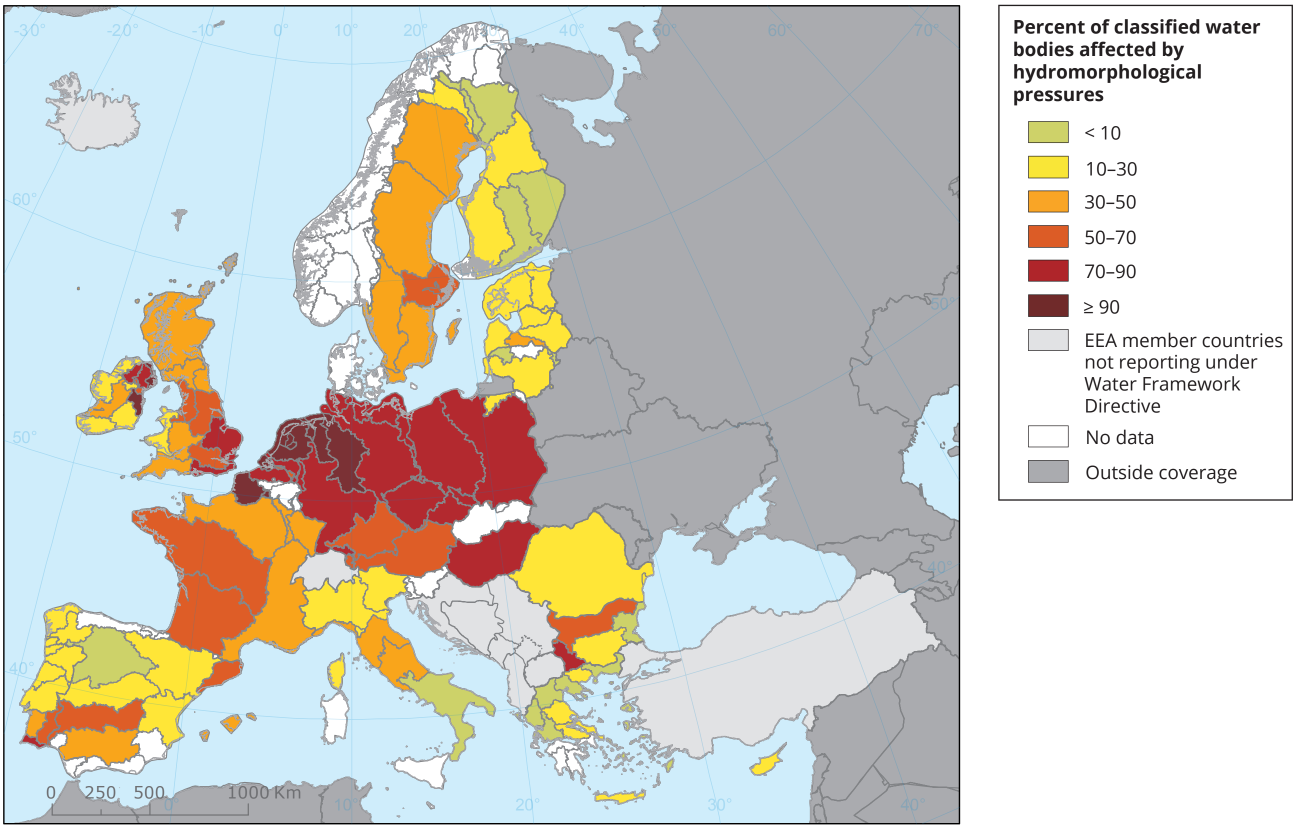
Key: Observed impact on biodiversity to date

Low	Moderate	High	Very high

(Habitat changes: very high; Climate change: moderate; Overexploitation: high; Invasive alien species: moderate; Pollution and nutrient enrichment: very high — as shown by cell colours.)

Source: Adapted from EEA, 2015a, and ETC/SIA, 2014c.

Map 5.24 **Percent of classified water bodies (in different river basin districts) affected by hydromorphological pressures**



Source: WISE-WFD database, June 2015. The results are calculated as a percentage of the total number of classified water bodies (http://www.eea.europa.eu/data-and-maps/figures/proportion-of-classified-water-bodies-4) accessed 12 December 2015.

are still in their natural state or only moderately altered, the majority of streams in Denmark have been directed into culverts or channels over the years, and over 90 % of rivers in Finland are regulated or otherwise modified (EEA, 2012c).

Climate change
Climate change is already affecting freshwater quantity and quality (EEA, 2012b). River flows have increased in winter and decreased in summer, but with substantial regional and seasonal variation (other factors also have a strong influence). The impact of river flow droughts, that is, prolonged periods of low river flow, is currently greatest in southern and south-eastern Europe. These impacts are projected to further increase with prolonged and more extreme droughts. Climate change has also increased water temperatures in rivers and lakes and has decreased ice cover.

Changes in stream flow and water temperature have important impacts on water quality and on freshwater ecosystems. Reduced river flow and groundwater discharge can affect water quality owing to reduced dilution of pollutants, and higher temperatures can stimulate the growth of algal blooms in areas affected by eutrophication. There is evidence that water bodies already under stress from other pressures are highly susceptible to the impacts of climate change, and that climate change may hinder attempts to restore some water bodies to good status, thus affecting their resilience, that is, their ability to absorb additional adverse pressures (EEA, 2012c).

Overexploitation
Although water quality has improved in recent years, water abstraction, storage and agricultural activities (irrigation and drainage) are altering freshwater ecosystems in many areas of Europe (EEA, 2012g). Abstraction for irrigation, household and industrial use has changed the flow regime of many river basins and lowered groundwater levels, particularly in southern Europe. Overabstraction is causing low-flow river stretches, lowered groundwater levels and the drying-up of wetlands, leading to significant

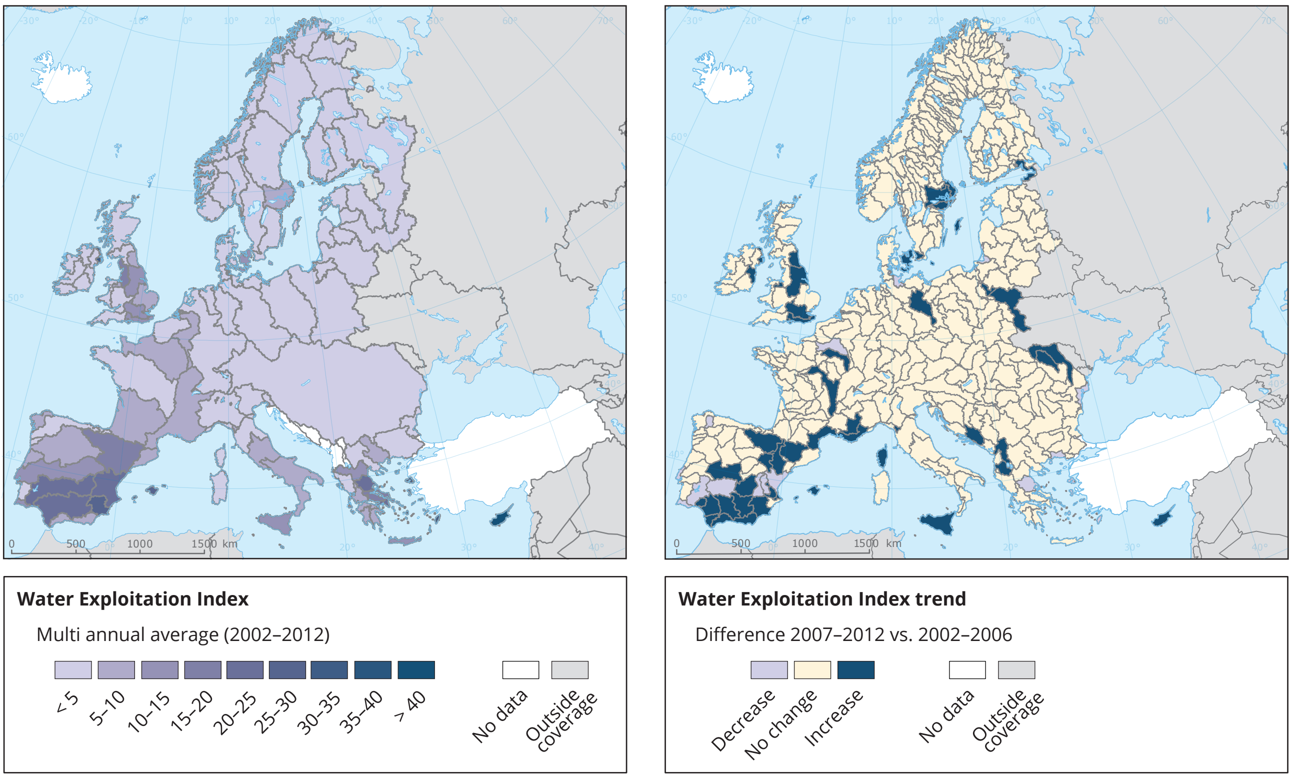
degradation of freshwater biodiversity (EEA, 2012c). Some activities related to energy production also result in pressures on water management, including hydropower generation, the use of water for cooling in power stations and cultivation of energy crops.

The water exploitation index (WEI) — the total water use as a percentage of the renewable freshwater resources in a given territory and time scale — provides an indirect indicator of the environmental impacts of overexploitation (Map 5.25). In Europe mainly areas in the Mediterranean region such as Cyprus, parts of Spain and Greece, and areas around big cities (e.g. France, Sweden, the United Kingsom) are affected by high water exploitation which creates water stress especially during summer (ETC/ICM, 2015b). Even if a time series of 11 years (2002-2012) is too short for robust trend detection, first analysis shows that overexploitation seems to further increase in many of these hot spot areas except for Greece and parts of Spain where a stable or even decreasing WEI was calculated. For most parts of Europe no significant changes are visible. Statistical analysis shows a slightly decreasing trend in WEI of less than 1% in these areas for the time period between 2002 and 2012 (ETC/ICM, 2015b).

Invasive alien species

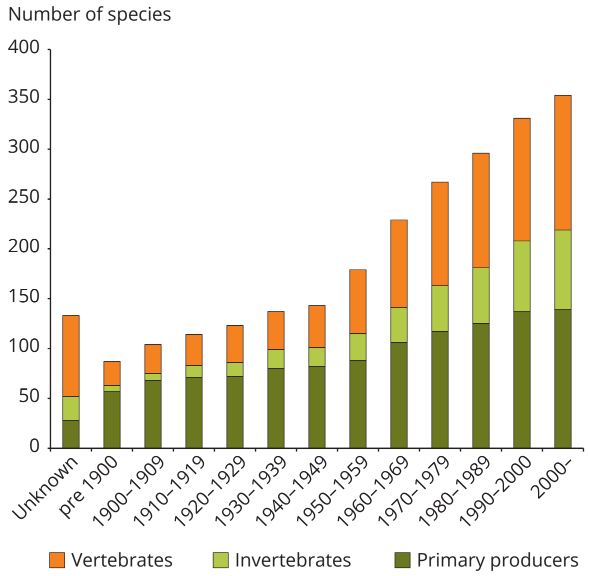
Alien species have been settling in European inland waters for centuries, but, according to the DAISIE (Delivering Alien Invasive Species Inventory for Europe) inventory, the number has increased significantly since the 1950s (see Figure 5.16), to reach 296 invertebrate and 136 fish species (DAISIE, 2009). The main introduction pathways are stocking of water bodies to support extensive fish culture and sport fishing (30 %), intensive aquaculture (27 %) and passive transport by ships (25 %) supported by channels connecting the major river systems of Europe such as the Danube–Rhine channel. Competition, predation and transmission of diseases between alien and native species are frequent and can pose a major threat to native species. Examples range from predatory mammals (the American mink, *Neovison vison*) and invertebrates (such as the signal crayfish, *Pacifastacus leniusculus*) to invasive plants such as the water hyacinth (*Eichhornia crassipes*), which can choke waterways (EEA, 2012d). Globalisation and climate change are projected to increase these aquatic 'bioinvasions' and reduce environmental resistance to organisms that are adapted to higher temperatures (Galil et al., 2007; EEA, 2010a, *Freshwater ecosystems*).

Map 5.25 Annual total water abstraction as a percentage of available long-term freshwater resources 2002–2012 (left) and average trend 2007–2012 compared to 2002–2006 (right)



Source: http://www.eea.europa.eu/data-and-maps/figures/water-exploitation-index-based-on-1, accessed 19 January 2016 (draft under Eionet review).

Figure 5.16 Cumulative numbers of all alien species in freshwater environments (data for 17 countries)



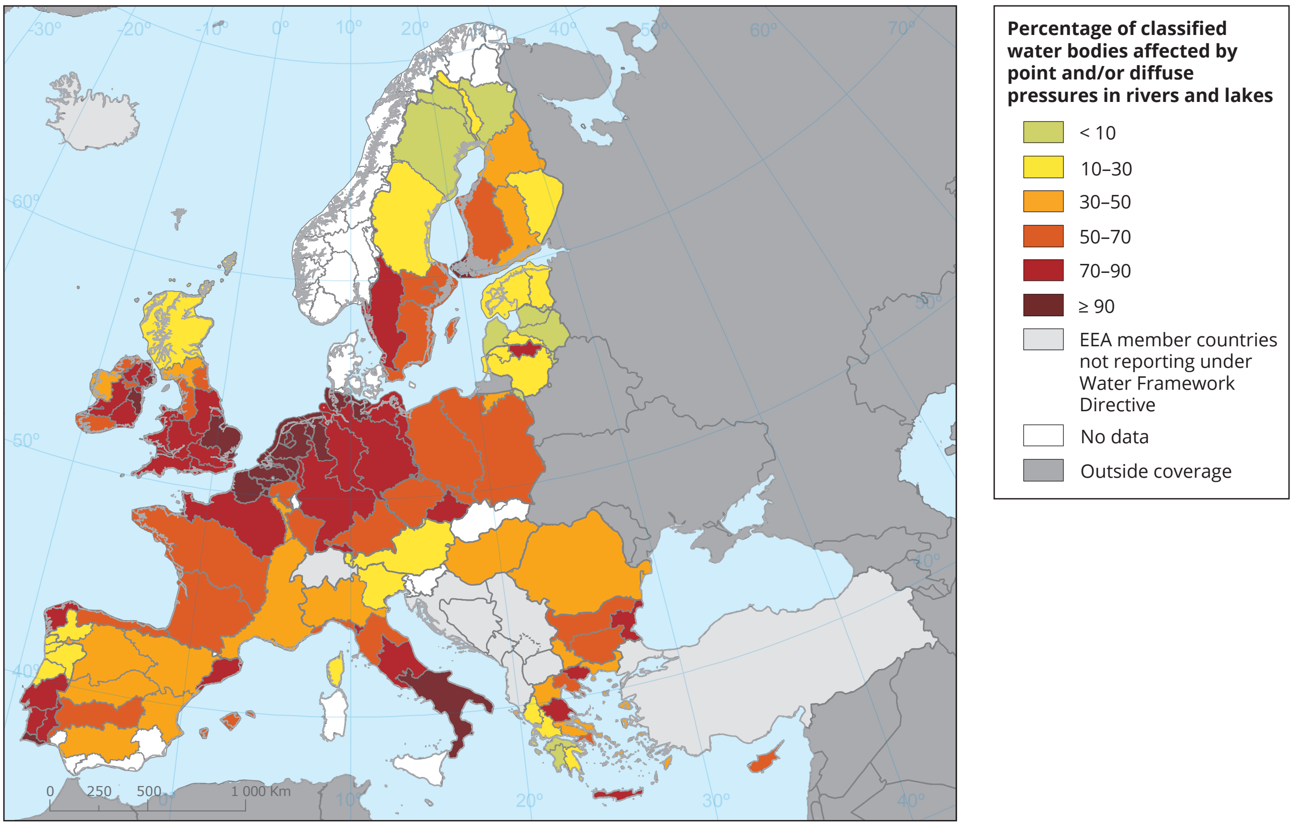
Source: EEA, 2012h.

Pollution and nutrient enrichment

Pollution from agriculture, industry, households and the transport sector has detrimental effects on aquatic ecosystems in many of Europe's surface waters, resulting in the loss of aquatic flora and fauna and causing concern for public health.

Significant progress has been made in reducing pollution in European waters over the last 25 years, (EEA, 2012c). The Urban Waste Water Treatment Directive (EC, 1991b), together with national legislation, has improved wastewater treatment across much of the continent, and this has been coupled with reduced volumes of industrial effluent, reduced use of fertilisers, reduced or banned phosphate content in detergents, and reduced atmospheric emissions. The average nitrate concentration in rivers has fallen by 20 % (EEA, 2015b, *Freshwater*). Nevertheless, a large proportion of water bodies are still affected by pollution, particularly in regions with intensive agriculture and high population density (Map 5.26).

Map 5.26 Percentage of classified water bodies affected by point and/or diffuse pressures in rivers and lakes



Note: The results are calculated as a percentage of the total number of classified water bodies.

Source: http://www.eea.europa.eu/data-and-maps/figures/proportion-of-classified-water-bodies-4, accessed 12 December 2015.

5.7.3 Condition

A large proportion of water bodies has a less than good ecological status (i.e. moderate, poor and bad), particularly in central and north-western areas of Europe with intensive agricultural practices and high population density (Map 5.27). Results from the first RBMPs in 2009 showed that only 43 % of surface water bodies had good or high ecological status, and this is only expected to improve to 53 % by 2015 — still far from meeting the Water Framework Directive objective of all water bodies having at least a good ecological status by 2015. Rivers have been reported to have worse ecological status and more pressures and impacts than lakes (EEA, 2012c).

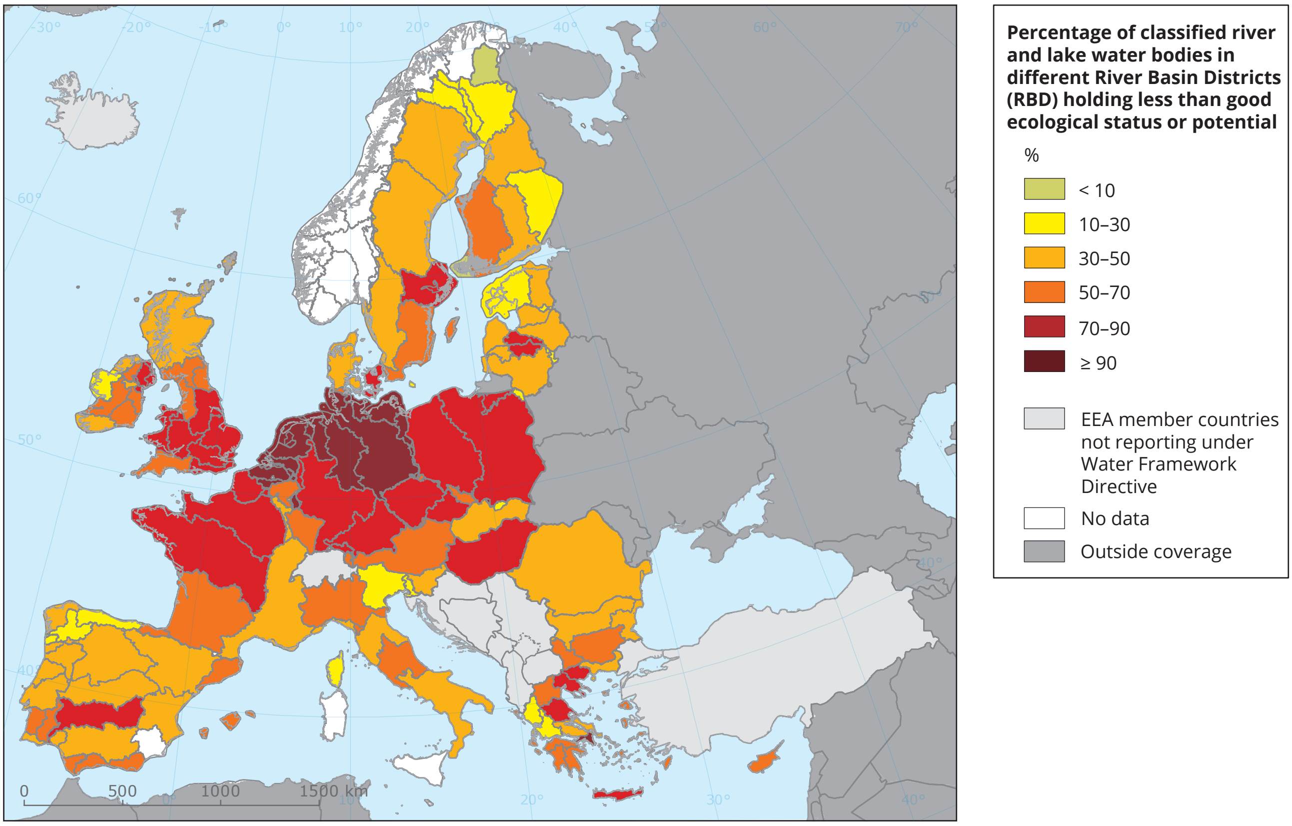
5.7.4 Policy response

To manage freshwater ecosystems effectively, policymakers need to balance the needs of water users with the health and resilience of the ecosystem, so that it can continue to deliver a range of ecosystem services into the future. This means that the focus needs to extend beyond the ecosystem itself in order to encourage sustainable use of water by households and industry, and to reduce pollution from industry, urban wastewater and agriculture. An integrated and ecosystem-based approach involving all stakeholders will be needed, encouraging all users in a river basin to focus on the achievement of healthy water bodies with good status.

It is important to address all pressures simultaneously (Heiskanen et al., 2012). For example, if the water flow is changed, then even a water body with good water quality may not achieve its full potential as habitat for wildlife (EEA, 2015b, *Freshwater*). The collaborators on the EU FP7 MARS project (MARS, 2015) argues that indicators are needed to assess the impacts of multiple pressures on freshwater ecosystems for developing a GIS-based web atlas of Europe-wide stressors, quality and services (Hering et al., 2015).

Freshwater ecosystems are protected through the same set of policies that were described in Section 5.6.4 on wetlands, that is, the Water Framework Directive, the Habitat Directive, the Urban Waste

Map 5.27 Percentage of classified river and lake water bodies in different River Basin Districts (RBD) with less than good ecological status or potential



Source: http://www.eea.europa.eu/data-and-maps/figures/proportion-of-classified-surface-water-4, accessed 12 December 2015.

Water Treatment Directive and the Nitrates Directive. Although the Water Framework Directive has led to a reduction in the discharge of pollutants, further investment is required in many European countries, and the next cycle of RBMPs need to take into account water resource management and the impacts of climate change. Full compliance with the Nitrates Directive is also required, and CAP reform provides an opportunity to further strengthen water protection by tackling agricultural pollution (EEA, 2012c).

A key policy document is *A blueprint to safeguard Europe's water resources* (EC, 2012a), part of the EU Biodiversity Strategy to 2020, which outlines measures that concentrate on better implementation of current water legislation, integration of water policy objectives into other policies and filling the gaps, particularly on water quantity and efficiency. The objective is to ensure that a sufficient quantity of good-quality water is available for people's needs, the economy and the environment throughout the EU by 2020.

Box 5.14 Case study: controlling invasive aquatic species and restoring natural communities in freshwater ecosystems (Ireland)

This project tackled invasive alien species at two sites:

- Lough Corrib in western Ireland: an internationally renowned brown trout fishery that is also protected under the EU Habitats and Birds Directives and is home to rare species including sea lamprey (*Petromyzon marinus*), Atlantic salmon (*Salmo salar*), freshwater pearl mussel (*Margaritifera margaritifera*), white-clawed crayfish (*Austropotamobius pallipes*) and the lesser horseshoe bat (*Rhinolophus hipposideros*).

- The Grand Canal — Barrow Line: a man-made watercourse stretching across Ireland, which supports Annex II species such as the opposite-leaved pondweed (*Groenlandia densa*) and the European river lamprey (*Lampetra fluviatilis*).

Both ecosystems are severely threatened by aquatic invasive alien species: curly-leaved waterweed (*Lagarosiphon major*) in Lough Corrib, and a range of species including Nuttall's pondweed (*Elodea nuttallii*), Asian clam (*Corbicula fluminea*) and Japanese knotweed (*Fallopia japonica*) in the Grand Canal. Apart from threatening the rare and diverse natural communities, these species also choke the waterways, increasing flood risk and impeding passage by boats. They are likely to spread to other linked water bodies unless effective eradication and control methods are developed.

The CAISIE (Control of Aquatic Invasive alien species and Restoration of Natural Communities in Ireland) LIFE+ Biodiversity project (2009–2013) aimed to develop and demonstrate new and effective control methods, particularly for submerged aquatic species. The project's achievements are listed below.

- 90 % of the curly-leaved waterweed was eradicated from Lough Corrib using a number of methods (light exclusion using jute matting, mechanical cutting using trailing knives or V-blades and manual removal by scuba divers), enabling re-establishment of native species and keystone plant habitats.

- New survey methods and a 'rapid reaction' capability were developed, allowing a quick response to new threats from invasive alien species in Lough Corrib.

- Pygmyweed (*Crassula helmsii*), Japanese knotweed, giant hogweed (*Heracleum mantegazzianum*) and Nuttall's pondweed were successfully controlled in the Grand Canal, and further spread of these species was prevented in a key dispersal corridor, using mechanical removal and targeted herbicide application. However, the Asian clam and Himalayan balsam (*Impatiens glandulifera*) remain a problem.

- The project's pioneering use of jute matting and trailing knives for the control of submerged aquatic weeds has already been applied in other weed-infested waters in Ireland, the Netherlands, the United Kingdom and further afield. The project also made considerable progress towards identifying a suitable biological agent to control curly-leaved waterweed.

Stakeholders were engaged through good communication and motivation, especially regarding the adoption of biosecurity guidelines for disinfecting fishing gear, which have been adopted by the main fishing organisations in Ireland. The project also produced guidelines on effective control measures and a list of national and international policy recommendations.

Source: CAISIE, 2013.

Wider initiatives, for example Danubeparks, a network of protected areas along the Danube (Zinke, 2011), aimed at reconnecting existing nature areas and improving the overall quality of ecosystems, are also relevant to freshwater ecosystems, helping to meet both the Water Framework Directive objectives and the EU Biodiversity Strategy's restoration target. The Green Infrastructure Strategy includes rivers and floodplains as important elements. Restoring freshwater ecosystems, such as by 'making room for the river', river restoration or floodplain rehabilitation has multiple benefits for freshwater ecosystems.

The link between water bodies and surrounding ecosystems has been investigated in two separate studies, one on the synergies between flood risks, flood plain restoration and polices (EEA, 2016b) and one on the importance of forests for water retention (EEA, 2015i). Urban rivers have attracted particular attention in recent years because of their role in enhancing urban ecology, green infrastructure and green areas in European cities (EEA, 2015b, *Freshwater*).

Tackling overextraction of water presents the challenge of meeting reasonable demands for water while leaving enough water in the environment to conserve freshwater ecosystems. This may require managers to cap water abstraction by each sector. The EEA and the European Commission are developing water accounts at the river basin level to inform the management of abstraction and the need to increase water use efficiency (EEA, 2015b, *Hydrological systems*) and provide additional information for water bodies (high-resolution layer), and riparian areas (very high-resolution layer) via the Copernicus Land Monitoring Services (Copernicus, 2015).

5.8 Marine ecosystems

5.8.1 Characteristics

Europe's seas include a wide range of marine and coastal ecosystems, ranging from the stable environment of the deep ocean to highly dynamic coastal waters (EEA, 2015c) (see Map 5.28). The deep-seabed ecosystem type beyond 200 m depth is the most extensive, representing almost 66 % of the total area (ETC/SIA, 2013c), but marine ecosystems also include the continental shelf, wave-washed coastal habitats and tidal marine inlets and transitional waters such as estuaries and fjords. They include over 1 000 EUNIS habitat types (Davies et al., 2004), which support over 36 000 species (Costello and Wilson, 2011). There is great variation in species richness across Europe's regional seas, although the Mediterranean Sea appears to host the highest natural biodiversity (UNEP/MAP, 2012). However, the task of identifying trends and patterns in the distribution of marine biodiversity is extremely challenging because of the fragmented information base.

Marine ecosystems supply services essential for human well-being, including food, materials, energy, recreational opportunities and climate regulation. Many of these services provide livelihoods for the estimated 41 % of the Europe's population living in coastal regions (in 2011), as well as contributing to the well-being of the wider population. However, human activities both at sea and on land are driving a range of pressures, resulting in pollution and eutrophication, the depletion of fish stocks, loss of biodiversity and damage to Water Framework Directive habitats (EEA, 2015c). Effective policy implementation is necessary to reduce these impacts and build and restore the resilience of the European marine ecosystem.

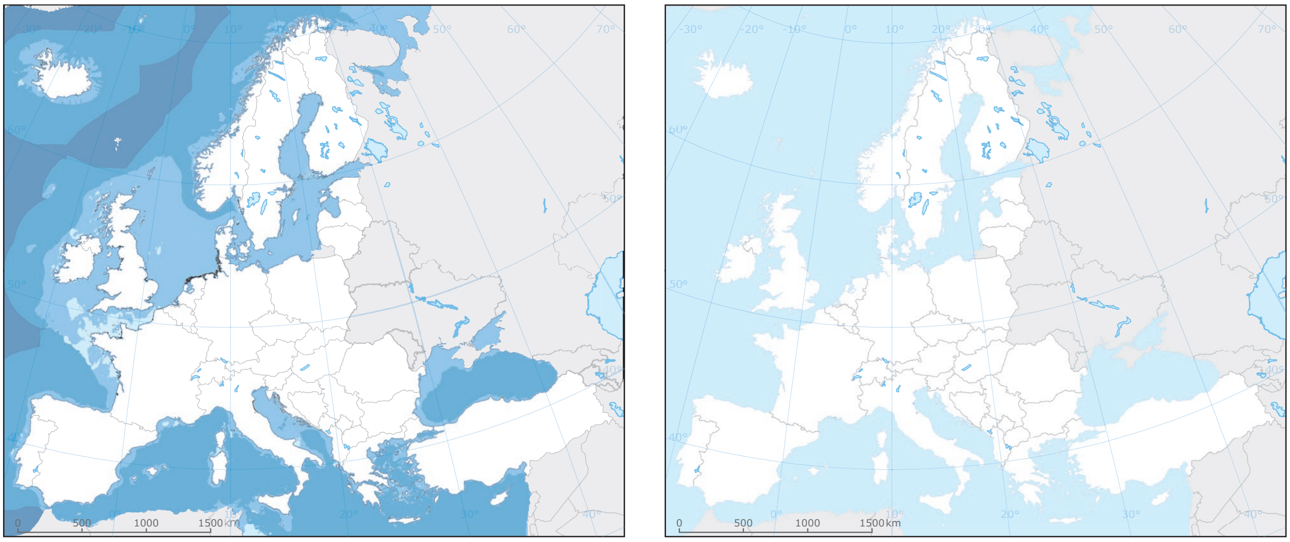
Box 5.15 Key messages for marine ecosystems

- Europe's seas provide essential ecosystem services, including the provision of food from fish, absorption of CO_2 and opportunities for recreation. Yet marine ecosystems are under pressure from overexploitation (overfishing and destructive fishing techniques such as bottom trawling), pollution and eutrophication, invasive alien species and climate change. There are some signs of improvement, for example overfishing and nutrient loading are decreasing in the Baltic and North Seas, but there is growing concern about the complex combined impact of multiple pressures.

- The Marine Strategy Framework Directive sets goals for Europe's seas to be healthy, clean and productive, yet only the last of these goals is being met. Only 9 % of the marine habitats and 7 % of marine species assessed under the Habitats Directive are in favourable conservation status, and 66 % of habitats are unfavourable. However, there are signs of recovery for some species in certain areas, such as the bluefin tuna (*Thunnus thynnus*).

- Despite recent progress and ambitious policies, the target of reducing the loss of biodiversity by 2010 has not been met. The 2020 target to conserve 10 % of Europe's marine ecosystems is challenging, as only 5.9 % of EU waters are currently within a network of Marine Protected Areas. Ecosystem-based management is a holistic approach that can help to reconcile conflicting demands on marine ecosystems, but its implementation is limited by lack of knowledge on the condition of marine ecosystems. It is therefore crucial to apply the EU's 'precautionary' and 'polluter-pays' principles until this knowledge can be gathered.

Map 5.28 Marine ecosystems in Europe



Marine ecosystems in Europe

- Infralittoral and circalittoral rock and other hard substrata
- Sublittoral sediment
- European regional seas (Deep-sea bed)
- Open waters
- Littoral rock and other hard substrata
- Littoral sediment
- Infralittoral rock and other hard substrata
- Circalittoral rock and other hard substrata
- Littoral rock or sediment
- Littoral rock or sediment and sea ice
- Infralittoral and circalittoral rock and other hard substrata and sea ice
- Littoral rock and other hard substrata and sea ice
- Littoral sediment and sea ice
- Sublittoral sediment and sea ice
- Deep-sea bed and sea ice
- Areas not covered by marine ecosystems
- Outside coverage

Coastal ecosystems in Europe

- Estuaries
- Coastal lagoons
- Areas not covered by coastal ecosystems
- Outside coverage

Note: Marine on the left and marine inlets and transitional and coastal waters on the right.

Source: http://discomap.eea.europa.eu/pages/Server_bio_Folder_Ecosystem.html, accessed 13 January 2015.

5.8.2 Drivers and pressures

Growing demand for food, energy and transport is driving the exploitation of Europe's seas. They have been affected by overfishing for many decades, and more recent pressures arise from marine aggregate extraction, offshore wind farms, coastal development, flows from intensive agriculture and aquaculture, and a huge increase in shipping (Airoldi and Beck, 2007). These activities are leading to the spread of invasive alien species, of water pollution and nutrient enrichment and of underwater noise, and there is also a substantial threat from large amounts of land-derived marine litter, especially plastic and microplastics (EEA, 2015c) (Table 5.8). Member State reports cite overfishing and pollution (including oil spills) as the two main pressures, and also add the impact of aquaculture (EEA, 2015d). Despite ongoing efforts to reverse these trends, current marine ecosystems, their biodiversity and their related ecosystem services remain under pressure.

Table 5.8 Major pressures on marine ecosystems, and their impacts on biodiversity in Europe

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Destructive fishing methods — bottom trawling Coastal land take (tourism development, wind farms)	Sea surface temperature Hypoxia Ocean acidification	Overfishing Marine aggregate extraction (locally)	Expansion of invasive alien species (introduced through shipping and aquaculture)	Eutrophication Heavy metals Fertilisers and pesticides Chemical pollution and oil spills or discharges from industries and shipping Marine litter (plastic)

Key: Observed impact on biodiversity to date

Low	Moderate	High	Very high

Source: Adapted from EEA, 2015a.

Habitat change
Physical loss of and damage to the seafloor is occurring in all European seas, affecting coastal zones as well as shelf and open ocean. Other pressures arise from land-based activities and industries, including agriculture (see section 'Pollution and nutrient enrichment') and urban development. The extent differs depending on the region. Fishing is the most widespread main cause of seafloor damage, but other causes include oil and gas installations, coastal and offshore constructions and tourism.

One of the main impacts on marine habitats is bottom trawling. Seabed habitats can take as long as 15 years to recover after the initial disturbance. Currently, 74 % of the EU fishing fleet uses mobile gear such as bottom trawling or dredging equipment, of which 61 % disturbs deep-sea ecosystems, although there is a gradual shift in the EU fishing fleet towards gear that has less impact on the seafloor. Estimates of the extent of physical damage vary greatly between Member States and regions, but this pressure was reported as being particularly high in areas of the North-East Atlantic Ocean and the Baltic Sea (EC, 2014d; Peterlin et al., 2014). The effects include physical loss of seafloor habitats, mortality of benthic communities and disturbances in the food web dynamics of the wider marine ecosystem (EEA, 2015c).

The increase in passenger ferry services as a result of the increase in tourism, as well as the maritime transport of goods, has led to the expansion of existing ports and marinas and the creation of new ones. This causes physical damage and loss to marine and coastal habitats, as well as creating additional pressures during construction and operation, such as sealing and smothering of coastal ecosystems, pollution and biological disturbances (e.g. species translocations) (EEA, 2015c).

Further coastal and marine habitat change may be caused by pipelines and cables that transport electricity, oil and gas, and telecommunications. In spite of a decline in oil and gas extraction in the North Sea and in Europe as a whole, the sector remains a vital part of the economy in the north-east Atlantic, including the North Sea, while new fields have been discovered in the Barents and Mediterranean Seas (EEA, 2015b, *Maritime activities*). Offshore renewables are also growing, with the value of offshore wind energy production increasing by 21.7 % between 2003 and 2008 (EEA, 2015b, *Maritime activities*). Some man-made coastal defence structures, such as sea walls, breakwaters or artificial reefs, can have positive impacts on the environment through preventing coastal erosion and protecting habitats from a rise in rise sea level or flooding. Nevertheless, it is essential that their environmental and socio-economic effects are thoroughly assessed before structures are built, as they can merely displace impacts elsewhere (EEA, 2015c).

Climate change
The oceans play a vital role in climate regulation. They are the largest carbon sink in the world, and it is estimated that each year they absorb approximately

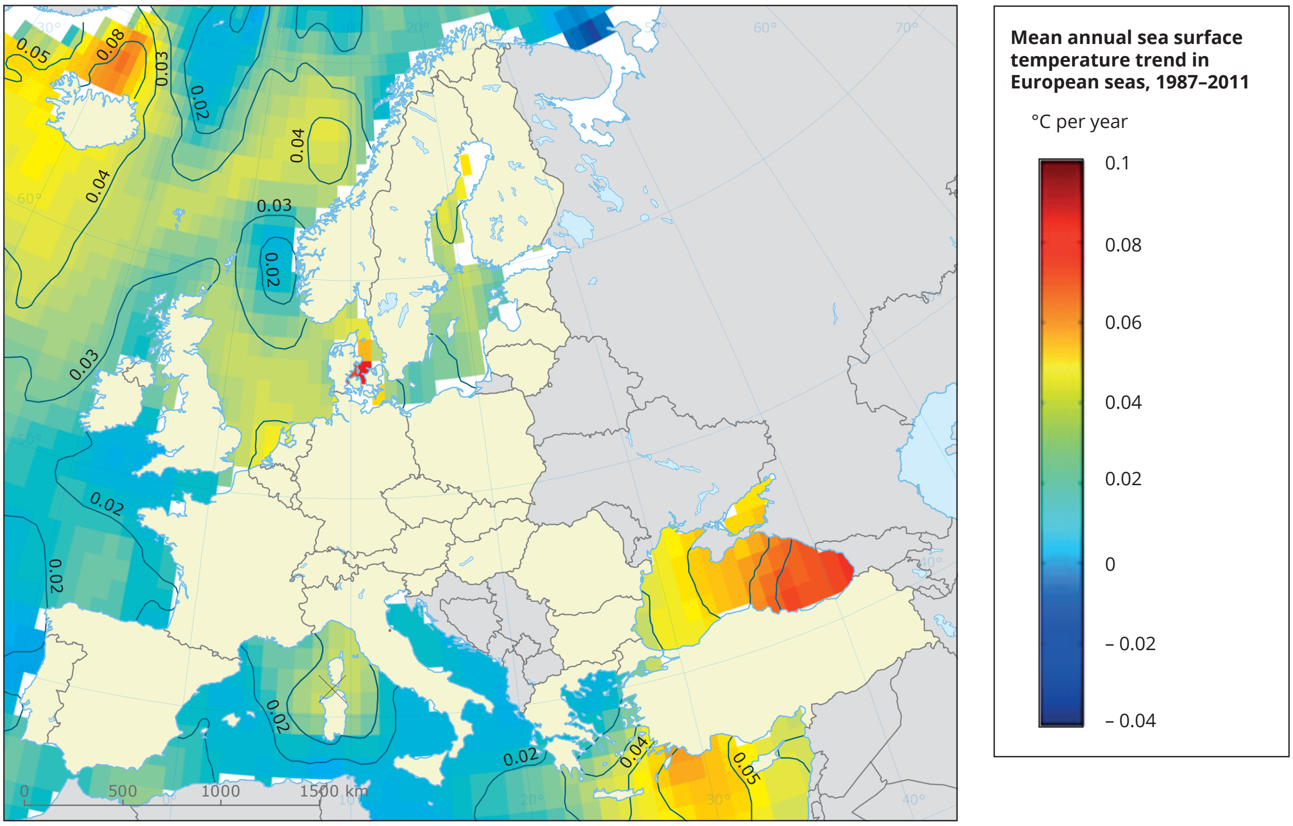
25 % of all the CO_2 humans emit. Nevertheless, they are vulnerable to increases in atmospheric CO_2 concentrations, which are leading to acidification of seawater, increased sea surface temperatures and oxygen depletion (hypoxia), all of which have been associated with mass extinction events in the past (EEA, 2015c). These phenomena are occurring at an accelerating rate: the rate of increase in sea surface temperatures in Europe's seas during the past 25 years is the highest ever measured, and it is faster than the average global rate (EEA, 2014a). The rate of warming varies across Europe's seas, although the fastest warming has been observed in the Black Sea (Map 5.29).

This rise in sea surface temperature causes marine organisms adapted to a certain temperature range to live under sub-optimal conditions or move elsewhere. In Europe's seas there are indications of a northwards movement in some species of fish and plankton. These behavioural responses cascade through the marine ecosystem, altering biogeochemical pathways and food webs, and eventually affecting fishing communities, which may cause tension between EU countries (EEA, 2012b).

Ocean acidification is occurring a hundred times faster than during previous natural events over the last 55 million years. It affects phytoplankton, which forms the basis of the marine food web, but also marine organisms such as corals, mussels and oysters, which have difficulty constructing their calcareous shell or skeletal material because of the low pH of the water (Hoegh-Guldberg, 2007). Hypoxia is also becoming more widespread, partly because warmer water can hold less dissolved oxygen, and partly because higher temperatures can stimulate the growth of algal blooms if excess nutrients are present (Deutsch et al., 2011).

The combined effects of these physical impacts decrease the overall resilience of marine ecosystems, making them even more vulnerable to other pressures (EEA, 2015b, *Maritime activities*). These changes often happen in a non-linear fashion, when so-called ecological 'tipping points' are crossed resulting in an entire ecosystem shifting into a new state, which may have a different species composition and changed resilience and is often less conducive to human well-being (EEA, 2015b, *Marine*).

Map 5.29 Mean annual sea surface temperature trend in European seas, 1987–2011



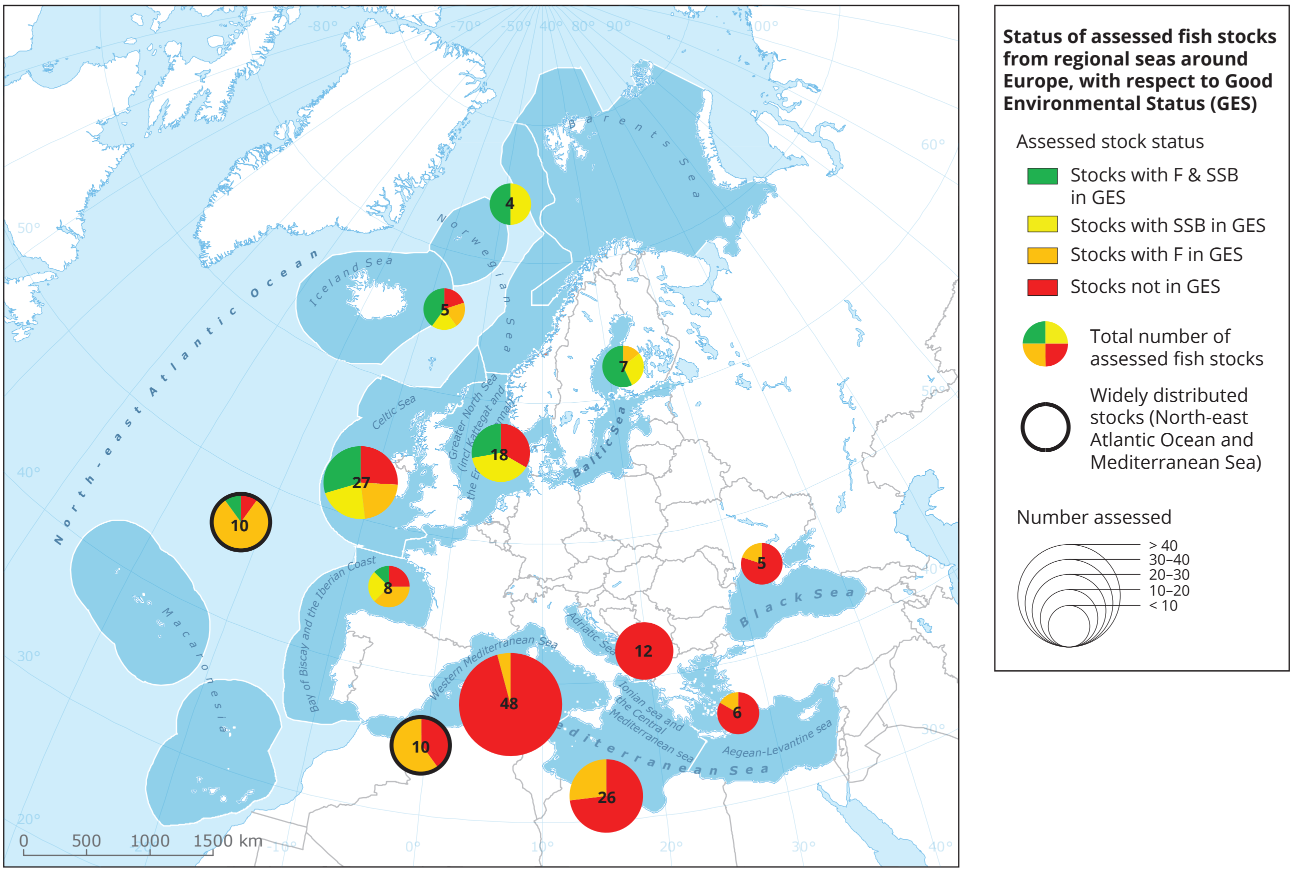
Source: http://www.eea.europa.eu/data-and-maps/indicators/sea-surface-temperature-1/assessment-1, accessed 12 December 2015.

Overexploitation
Exploitation of Europe's seas and coasts is increasing as new industries emerge and traditional ones move further off shore. The main pressures include seafloor exploitation, which also induces habitat change, extraction of species and mineral mining (EEA, 2015b, *Maritime activities*).

The second major pressure is overexploitation of fishing stocks. Only 19 % of EU commercial fish stocks are exploited sustainably, and 58 % are not in GES (Map 5.30). There are regional variations, with 84 % of the assessed stocks in the Mediterranean and the Black Seas failing to achieve good environmental status, but significant progress being made in the North-East Atlantic Ocean and the Baltic Sea, where overfishing of assessed stocks fell from 94 % in 2007 to 41 % in 2014. The assessments cover 60 % of the EU commercial catch but many stocks remain unassessed, including 68 % of those in the Mediterranean and the Black Sea (EEA, 2015c).

Invasive alien species
Records show that more than 1 400 marine alien species have been introduced into Europe's seas since the 1950s, some of which have already or will become invasive. The introduction rate is continually increasing, with around 320 new species observed since 2000 (see Map 5.31; EEA, 2015c). The main introduction pathways are shipping (51 %) and the Suez Canal (37 %), followed by aquaculture-related activities (17 %) and, to a much lesser extent, the aquarium trade (3 %) and inland canals. There are regional differences, as shown in Map 5.30. Shipping and aquaculture are the main pathways for most regions, but in the eastern Mediterranean Sea the introductions via the Suez Canal have enabled Red Sea species to migrate into the south-eastern Mediterranean Sea. Shipping is responsible for 85 % of invasive alien species in the Black Sea, while the contribution from aquaculture is highest in the North-East Atlantic Ocean, accounting for 54 % of the introductions in the Bay of Biscay and along the

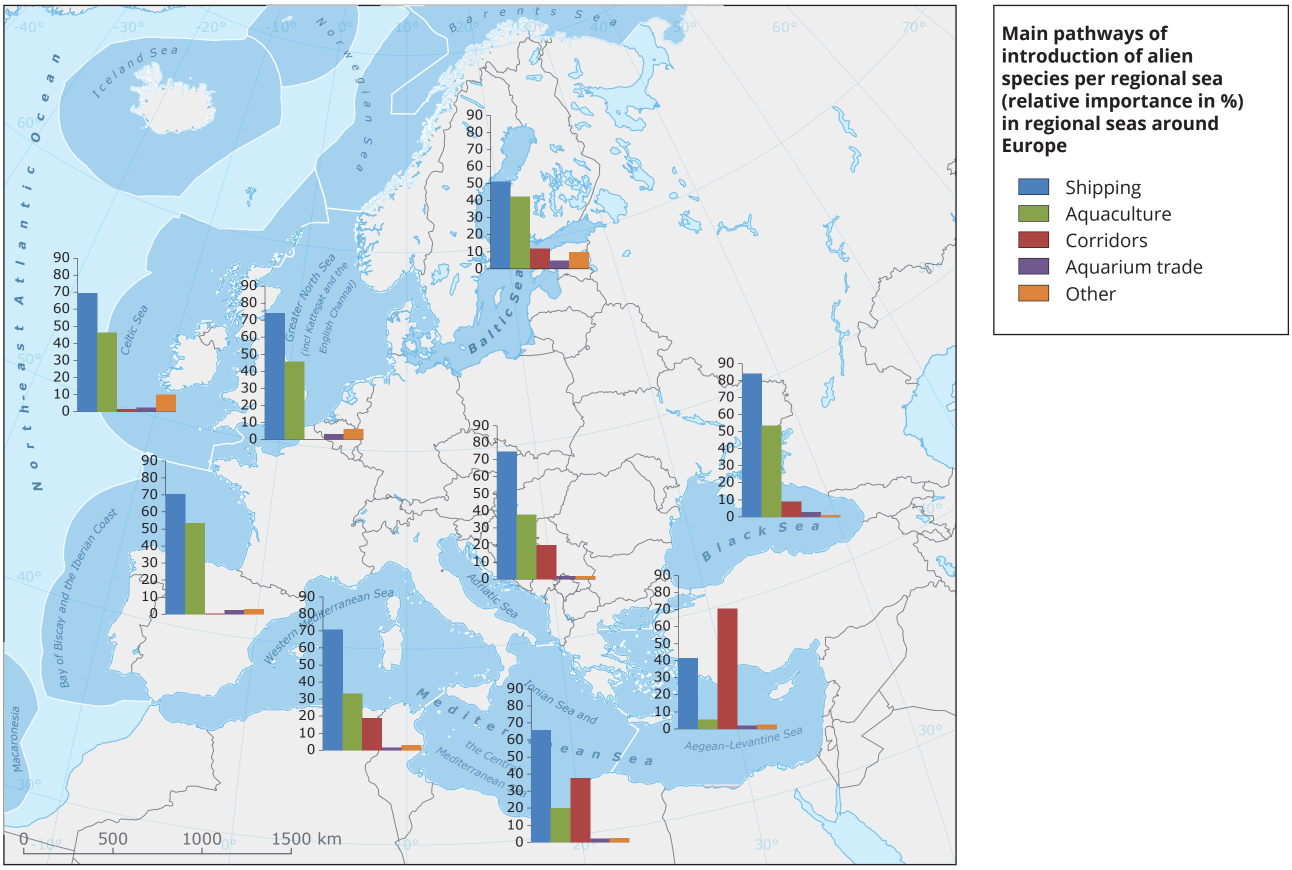
Map 5.30 **Status of assessed fish stocks from regional seas around Europe, with respect to Good Environmental Status (GES)**



Note: The numbers in the circles indicate the number of stocks assessed within the given region, and the size of the circles is proportional to the magnitude of the regional catch. Status refers to fishing mortality (F) and reproductive capacity (SSB) criteria, as defined by the Marine Strategy Framework Directive

Source: EEA, 2015c, based on initial assessments by Member States under the Marine Strategy Framework Directive.

Map 5.31 **Main pathways of introduction of alien species per regional sea (relative importance in %) in regional seas around Europe**



Source: EEA, 2015c.

Iberian coast, and approximately 45 % in the Greater North Sea and Celtic Sea (EEA, 2015c).

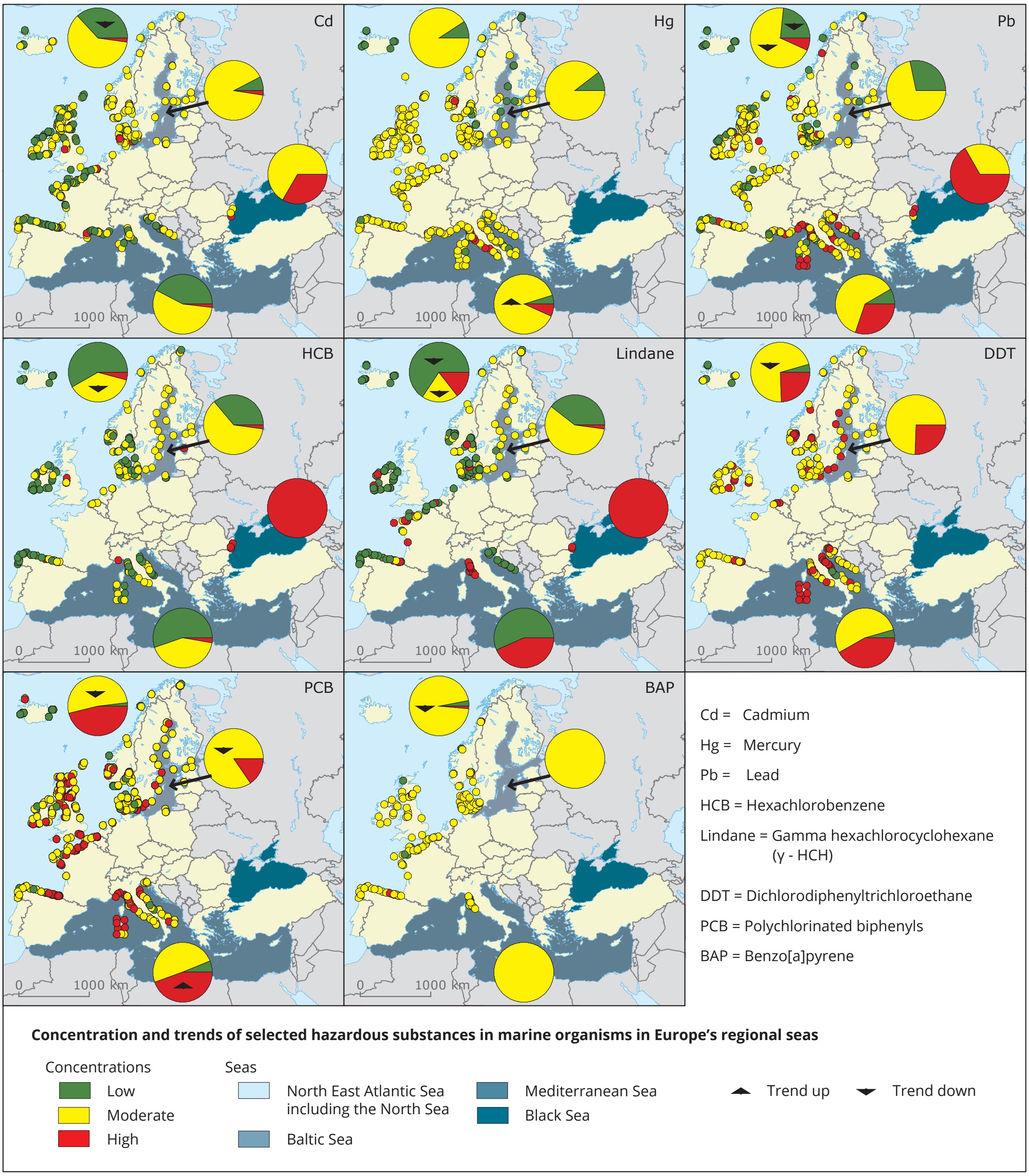
Although invasive alien species are widely accepted to be one of the main threats to biodiversity and ecosystem health, with widespread and irreversible impacts, impact assessments have been carried out for only a few of the introduced species (EEA, 2015c). Katsanevakis et al. (2014) identified marine alien species that have a high impact on ecosystem services and biodiversity in Europe's seas and found that food provisioning was most affected.

Pollution and nutrient enrichment

Excess nutrients come from agricultural fertilisers, urban wastewater, aquaculture, shipping and fossil fuel combustion. In spite of reductions in these inputs since 1985, as a result of EU directives, eutrophication continues to cause widespread environmental degradation in the Baltic, Black and Greater North Seas, by stimulating algal blooms and hypoxia that affect fish and benthic fauna, decrease the aesthetic and recreational value of the marine environment and are potentially toxic to animals and humans (EEA, 2015c). Assessments under the Water Framework Directive suggest that further nutrient reductions are needed in many parts of Europe. The Baltic and Black Seas are particularly vulnerable as they are semi-closed, with little or no water exchange with the open sea and with relatively large catchment areas and river inputs, allowing nutrients to accumulate and remain stored in the seafloor for decades. Hypoxic areas now cover 15 % of the Baltic Sea. In contrast, the Mediterranean Sea, although it is also enclosed, has very low river inputs and hypoxia is restricted to certain areas such as the northern Adriatic Sea, which receives a high nutrient load from the River Po. Climate change is already increasing the impact of eutrophication in the Black Sea, as warmer temperatures stimulate the growth of algal blooms (EEA, 2015c).

Other contaminants are widespread in the marine environment, due to the persistent nature of many substances. These include toxic substances originating from untreated waste water, shipping, port activities and other industries, plus chemicals that are used in everyday life (EEA, 2015c). While the sea has the ability to decompose some pollutants, such as wastewater and oil, they are becoming increasingly widespread in the marine environment. Map 5.32 shows the concentrations of seven pollutants, with regional trends indicated by arrows. A downward trend is seen in the North-East Atlantic Ocean for lead and lindane, whereas mercury and lead concentrations

Map 5.32 Aggregated assessment of hazardous substances in biota measured in the North-East Atlantic Ocean and the Baltic and Mediterranean Seas, 1998–2010



Source: EEA, 2015c.

in the Mediterranean Sea are increasing. Hazardous substances can accumulate through the food chain and can pose health risks to humans with a high dietary intake of seafood. Increasing amounts of marine litter, largely plastic coming from land-based sources, is also of growing concern in Europe's seas (EEA, 2015b, *Maritime activities*). Finally, underwater noise and disturbance from shipping, offshore construction, oil and gas exploitation and military activities is also a growing concern (EEA, 2015c).

5.8.3 Condition

Most marine habitats are subject to multiple pressures affecting marine ecosystem condition. The most comprehensive review of the condition of Europe's marine habitats is provided in the EEA report *State of Europe's seas* (EEA, 2015c), which summarises information from the initial assessments carried out by Member States under the Marine Strategy Framework Directive (see Section 4.2), and supplements this with a wide range of other sources including the Habitats Directive. Seven ecosystem components were assessed: Water Framework Directive and water column habitats, marine mammals, invertebrates, fish, turtles and birds. The report concludes that Europe's seas satisfy only one of the three goals of the Marine Strategy Framework Directive, in that they are productive but not healthy or clean, and thus the long-term delivery of ecosystem services is in jeopardy. Although the information base is fragmented, observations show that populations of many marine species across all Europe's seas are decreasing, and their distribution range and habitat is shrinking as a result of impacts from human pressures. At the same time, there are also examples of species where the declining trends appear to be halted, such as for bluefin tuna (*Thunnus thynnus*) in certain areas (EEA, 2015c).

Although the Marine Strategy Framework Directive is intended to cover all the main species and habitats within each marine region, the actual data reported were limited, with 80 % of the species and habitats categorised as unknown. Only 4 % were reported to have good status, with 2 % in bad status (Map 5.33). The State of Europe's seas report (EEA, 2015c) therefore relied to a large extent on Member States reporting under the Habitats Directive for 2007–2013, although this assesses only species and habitats of conservation interest. These reports show that only 9 % of the marine habitats assessed were considered to be in favourable conservation status, 66 % were in bad-inadequate status, and 25 % were unknown. For marine species, only 7 % of the assessments were favourable, 26 % were bad-inadequate and over 66 % were categorised as unknown.

Similarly, assessments by Regional Sea Conventions (OSPAR and HELCOM), are finding that marine ecosystems, their biodiversity features and their related ecosystem services remain under pressure in spite of ongoing efforts to reverse current trends. Europe has not yet achieved healthy seas, and it is thus eroding the potential services and benefits that such seas could deliver. HELCOM found that, out of 24 marine ecosystem services identified in the Baltic Sea, only 10 were operating properly with 7 being under severe threat (EEA, 2015b, *Marine*).

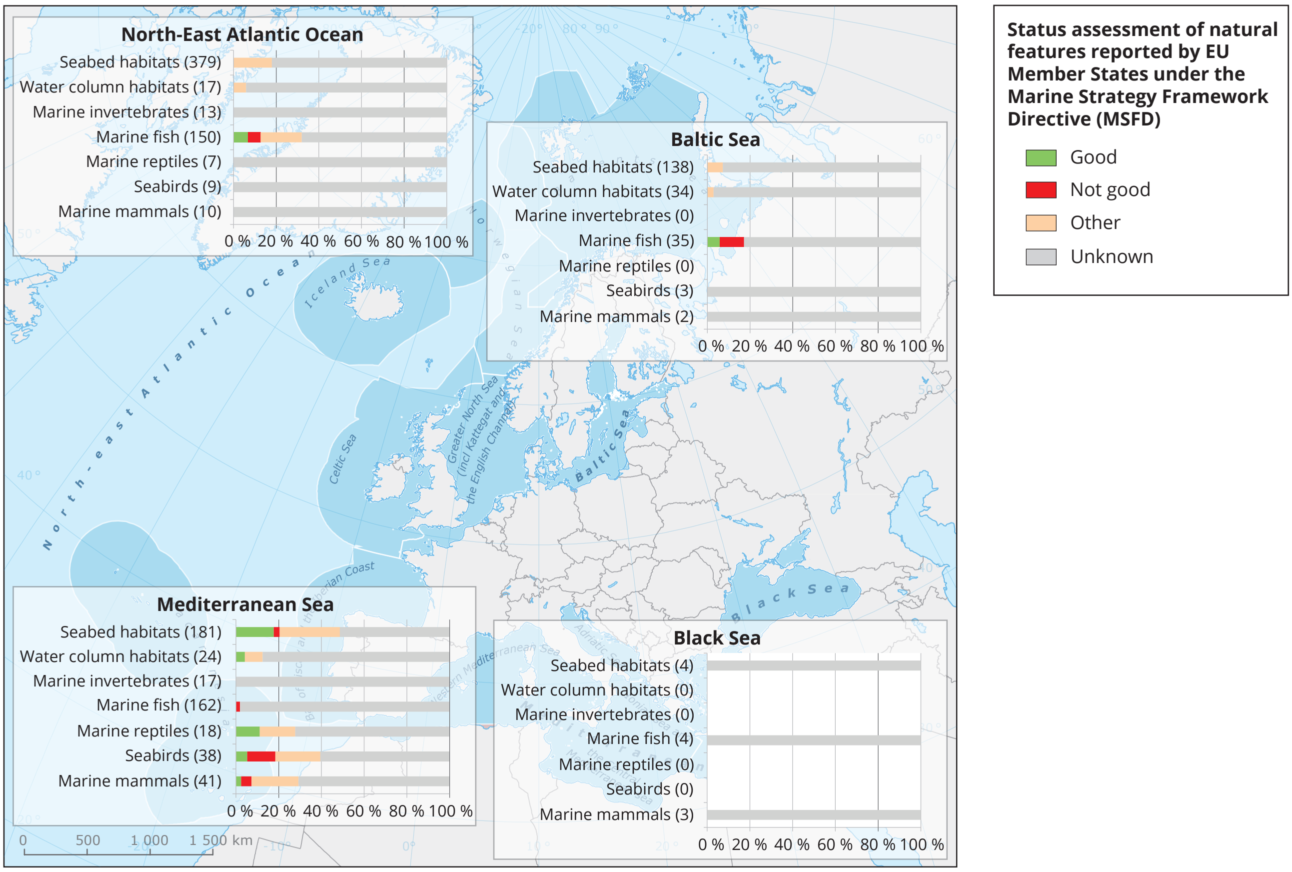
5.8.4 Policy response

Marine and coastal regions drive economic growth, by providing resources such as fish, oil and gas, enhancing trade and transport, and creating opportunities for recreation and tourism. It is estimated that maritime activities contribute about 6.1 million jobs and EUR 467 billion in gross value added to the European economy. Furthermore, they provide social, cultural and recreational benefits, whose value is difficult to assess in monetary terms but which all result in increased human well-being (EEA, 2015c). In recognition of the huge growth potential of the marine sector and related industries, including offshore renewable energy, coastal tourism, seabed mining and 'blue' biotechnology, the European Commission launched the Blue Growth Strategy in 2012 (EEA, 2015b, *Maritime activities*).

However, the exploitation of marine resources involves trade-offs. Maritime activities such as fishing, tourism and mineral extraction can damage biodiversity and marine habitats. In addition, land-based activities such as agriculture and urban development are damaging marine ecosystems through pollution and nutrient input. The available data, although limited, point to significant degradation of marine ecosystems, as reported in the previous section. In the long term, this can affect not just economic activities, such as commercial fishing and marine tourism, but also essential ecosystem services, such as climate regulation. In fact, the value of carbon capture and storage by the high seas worldwide has been estimated as USD 148 billion a year, compared with USD 16 billion a year for food provisioning (Rogers et al., 2014).

The EU has a range of policies relevant to reducing pressure on marine ecosystems. For marine ecosystems, the Seventh Environment Action Programme focuses on achieving sustainable fisheries and on reducing marine litter. The Biodiversity Strategy for marine ecosystems focuses on sustainable management of fish stocks and control of invasive alien species (EC, 2011a). Similarly, the Common Fisheries Policy emphasises the importance of managing fishing and aquaculture in a way that is

Map 5.33 Status assessment of natural features reported by EU Member States under the Marine Strategy Framework Directive (MSFD)



Note: The figures in parentheses are the number of reported features. The confidence rating of the information is rarely high.

Source: EEA, 2015c.

environmentally, economically and socially sustainable. The Maritime Spatial Planning Directive (EC, 2014g) aims to steer human activities at sea to be as efficient and sustainable as possible (EC, 2015h). The Water Framework Directive (see Section 4.2) aims to achieve good ecological and chemical status in coastal waters. However, it is clear that integrated policies are needed to address the systemic challenges facing Europe's seas, and this is the aim of the 2008 Marine Strategy Framework Directive (see Section 4.2), which is the key environmental component of Europe's Integrated Maritime Policy. The Marine Strategy Framework Directive aims to use a holistic ecosystem-based approach to achieving healthy, clean and productive seas, with a target for European marine waters to achieve GES by 2020. This approach considers the entire ecosystem, including humans, and acknowledges connections, cumulative impacts and multiple objectives, thus steering away from traditional approaches that address single species, sectors or activities. However, its application is severely limited by lack of information on ecosystem condition, implying that it is essential to use the precautionary principle and the 'polluter-pays' principle until the information base is adequate for a full assessment (EEA, 2014b, EEA, 2015c).

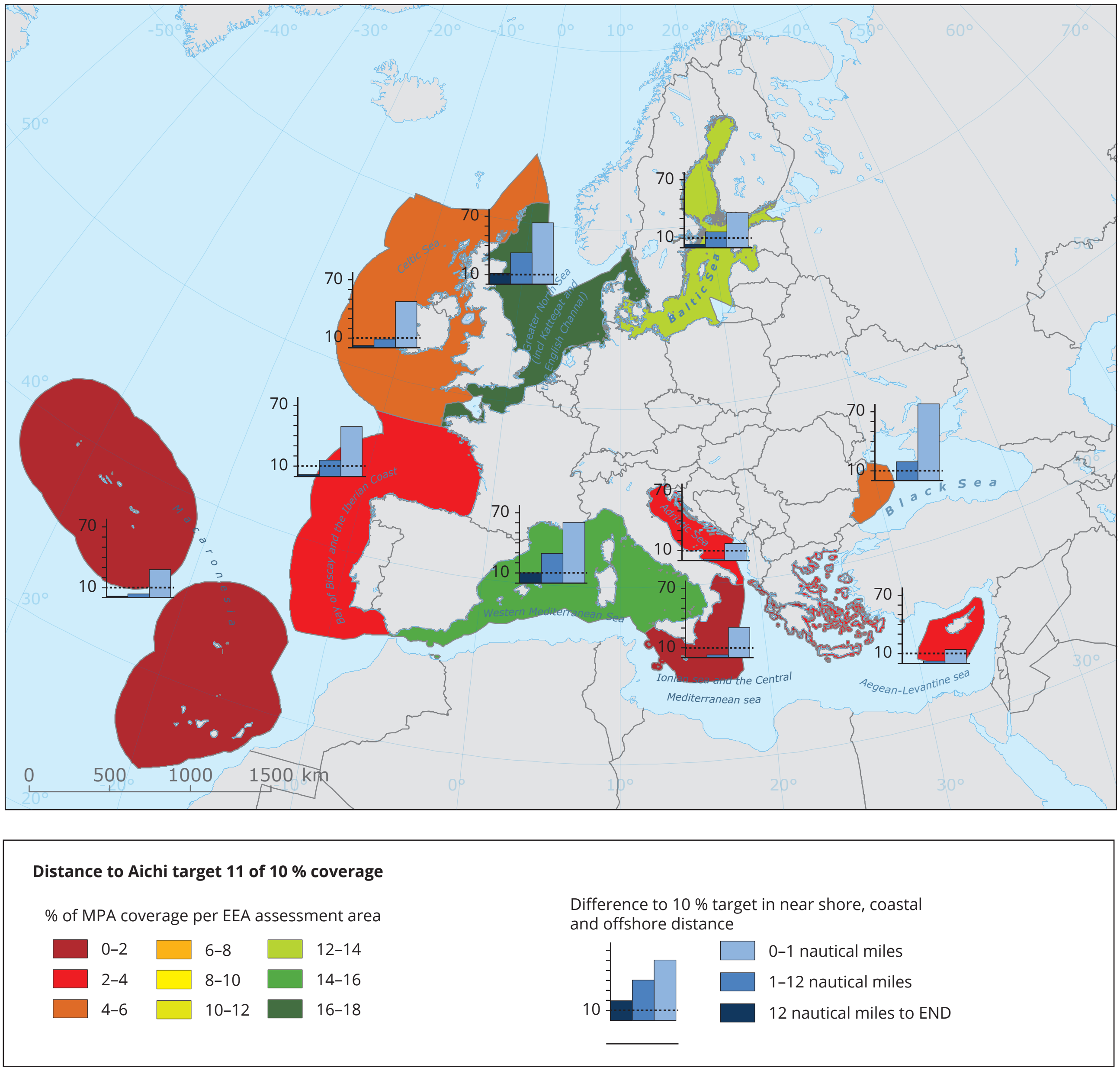
In spite of these strong policy ambitions, we saw in Section 5.8.3 that marine ecosystems in Europe are not in good condition, and marine natural capital is not being used sustainably. Strong action is required to restore and protect Europe's seas from further degradation. The Marine Strategy Framework Directive requires Member States to implement programmes of measures in 2016, with the aim of reversing marine degradation by 2020, although it will be challenging to achieve this target in the short time available (EEA, 2015c). A key element is the establishment of Marine Protected Areas, but these cover only 5.9 % of EU marine waters. For comparison, Target 11 of the Convention on Biological Diversity is for effective conservation of at least 10 % of Europe's marine ecosystems by 2020. Map 5.34 reveals a great disparity in the distribution of the Natura 2000 Marine Protected Areas, with most being coastal habitats and many located in the Baltic Sea (EEA, 2012f).

Certain EU marine nature conservation and fisheries management measures, however, are clear examples of positive action (EEA, 2015b, *Marine*). In response to these findings some Member States have established additional national protected areas, such as the Marine Conservation Zones in the United Kingdom offshore waters (2009) and the Marine Protected Areas in Scotland (2010) (EEA, 2012f).

Innovative solutions are emerging to balance trade-offs between conflicting uses of marine ecosystems. For example, marine and coastal tourism can offer an essential source of income for remote regions and areas that lack other major economic activities (EC, 2012b), but at the same time it contributes to a number of pressures on the environment. This conflict can be minimised by using tourism, especially eco-tourism, to fund and protect conservation measures. Box 5.16 shows an example of eco-tourism in Malta.

The State of Europe's Seas report concluded that many of the main environmental concerns are tackled by policies, but still objectives are not or only very slowly being met (EEA, 2015c).

Map 5.34 European marine regions and the coverage of Marine Protected Areas (MPAs)



Source: EEA, 2015h.

Box 5.16 Case study: marine ecotourism — Marine Protected Areas and underwater trails in Malta

The Maltese Government is developing underwater trails for divers and snorkelers to support the improved management of Marine Protected Areas. The project, entitled MedPan North, receives funding through the EU and brings together 11 organisations from around the Mediterranean (MEPA, 2014).

The Marine Protected Area is on the north-west coast of the Maltese Islands and covers 11 km of coastline. The area exhibits the main marine habitats occurring around the Maltese Islands, including a number of rare and threatened habitats, as well as species which are protected or of conservation interest. The underwater trails start at the shore and follow a seaward route through 11 stations. Waterproof information booklets placed at each station explains the various habitat types, flora and fauna, enabling snorkelers and divers to learn about the marine environment they encounter in the area (Adi Associates, 2014).

The MedPan North project demonstrates the value of Marine Protected Areas for recreation and tourists. It will potentially attract snorkelling and diving enthusiasts to the area and support local communities through increased tourism revenues.

Source: EEA, 2015c.

5.9 Synthesis

5.9.1 Trends in pressures

Table 5.9 gives an overview of the impact of each pressure on biodiversity to date (colour of box) and the projected future trend in the pressure (direction of arrow) across each ecosystem. Some patterns can be seen; for example, past impacts and future trends are the same across freshwater and wetlands, and future trends are the same across cropland and grassland, due to the similarities between these ecosystems. Habitat change and pollution/nutrient enrichment are estimated to have caused the greatest overall impact across ecosystems until now, but climate change pressures are projected to significantly increase across all ecosystems in the future. This broadly reflects the findings of the global Millennium Ecosystem Assessment (MA, 2005), although there are some differences: the intensity of past pressures is greater in Europe, owing to its history of industrialisation and intensive agriculture, but the pressure of 'pollution and nutrient enrichment' is predicted to decrease as a result of improved policies and legislation. Indeed, all but three pressures (habitat change for forest ecosystems and pollution for freshwater and wetland ecosystems) are anticipated to remain stable or increase in the future. This will make the fulfilling of biodiversity policy objectives more challenging.

5.9.2 Ecosystem interactions

Ecosystems are inextricably linked to each other through land use and management and processes such as horizontal and vertical flows and interactions as well as by decision-making. Landscape mosaics and spatial patterns of ecosystems are important for many functions such as providing species habitats, flood protection and attractive landscapes for recreation. Land use changes, driven by population growth and increased consumption, are causing urban, agricultural and forest ecosystems to expand in many parts of Europe at the expense of the area and quality of other habitats such as grassland, wetlands and heath (EEA, 2016c). At the same time, farmland is being abandoned in some areas, leading to natural succession to shrub and woodland (Figure 5.17). Thus an increase in the area of one ecosystem causes habitat loss and fragmentation of others. The impacts of land use change extend beyond the boundaries of Europe, and changes in food or timber production can indirectly affect overseas ecosystems that are used to produce commodities for import to Europe, which is also addressed in Target 6 of the EU Biodiversity Strategy to 2020. The significant role of the ocean as a carbon sink also means that changes in marine ecosystems can affect terrestrial and freshwater ecosystems through climate regulation.

Similarly, changes in land management, such as more intensive use of fertilisers or pesticides in agricultural areas, can affect neighbouring ecosystems and also, by the transport of air or water pollutants or changes in greenhouse gas emissions, those further away, such as coastal and marine ecosystems. Member States report that agricultural land management is the main pressure on species and habitats in cropland and grassland ecosystems, and forest management is the main pressure in woodland and forest ecosystems. For heathland and shrub ecosystems, both agricultural intensification and farmland abandonment were top-ranked pressures for birds, whereas for non-bird species it was forest management (EEA, 2015d).

Table 5.9 Trends in pressures on ecosystems

Ecosystem type	Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Urban	↗ (Very high)	↑ (Moderate)	↗ (Low)	↗ (High)	↑ (Very high)
Cropland	↗ (Very high)	↑ (Moderate)	↗ (High)	↗ (Moderate)	↑ (Very high)
Grassland	↗ (High)	↑ (Low)	↗ (Moderate)	↗ (Low)	↑ (Low)
Woodland and forest	↘ (High)	↑ (Low)	→ (Moderate)	→ (Moderate)	↗ (Moderate)
Heathland, shrub and sparsely vegetated land	→ (Moderate)	↑ (Moderate)	→ (Low)	↗ (Moderate)	↗ (Low)
Wetlands	→ (Very high)	↑ (Moderate)	→ (High)	↗ (Moderate)	↘ (Very high)
Freshwater (rivers and lakes)	→ (Very high)	↑ (Moderate)	→ (High)	↗ (Moderate)	↘ (Very high)
Marine (transitional and marine waters, combined)	↗ (Very high)	↑ (Moderate)	→ (High)	↗ (High)	→ (High)

Key:

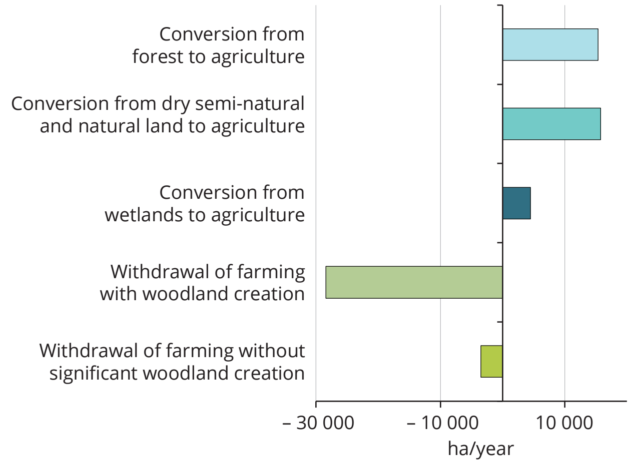
Projected future trends in pressure			
↘	→	↗	↑
Decreasing	Continuing	Increasing	Very rapid increase

Observed impact on biodiversity to date			
Low	Moderate	High	Very high

Source: Adapted from EEA, 2015a.

These interactions also relate to synergies and trade-offs between ecosystem services. Often, land use and management changes are driven by the desire to increase the supply of provisioning services, such as food, timber or fuel, but this can have negative impacts on biodiversity and on other services, especially regulation and maintenance, such as water quality regulation and erosion protection, and cultural services, such as the availability of aesthetic landscapes. Similarly, for marine ecosystems, the desire to increase the supply of wild fish provisioning could lead to ecosystem impacts, reducing the delivery of the other services. For example, the by-catch of other marine species, such as small cetaceans and turtles, would affect the delivery of cultural services, such as wildlife tourism. Ecosystem mapping and assessment can help policymakers to manage these interactions, minimising trade-offs and maximising synergies as far as possible. Ecosystem-based management approaches, which seek to jointly manage all human activities on ecosystems and involve all stakeholders, can help to develop integrated management plans that balance demand for different ecosystem services with the need to protect biodiversity in order to maintain healthy and resilient ecosystems and ensure continued service delivery. These integrated plans can span many different policy areas. For example, a plan to improve the condition of agro-ecosystems could include innovative farming techniques, reducing food waste, efficient biofuel production, better spatial planning in order to minimise land take, and changes in diet (EEA, 2015b). Integrated approaches are essential to enable the transition to a sustainable, resource-efficient future.

Figure 5.17 Main annual conversions between agriculture and forests and semi-natural land, 2000–2006 (ha/year



Source: Land Cover Accounts, based on CLC 2000–2006 data, and EEA, 2015 (http://www.eea.europa.eu/data-and-maps/indicators/land-take-2) accessed 12 December 2015.

5.9.3 Gaps in knowledge and data

During the assessments of the main ecosystem types, gaps in our knowledge were identified and highlighted. A notable lack of data was identified with reference to urban and marine ecosystems. For marine ecosystem areas, the information base generated by the implementation of relevant EU legislation is poor and fragmented, so that assessment at the European level remains challenging. For urban areas, the gaps could be attributed to the relatively low ecological value of these ecosystems, although the increasing focus on the role of green and blue infrastructure in providing regulating and supporting services is likely to result in this gap being filled. There is also a lack of data on the extent to which the re-use of previously developed land is reducing pressures for development on virgin land (EEA, 2015b *Land systems, Urban systems*). There were also gaps in the data for specific regions, for example a lack of assessments in the Mediterranean region was evident in recent reporting (2007–2012) under the Habitats Directive.

There was some lack of clarity in the ecosystem typology, in particular with regards to marine ecosystems (Section 3.1). In addition, there was a lack of a coherent/common categorisation between the different sources of data. This is related to the issue of 'paired' ecosystems, that is, those which are commonly (although not always) addressed together, such as grassland and cropland under 'agro-ecosystems'. Avoiding overlaps between ecosystems is challenging in these cases.

As mentioned in Section 4.3.1, policymakers also need a better understanding of interactions between pressures in order to assess the impacts of cumulative pressures on ecosystems. This would help in understanding the effects of concurrent changes in pressures and their drivers, and in distinguishing the individual impacts of pressures on ecosystems, which may not always be synergistic but in some cases may also be antagonistic. There is also limited knowledge of the positive and negative interactions between ecosystems, in their functions of providing habitats for species and capacity for service provision, and of the trade-offs and synergies between ecosystem services.

5.9.4 Strategic outlook

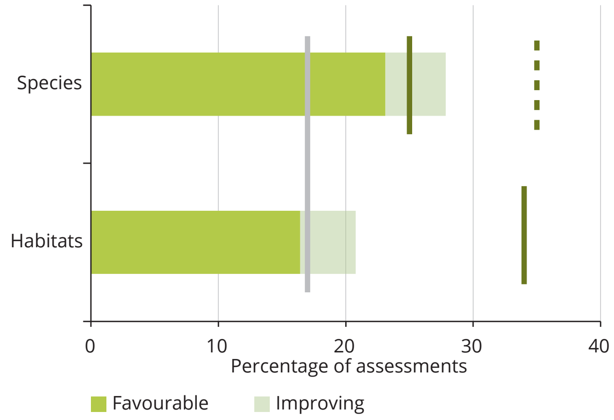
In the past decades the enhancement of environmental legislation and the establishment of common EU policies has led to significant reductions in some specific, sector-based pressures, such as those leading to acidification in terrestrial and freshwater ecosystems, with resulting benefits for habitats and species across Europe and ecosystem service provision. Such progress can be assessed against Target 1 of the EU Biodiversity Strategy. This aims to halt the deterioration in the status of all terrestrial and freshwater species and habitats covered by EU nature legislation and achieve a significant and measurable improvement in their status so that, by 2020, compared with current assessments:

1. 100 % more habitat assessments and 50 % more species assessments under the Habitats Directive show a favourable or an improved conservation status; and

2. 50 % more species assessments under the Birds Directive show a secure or improved status.

In contrast, recent assessments of the conservation status of habitats in Member States reveal that most have an 'unfavourable' conservation status and few are in 'favourable' condition, with some exceptions in eastern European and south-eastern Mediterranean countries (EEA, 2015d). Only 20 % of habitat types reached the target condition of favourable or improving, compared with the 2020 target of 34 % (Figure 5.18). Although the target for species has been achieved, with more than 28 % of species assessments listed as favourable or improved, this apparent progress is mainly attributed to better data or changes in methodology than to real conservation efforts. For example, many species previously assessed as 'unknown' are now 'favourable'.

Figure 5.18 Progress to the 2020 target for habitats and species assessed under the Habitats Directive



Note: The vertical black bar indicates the target (34 % for habitats and 25 % for species) and the grey bar the proportion achieved in 2001–2006 (17 % for both species and habitats).

Source: EEA, 2015d.

Similarly, progress for habitats and species across Europe could be assessed against Target 2, which aims to maintain and enhance ecosystems and their services by establishing green infrastructure and restoring at least 15 % of degraded ecosystems. However, it is widely recognised that restoration of habitats can often take a long time regarding the full realisation of the benefits and impacts; for example, the positive impacts achieved by restoring forest ecosystems to a more favourable age structure could take many decades. Hence, achieving this target will be more challenging (see also EC, 2015c).

To summarise, Europe needs to intensify its efforts to meet the challenge of reconciling food and energy security, low environmental impact, human well-being and economic prosperity. Impacts and pressures need to be viewed holistically to implement policies and develop management measures that can lead to landscape and (sub-)regional sea-scale improvements for Europe's ecosystems. A robust evidence base of pressures and impacts will be crucial in guiding these developments and drawing links between existing policies. An example that links agricultural and biodiversity policy is the recent CAP reform to reward farmers for maintaining permanent grassland, ecological focus areas and crop diversification instead of maximising production (EEA, 2015b). Other measures imply a further reduction in CO_2 emissions to reduce acidification and subsequent pressures on marine ecosystems and their species (EEA 2012b).

6 European restoration and green infrastructure strategies: progress and knowledge base

6.1 Background and policy context

The European Commission defines green infrastructure (GI) as:

> *a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are of interest) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.*
>
> EC, 2013b.

This section focuses on the way in which mapping and assessment of ecosystems can help with the delivery of this 'strategically planned network' and the 'wide range of ecosystem services' that it intends to deliver.

The provision of green infrastructure is a key policy response to help planners to protect and restore ecosystems in line with the goals of many European Commission policies, especially the EU Biodiversity Strategy to 2020, which required the European Commission to develop a Strategy on green infrastructure. Target 2 calls for ecosystems and their services to be 'maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems' by 2020, and Action 6a states that 'by 2014, Member States, with the assistance of the Commission, will develop a strategic framework to set priorities for ecosystem restoration at sub-national, national and EU level' (EC, 2011a). The importance of green infrastructure and the need for restoration is expected to increase in future (Maes et al., 2014).

The Green Infrastructure Strategy, adopted by the Commission in 2013, makes the case that 'GI is a successfully tested tool for providing ecological, economic and social benefits through natural solutions' (EC, 2013b). It clarifies the relationship between green infrastructure and ecosystem services and makes clear the importance of ecosystem mapping (as implemented through Action 5 of the Biodiversity Strategy) in supporting the delivery of green infrastructure.

The strategy also seeks to promote green infrastructure within wider European policy: research for the EEA indicated that there is a reasonable degree of policy coherence around green infrastructure, with European policies across multiple sectors and funding sources supporting its enhancement (EEA, 2011c; EEA, 2016e). Examples include:

- **the Water Framework Directive, Nitrates Directive and Floods Directive**, which include opportunities related to green infrastructure (for instance by supporting measures to put in place green infrastructure to improve soil retention, act as buffer strips between agricultural production and water sources and provide water storage during flood events);

- **the Thematic Strategy on the Urban Environment**, adopted in 2006, supports the integrated management of the urban environment in a way that avoids the loss of natural habitats and biodiversity, currently referred to as green infrastructure;

- **the Seventh Environment Action Programme** picks up within its priority objectives 1 and 7 the importance of 'expanding the use of green infrastructure', in part to 'help overcome fragmentation' while recognising within priority objective 3 the positive 'socioeconomic benefits' of green infrastructure (EC, 2013c);

- **Cohesion Policy Funds** now identify biodiversity, brownfield redevelopment and green infrastructure among their spending areas (IEEP and Milieu, 2013);

- **the CAP** states that rules should be introduced to build up adjacent ecological focus areas (EFAs) to ensure that regional implementation brings additional benefits from the environmental and landscape points of view and contributes to the implementation of the Green Infrastructure Strategy (CAP Delegated Acts R639/2014; EC, 2015i);

- **the LIFE Programme** includes funding for 'pilot or demonstration projects testing and then implementing Green Infrastructure actions';

funding is also available for green infrastructure development (EC, 2014c).

The Green Infrastructure Strategy will also support other policy lines. For example:

- **the EU Adaptation Strategy** will draw in the Green Infrastructure Strategy to explore the need for additional guidance for authorities and decision-makers, civil society, private business and conservation practitioners to ensure the full mobilisation of ecosystem-based approaches to adaptation;

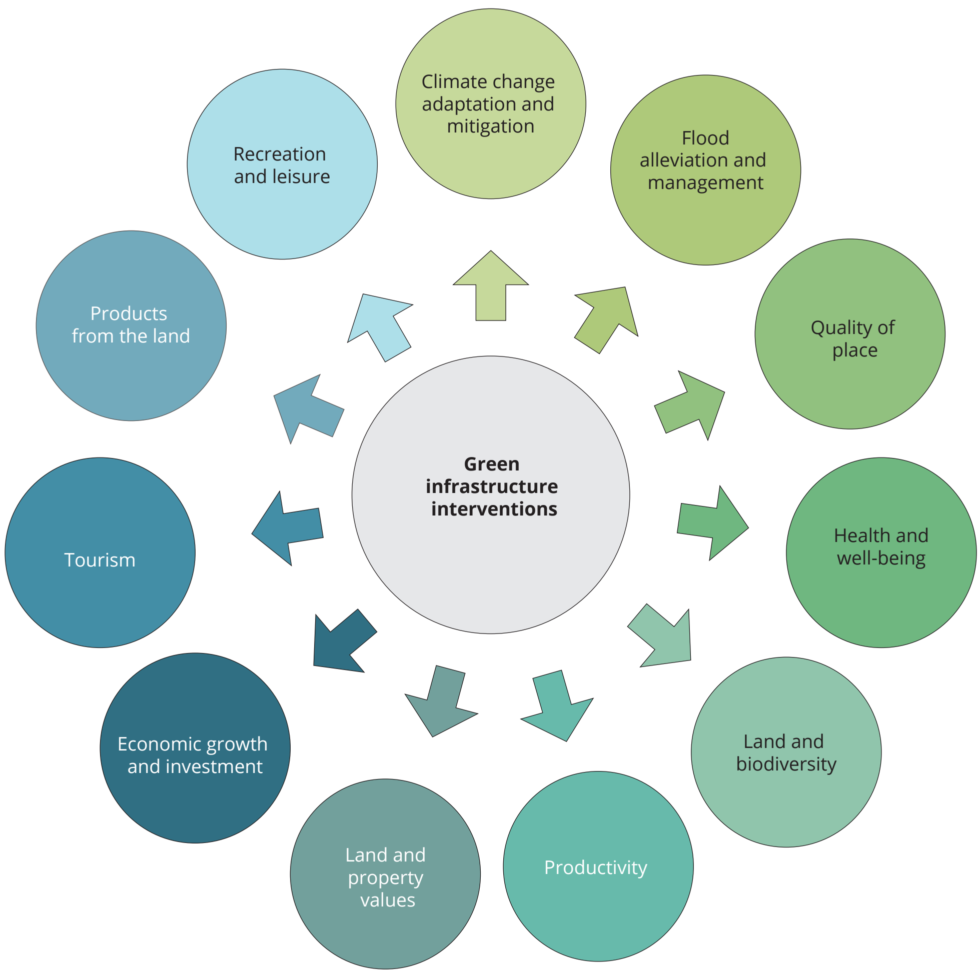
- **the Research and Innovation Policy**, for example the focus on nature-based solutions (EC, 2015e) and their potential enables sustainable urbanisation and manages disaster risk reduction in cities (Horizon2020; EC, 2015j), or the focus on green and blue infrastructure and its role in improving ecosystem functioning and the delivery of ecosystem services in the BiodivERsA3 joint call 2015 (EC and ERA-Net, 2015).

EEA work has supported the emerging policy, for instance through developing methodologies for spatial analysis of green infrastructure (EEA, 2014d) and exploring linkages between green infrastructure and territorial cohesion (EEA, 2011c) and producing a report on the role of green infrastructure in mitigating climate hazards (EEA, 2015f).

6.2 Mapping and assessment of ecosystems to prioritise the restoration of green infrastructure

One of the strengths of green infrastructure is its ability to present the environment as a multifunctional medium that has the potential to support numerous aspects of Europe's economy and society (Figure 6.1; EC, 2012c). The challenge is to understand how the

Figure 6.1 Multiple functions provided by green infrastructure



Source: EEA, 2014d (original source: Ecotec and NENW, 2008).

potential delivery of these multiple functions varies in different ecosystems, in different compositions and at different scales, so that decision-makers can prioritise the maintenance and restoration of specific elements of green infrastructure.

The EEA has developed a methodology for mapping terrestrial green infrastructure (EEA, 2014d), as shown in Figure 6.2. It assesses the potential for green infrastructure to deliver ecosystem services and to provide habitats. The ability of ecosystems to deliver relevant regulation and maintenance ecosystem services is mapped through the EEA approach either directly or using land use or land management as proxies. Areas with maximum capacity for delivery are defined as 'key service areas' and those with moderate capacity are defined as 'moderate service areas'. This is combined with the identification of 'key habitat areas', based on the locations of 'key species' and their core habitats ([8]), together with information on habitat condition (connectivity and quality). The combined results are used to classify areas into one of four levels, according to a model developed in a report on the prioritisation of restoration to the European Commission (Lammerant et al., 2014).

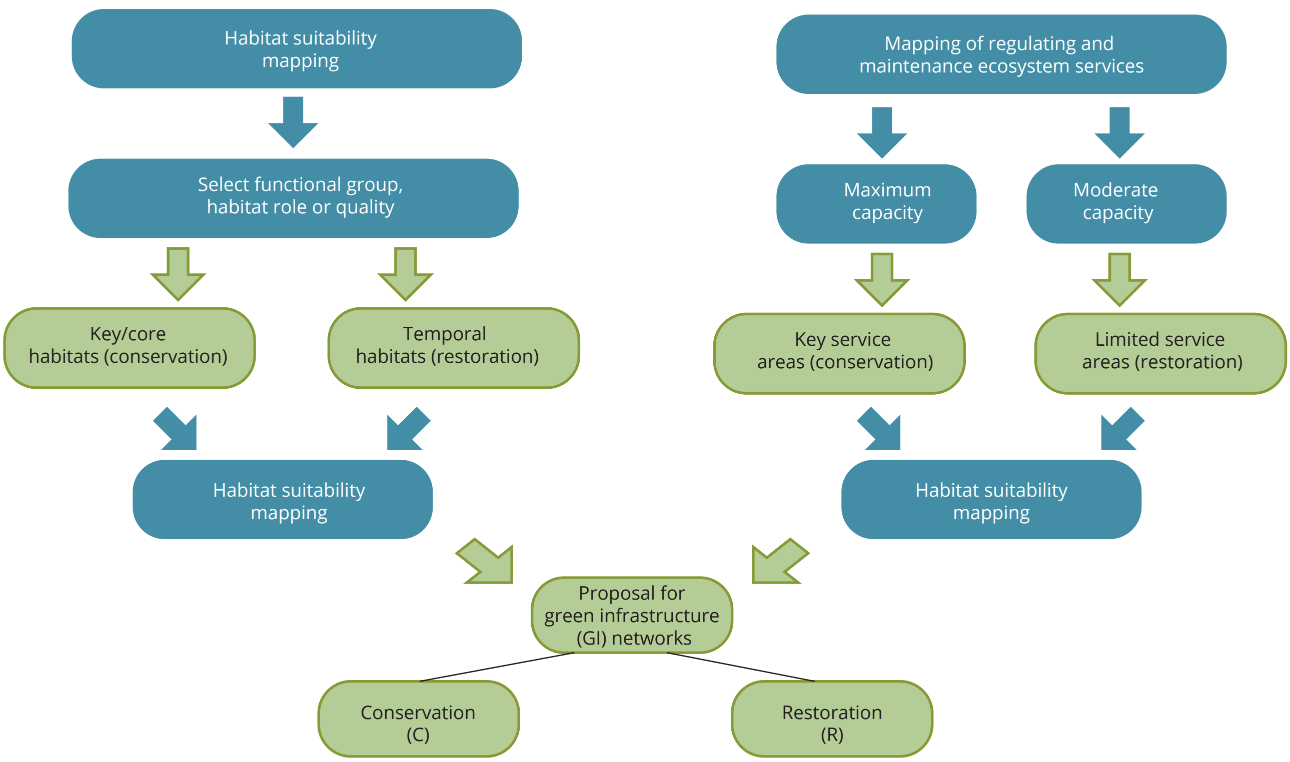
- Level 1 are key service areas that should be protected and conserved to maintain natural capital (EEA, 2014d). These form part of the green infrastructure network 'C' (for conservation), as they perform key ecological roles for both wildlife and human well-being.

- Level 2 are limited service areas, where ecosystem service functions could be boosted by restoring or enhancing the habitat. These might be included in the green infrastructure network 'R' (for restoration).

- Levels 3 and 4 are low service areas, which are the most degraded in terms of ecological function or have high intensity of use.

The methodology was tested for the EU-27 area, but it can also be used at different scales (EEA, 2011c). Map 6.1 shows the key service areas, the key habitat

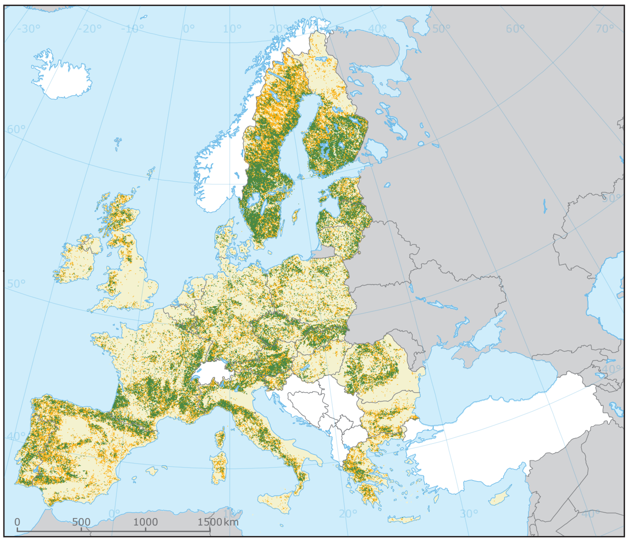
Figure 6.2 Methodology developed for mapping terrestrial green infrastructure



Source: EEA, 2014d.

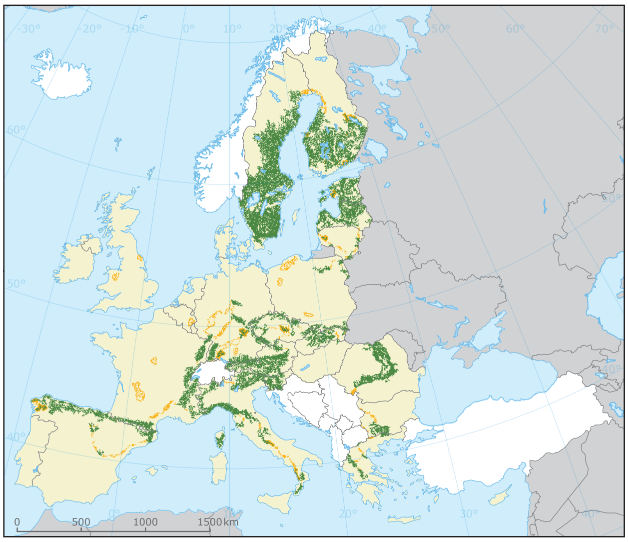
([8]) Core habitats are those used for reproducing, wintering or foraging, whereas temporal habitats are used for migration or as secondary habitats.

Map 6.1 **Key terrestrial ecosystem service areas, key habitat areas and a combined map showing green infrastructure (GI) networks prioritised for conservation (C) or restoration (R)**



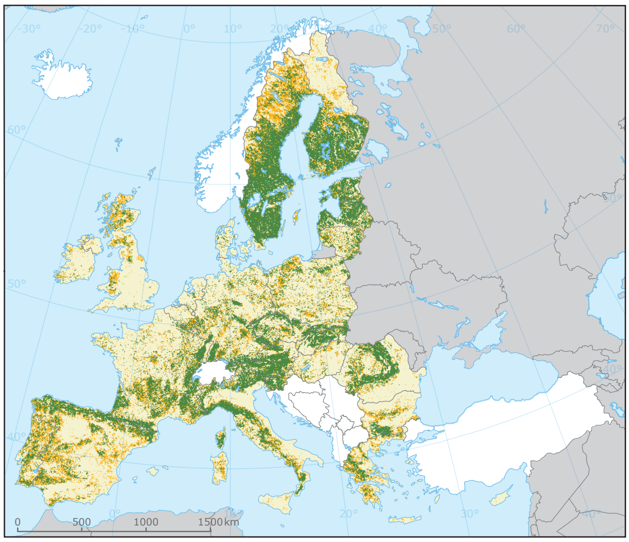
Ecosystem services (terrestrial)

- Level 1 areas
- Level 2 areas
- Level 3 or 4 areas
- No data
- Outside coverage



Key habitats (terrestrial)

- Level 1 areas
- Level 2 areas
- Level 3 or 4 areas
- No data
- Outside coverage



GI networks (terrestrial)

- Level 1 areas
- Level 2 areas
- Level 3 or 4 areas
- No data
- Outside coverage

Note: Green denotes Level 1 terrestrial areas (key services and/or key habitats) scheduled for conservation (C);

Orange denotes Level 2 areas (limited services; temporal habitats) scheduled for restoration (R);

Yellow denotes Level 3 or 4 areas (degraded habitats or high-use areas such as intensive agriculture or hard infrastructure).

Source: EEA, 2014d.

areas, and the combined map that is used to identify areas as Level 1 (C) or 2 (R). Areas prioritised for conservation (green infrastructure network C) cover 27 % of the terrestrial area of the EU-27, and areas for restoration (green infrastructure network R) cover 17 %, providing more than enough opportunities to meet the Biodiversity Strategy target of restoring 15 % of degraded ecosystems. The improvement of services in Level 3 or 4 areas could also contribute to the restoration target.

Green infrastructure mapping in accordance with this approach provides a transparent and consistent knowledge base for decision-makers, helping them to prioritise measures by supporting the strategic spatial identification of habitats to be restored (although what is considered Level 1 may vary according to scale or location). There is an increasing number of studies using the green infrastructure concept in the context of policy implementation, for example to mitigate climate change-induced natural hazards and for flood management (EEA, 2015f) and requirements to establish green infrastructure elements to maintain ecosystem services (Maes et al., 2015). Further challenges imply the consolidation of analytical approaches for green infrastructure, including the integration of ecosystem condition into green infrastructure mapping and assessment to attribute functioning to green infrastructure elements in terms of biodiversity and capacity to provide services.

7 Accounting for ecosystem capital

7.1 Introduction to ecosystem accounting

Natural capital comprises two major components (Maes et al., 2013; EEA, 2015b, *Natural capital and ecosystem services*):

- *abiotic natural capital*, comprising subsoil assets (e.g. fossil fuels, minerals, metals) and abiotic flows (e.g. wind, waves and solar energy);
- *biotic natural capital* or *ecosystem capital*, consisting of ecosystems, which deliver a wide range of valuable services that are essential for human well-being (Box 7.1).

Although definitions vary, ecosystem capital is a component of natural capital (see Figure 7.1). The MAES pilot study on natural capital accounting (NCA) and a related draft EU reference document on NCA (Petersen and Gocheva, forthcoming) use the term 'natural capital', but focus on the ecosystem component rather than abiotic assets.

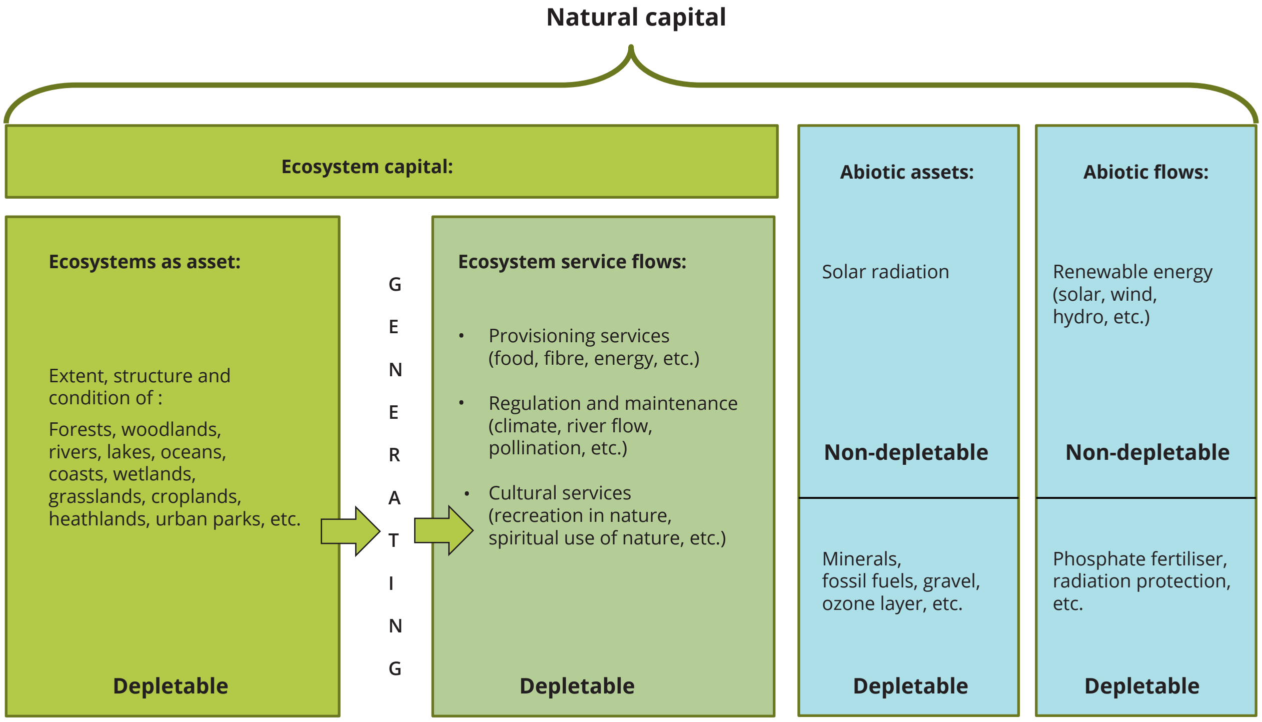
Ecosystem capital is normally renewable if managed sustainably, but it can be depleted or degraded if mismanaged. Abiotic capital can be either renewable (e.g. wind energy) or depletable (e.g. minerals and fossil fuels). For marine ecosystems, human use of abiotic environmental outputs has been recognised as a key pressure on (biotic) ecosystem capital (EEA, 2015c). Natural capital underpins the other capitals recognised as essential for economic and social prosperity, that is, man-made, human and social capital (Petersen and Gocheva, forthcoming).

Box 7.1 Ecosystem service classification for ecosystem accounting

A common international classification for ecosystem services is an important tool for developing an ecosystem accounting system and to enable cross-country comparisons. The Common International Classification of Ecosystem Services (CICES) was developed from the work on ecosystem accounting undertaken by the EEA and builds on previous classification approaches, such as Millennium Assessment or The Economics of Ecosystem and Biodiversity (TEEB) (Maes et al., 2014). CICES classifies ecosystem services into provisioning services, which deliver food, fuel and water; regulation and maintenance services, such as flood protection and climate regulation; and cultural services, such as recreation and the availability of aesthetic landscapes. It was part of the EEA contribution to developing an international System of Environmental–Economic Accounting (SEEA), led by the UN Statistics Division.

As a result of consultations with members of different user communities in 2012–2013, an updated version of CICES (version 4.3) was produced and can be accessed at http://cices.eu (accessed 12 December 2015). A number of important adjustments were included, such as focusing on interactions between biotic and abiotic processes and biodiversity (see also definition of ecosystems in UN, 1992), separating purely abiotic outputs such as mining of metals and minerals from ecosystem services, cross-referencing ecosystem services to standard product and activity classifications, ensuring the hierarchical four-level classification, which avoids overlaps and redundancy, and clarifying the interpretation of cultural services (Haines-Young and Potschin, 2013). The CICES process also suggests a first separate list of abiotic outputs. An application of this list to the marine environment can be seen in the report *State of Europe's seas* (EEA, 2105c).

Figure 7.1 Components of natural capital



Source: Maes et al., 2013.

7.2 Policy context

7.2.1 The international context

The concept of NCA and, more broadly, environmental accounting, has been discussed within international policy and statistical arenas for more than two decades (Petersen and Gocheva, forthcoming). Building on this, the World Bank launched the Wealth Accounting and the Valuation of Ecosystem Services (WAVES; World Bank, 2015) project in 2010, which aims to help partner countries implement NCA (Dickson et al., 2014). The Rio+20 conference, through its Natural Capital Declaration, reaffirmed the importance of global and national-level accounting for our natural wealth (UNEP, 2012). The Convention on Biological Biodiversity (CBD) Secretariat recently published *Ecosystem natural capital accounts: A quick-start package* (CBD, 2014) to support implementation of Aichi Target 2, which calls for biodiversity values to be incorporated into national accounting by 2020 (CBD, 2012).

In 2012 the UN Statistics Division approved the revised SEEA as an international statistical standard (like the System of National Accounts; UNSD, 2016), providing an agreed methodology for producing internationally comparable environmental–economic accounts. As indicated above, there is strong interest in taking environmental accounting beyond quantifying the SEEA-approved 'material resources', to include ecosystem services and other natural assets that are not traded. The UN Statistics Division, with support from experts and countries, has therefore developed guidance on 'experimental ecosystem accounting' (SEEA-EEA; UNSD, 2012), which will facilitate this (UNSD, 2014).

7.2.2 The European context

The first formal EU rules on environmental accounting were established in 2011 (EC, 2011b) and amended in 2014 (EC, 2014h). The following accounting modules are now subject to EU regulation: air emissions; environmental taxes and material flow; energy; environmental goods and services; and environmental protection expenditure. It is possible that more modules will be added (Petersen and Gocheva, forthcoming).

Target 2, Action 5, of the EU Biodiversity Strategy to 2020 contains a clear commitment to 'assess the economic value of (ecosystem) services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020'. This goal is reinforced by the Seventh Environment Action Programme (EC, 2013c):

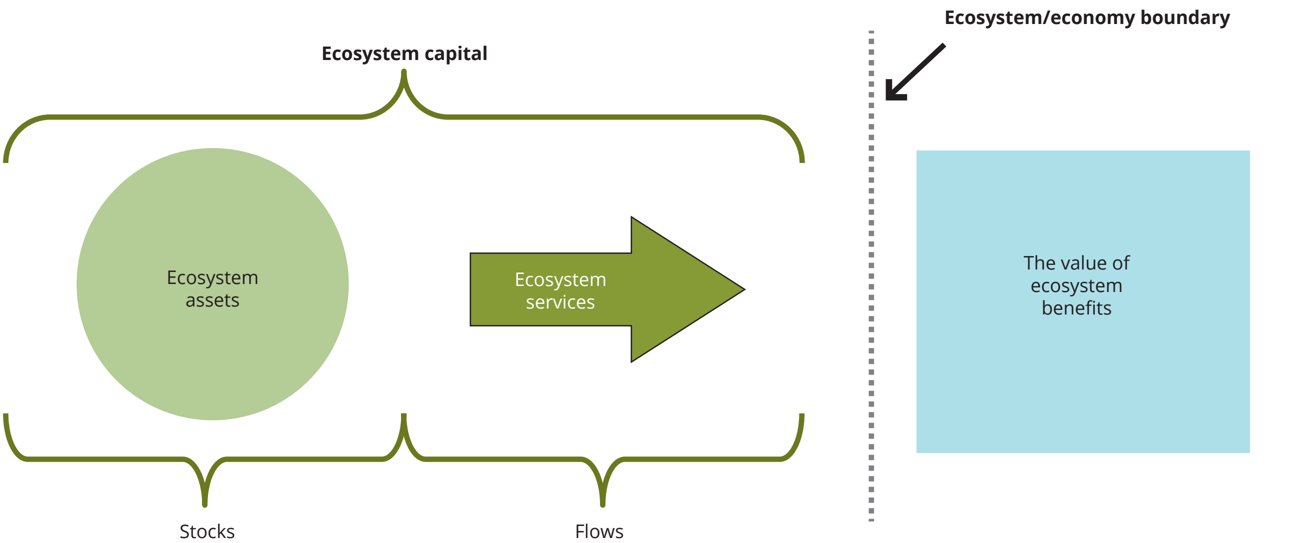
The integration of the economic value of ecosystem services into accounting and reporting systems at EU and national level by 2020 will result in better management of the EU's natural capital. [...] Work to develop a system of environmental accounts, including physical and monetary accounts for natural capital and ecosystem services, will need to be stepped up.

As part of the EU MAES process a pilot study was established to summarise methodological guidance on natural capital accounting and enable an exchange of information between Member States on this topic (Petersen and Gocheva, forthcoming). This work is now being continued under a joint project by Eurostat, the EEA, DG Environment, JRC and DG Research and Innovation to develop an integrated EU ecosystem accounting system (KIP-INCA, the Knowledge Innovation Project for an Integrated system for Natural Capital and ecosystem services Accounting) ([9]).

7.2.3 The aim of ecosystem accounting

The 'mapping and assessment of ecosystems and their services' under the MAES process has greatly improved our knowledge of the extent, distribution and condition of ecosystems in Europe (although further work remains to be done). Chapter 5 of this report showed that this ecosystem capital is vulnerable because it is heavily exploited through agriculture, unsustainable forest management and other land and marine uses that threaten the species and habitats that depend on specific conditions being maintained. One remaining question is, therefore, how to integrate the benefits and value of ecosystems and their services into economic decision-making. National (and corporate) accounting approaches do not fully recognise the value of natural or ecosystem capital, as they are not geared to measuring the public good that ecosystems provide. In this context, the purpose of developing ecosystem accounting approaches is to support improved management of ecosystems, by assessing the sustainability of the economy–ecosystem interaction from the standpoint of nature. Ecosystem accounts are meant to provide information to decision-makers on the role of nature in the economy, by describing the stocks of ecosystem capital and the benefits that flow from them in physical terms and, where appropriate, in monetary terms (Petersen and Gocheva, forthcoming). Figure 7.2 illustrates how ecosystem capital stocks (assets) and flows (services) lead to ecosystem benefits to society (often with the help of other capital inputs, such as human, manufactured and social capital). Traditional approaches to accounting mostly capture only the economic value of products or services derived from nature on the right-hand side of Figure 7.2. Ecosystem accounting, however, aims to develop quantitative measures of the condition of ecosystem assets ([10]) and the development of service flows to give us an early warning system to improve the management of ecosystems and their services.

Figure 7.2 Ecosystem assets and services: stocks and flows



Source: Petersen and Gocheva, forthcoming, based on Dickson et al., 2014.

([9]) http://projects.eionet.europa.eu/ecosystem-capital-accounting/library accessed, 12 December 2015.
([10]) Ecosystem assets are 'spatial areas containing a combination of biotic and abiotic components and other characteristics that function together' (SEEA-EEA; UNSD, 2014).

7.3 Overview of the principles of ecosystem accounting

The term 'accounting' is associated with monetary values, but the UN SEEA established the principle that, whereas aspects of environmental accounts could be represented in monetary terms, information about our natural capital in physical terms, for example areas, volumes and counts, could be equally useful. Current approaches to ecosystem accounting envisage physical accounts sitting alongside economic information as 'satellite accounts'. Subsequent valuation for policy purposes may or may not include monetisation (Petersen and Gocheva, forthcoming).

The UN SEEA provides an internationally agreed approach to account for material natural resources. The SEEA-EEA extends this to include ecosystem assets and services that are not traded by providing a proposal to develop a set of ecosystem accounts that are largely consistent with the System of National Accounts (UNSD, 2016) in terms of structure, classifications, definitions and accounting rules. This means that changes in the status of natural capital can be documented and its contribution to the economy and the impacts of economic activities analysed. The SEEA-EEA thus provides a platform for integrating the value of ecosystems and their services into the System of National Accounts (UNSD, 2014).

In the SEEA-EEA, and other ecosystem accounting systems, physical accounts consist of the following key elements (see Table 7.1; Dickson, 2014; Petersen and Gocheva, forthcoming).

- *Asset accounts* are stocks of environmental assets, and changes in these stocks occur due to extraction, new discoveries, natural growth, natural disasters and other reasons. Asset accounts include minerals and energy, along with land and soil resources, timber resources, water resources and accounts for other biological resources.

Table 7.1 Example of an accounting table, based on SEEA-EEA

Basic form of an asset account
Opening stock of environmental assets
Additions to stock
Growth in stock
Discoveries of new stock
Upward reappraisals
Reclassifications
Total additions of stock
Reductions of stock
Extractions
Normal loss of stock
Catastrophic losses
Downward reappraisals
Reclassifications
Total additions of stock
Revaluation of the stock
Closing stock of environmental assets

Source: UNSD, 2014.

- *Flow accounts* are accounts of the physical flows of materials and energy within the economy and between the economy and the environment, for example energy accounts, water accounts and material flow accounts, and outputs, for example air emission accounts, wastewater accounts and solid waste accounts.

While much progress has been made on the physical accounts that are the platform on which to build economic valuation, more conceptual and methodological work is required on valuation, both for monetary and non-monetary approaches. There is a number of methodological challenges, ranging from measuring components that are difficult to quantify, for example cultural ecosystem services and intrinsic value (Box 7.2), to developing sufficiently accurate and

Box 7.2 Intrinsic values

A number of different values have been recognised for nature. These include the supply of ecosystem services that benefit humans and the intrinsic value of nature beyond its utility to mankind (see Howard et al., 2013, for a review). The wider values of nature were recognised in the recent Rio+20 outcome document, which reaffirms 'the intrinsic value of biological diversity, as well as the ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity and its critical role in maintaining ecosystems that provide essential services, which are critical foundations for sustainable development and human well-being' (United Nations Conference on Sustainable Development 2012, paragraph 197; UN, 2015).

Source: Based on Maes et al., 2014, Chapter 6.

complete physical accounts and the potential use of monetisation approaches (Brouwer et al., 2013; Petersen and Gocheva, forthcoming). A review of the various methods is provided in Gómez-Baggethun et al. (2014).

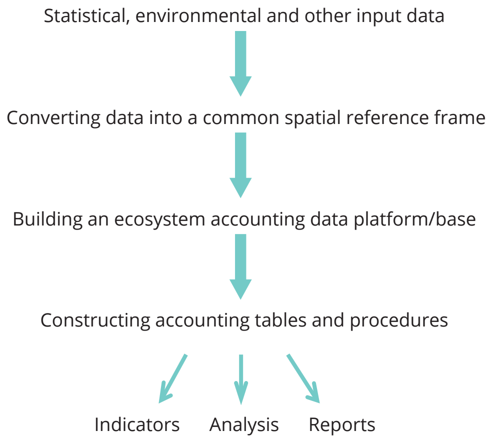
7.4 Mapping and assessment of ecosystems as an input to ecosystem capital accounting

The SEEA-EEA proposes to account for ecosystem assets by measuring the extent and condition of different ecosystems and their services. This requires geo-referenced data that at least provide a proxy distribution for the different types of ecosystem assets of interest. The UNEP report *Towards a global map of natural capital: Key ecosystem assets* (Dickson et al., 2014) provides a concise overview of key methodological issues and builds on SEEA-EEA guidance to produce the first map of key global ecosystem assets.

At the European level, this approach provides scope for synergies with ecosystem/ecosystem service assessment (MAES Working Group, Action 5 of the EU Biodiversity Strategy to 2020). As stated above, the mapping and assessment of ecosystems and their services will provide an important input to the further development of ecosystem accounting at EU level. Given the structure and rigour that (ecosystem) accounting approaches demand, they can also provide a useful framework for structuring ecosystem-related data and integrated analysis (Maes et al., 2014).

Figure 7.3 sets out a potential work flow for organising and analysing data for the development of physical ecosystem accounts in future. In relation to ecosystem assets the first stage is to compile input data for mapping and assessing the condition of European ecosystems, as described in earlier chapters of this report. The second stage, which is the key one, requires aggregating or down-scaling data to basic biophysical accounting units, such as water catchments or ecosystem types that can be mapped to a geo-spatial reference frame. This would allow reporting at different levels in the EU NUTS (Nomenclature of Territorial Units for Statistics) hierarchy of administrative regions for the terrestrial environment. The analysis of supply of and demand for ecosystem services and the representation of natural capital stocks and the benefit flows that arise from them (stages 3 and 4) hinge critically on the spatial integration of different sources of data (Petersen and Gocheva, forthcoming).

Figure 7.3 Potential work flow for data organisation and analysis



Source: Petersen and Gocheva, forthcoming.

For the marine environment, recent work by the EEA and the ETC/ICM (European Topic Centre on Inland, Coastal and Marine Waters) has already resulted in a classification of marine ecosystem services (based on CICES and building on Maes et al., 2014) and marine abiotic outputs, as well as establishing links between marine ecosystem condition and its potential to supply services (EEA, 2015c). However, it is recognised that there are gaps in our knowledge of marine ecosystem functioning, that the condition of many marine ecosystems is unknown (considering the information available at the EU level from the reporting on the implementation of EU environmental legislation), and that the existing EU-level information on marine ecosystem condition (from EU environmental legislation) is not sufficiently geo-referenced to allow mapping (EEA, 2015c).

7.5 Where next for ecosystem accounting?

This chapter has given a brief overview of ecosystem accounting, covering physical accounts and monetary approaches, in which ecosystem assets and services are subject to economic valuation. Substantial progress has been made in relation to physical accounts, building on the EEA's experience of developing ecosystem capital accounts, the methodological framework developed at UN level and the work under the EU pilot study on natural capital accounting, as well as the recent EU project 'Accounting for natural capital and ecosystem services'. The background material prepared for an

EU workshop 'Developing an integrated EU ecosystem accounting system' provides a good overview of the current state of development of physical accounts at EU level ([11]).

More challenges remain, however, with regard to developing monetary accounts. The most recent study for the European Commission stated that 'hardly any initiative has [yet] been able to integrate ecosystem services assessment and mapping into valuation and accounting' (Brouwer et al., 2013). The study found a wide variety of approaches in practice at different geographical and temporal scales, but only a small subset of them used monetary valuation. In general, monetary valuation of ecosystem services is, therefore, still at a very early stage. Most provisioning services are, or will be, valued using market prices, and most regulating services valued using methodologies based on (substitution) costs, where possible; however, monetary valuation of cultural ecosystem services, mainly using stated preference methods, is much more complicated. This is due to methodological challenges, lack of data, lack of resources to conduct original valuation studies and criticism of the use of monetary non-market valuation in some countries (Brouwer et al., 2013; Petersen and Gocheva, forthcoming).

Furthermore, if different methodologies are used for monetary valuation, then the values obtained for different ecosystem services can be difficult to aggregate because they are not directly comparable. A particular issue is that market prices for ecosystem goods and services should ideally not be conflated with economic values derived from methods such as 'willingness to pay'. This may pose a problem if monetary valuation is to be used for accounting purposes (Brouwer et al., 2013). Overall, there is not yet an agreed method for integrating monetary measurements across different types of accounts, and considerable methodological challenges remain. The EU OpenNESS project has provided an integrated valuation framework that covers the monetary and non-monetary values of ecosystem services (Gómez-Baggethun et al., 2014) and this work is ongoing.

Notwithstanding the challenges described, there is substantial potential for ecosystem accounting to improve the management of natural assets that provide public good and to avoid negative effects from economic activities that can damage natural capital. The forthcoming EU reference document on natural capital accounting (Petersen and Gocheva, forthcoming) describes the technical and conceptual issues that need to be tackled in order to rollout the approach across Europe. The mapping and assessment of the extent and distribution of ecosystems and their condition is an important input for quantifying ecosystem assets and as such a major building block for ecosystem accounting. In the coming years we need to increase our knowledge of the link between ecosystem condition and ecosystem services to improve our understanding of the contribution of healthy ecosystems to economic prosperity and well-being in Europe (see the following chapter). This will ultimately enable a valuation of the resulting benefits to society even if not all components of our natural capital can or should be measured in solely economic terms.

([11]) http://projects.eionet.europa.eu/ecosystem-capital-accounting/library, accessed 12 December 2015.

8 Key findings and the way forward

8.1 Mapping and assessment of ecosystems and their services as a knowledge base for policy action

Comprehensive and reliable information on the status of biodiversity, ecosystems and ecosystem services, and the capacity to monitor change, is essential to know whether or not policy targets have been reached, and whether or not further policy measures are needed. Mapping and assessment is also needed to underpin the implementation of environmental legislation, the integration of biodiversity objectives into sectoral policies and the development of, inter alia, sustainable agriculture, forest management and fishing (Maes et al., 2014). The ultimate aim is to enable policymakers to achieve multiple objectives across diverse policies, taking account of synergies and trade-offs.

This report has described the development of a common analytical framework to map and assess the state of ecosystems and their services, as required by Target 2, Action 5, of the EU Biodiversity Strategy. This is a critical first step towards delivering the goal of maintaining and restoring ecosystems and their services in the EU and at the national level. The framework sets out broadly how to map and assess the condition of ecosystems, highlighting the role of pressures arising from human activities. By using a coherent approach and comparable data sets, policymakers can compare pressures and impacts across different regions of the EU, enabling them to identify hot spots where multiple pressures threaten key ecosystems and their services. With further development, this approach could be used to spatially identify interactions between ecosystems, and prioritise action to maximise synergies and minimise trade-offs between ecosystem services. This demonstrates the potential of mapping and assessment of ecosystems and their services as a critical knowledge base for policy action, which was confirmed at the High-Level Conference on Mapping and Assessment of Ecosystems and their Services (MAES) in Europe on 22 May 2014 in Brussels (EC, 2015k).

One example of the use of this knowledge base was presented in Chapter 6, which showed how ecosystem mapping and assessment can be used to identify priority areas for green infrastructure development, habitat restoration and conservation, while also making the case that enhancing and protecting green infrastructure has benefits across sectors and policies.

Throughout this report multiple strands of information have been explored, yielding different viewpoints on assessing ecosystems and, in the future, their services. The technical aspects relating to pressures and their impacts on ecosystems; the policy aspects that aim to understand the current EU policy context and prioritise measures; the practical aspects looking into sustainable planning and management solutions, such as green infrastructure; and the economic aspects trying to evaluate the benefits of ecosystems and the cost of the deterioration in their condition. The spatial dimension is, to varying degrees, a key element in all of these.

European mapping and assessment provides invaluable support and guidance to Member States that are developing their own national assessments. Equally, lessons are emerging from countries with established national assessments, such as Belgium, Spain and the United Kingdom, which can help inform the approaches to and framework for undertaking ecosystem assessments. The European Commission's DG Environment MESEU project (ECNC, 2015) provides assistance to the Member States, in the context of Action 5 of the EU 2020 Biodiversity Strategy, on the mapping and assessment of the state of ecosystems and their services in their national territories, making best use of studies and work already undertaken at EU and Member State levels. This information will enable governments, and the EU itself, to identify and prioritise actions to safeguard Europe's natural capital. For example, the Spanish national assessment, which had a stronger social component, also contributed to improving understanding of the relationships among ecosystems, biodiversity and human well-being and to characterising and prioritising options for development strategies based on the social dimension of ecosystems and biodiversity. There is a widely recognised need to continue capacity-building in Member States in order to create a community of practitioners in Europe that will improve the knowledge and evidence bases for EU environment policy (Maes et al., 2014). Two current European research projects (OpenNESS and

OPERAs) are contributing to such a community and a knowledge base to operationalise ecosystem services and natural capital by developing the platform OPPLA (OPPLA, 2016).

8.2 Advantages and constraints of European assessment

Assessment at a European scale is challenging as it requires high levels of information that are accurate, detailed and comparable across countries, but it can help answer complex questions such as 'Are Europe's ecosystems healthy enough to continue to deliver essential services?', by cutting across themes and national boundaries to establish what action is needed to improve the situation at a European level (Maes et al., 2014). It can provide support for countries which have not yet developed their national assessments, or are in the process of developing them, to speed up the process. Member States, together with DG-Environment, JRC and EEA, have agreed on a list of European ecosystem types that are feasible to map both from the aggregation of national and local data and the disaggregation of European data. Solutions are being sought to some of the difficulties that have emerged, for example in the existing typology of marine ecosystems as described in Maes et al. (2013, 2014). Input data and methods to aggregate the inputs have been developed to provide more detailed insights into the biodiversity we may expect for each ecosystem type across Europe. We have seen that, due to the variability of different habitats, it is likely to be necessary to assess each ecosystem individually before they are reviewed together to establish similarities, differences and interactions; this approach is likely to be equally appropriate at the national level.

Input data for mapping ecosystem condition is currently to a large extent based on the reporting obligations of EU environmental legislation (Section 4.2.1). Improvements to these data sets (e.g. increased comparability at the EU level, adequate regularity and synchronicity of reporting across the legislation) will enable the approach to be further consolidated in terms of data availability and quality for mapping pressures and condition of European ecosystem types and related biodiversity. In addition, the integration of complementary data sets, such as on distribution and trends of European bird or butterfly populations, into EU level data systems should be pursued.

The analysis has highlighted some data and knowledge gaps to be addressed for a full implementation of the approach. Gaps include an overall lack of data in some ecosystems and regions (see Section 5.9.3); lack of knowledge, capability and/or capacity to undertake ecosystem assessments at a national level; and insufficient research on the links between pressures, biodiversity, ecosystem condition and the delivery of ecosystem services (see Section 4.3). Guidance is also needed on upscaling or downscaling data and indicators for condition and services to a desired spatial unit (Maes et al., 2014), especially those relevant for valuation. These gaps can help identify research priorities for examining the interactions between nature and society.

8.3 Extending the analysis to assess ecosystem services

This report has illustrated the EEA's work in mapping the spatial extent of ecosystem types and assessing their current physical, chemical and ecological condition. The next step is to devise a method for linking the condition of the ecosystem types to the supply of ecosystem services, so that Member States can 'map and assess the state of ecosystems and their services' as required by Target 2, Action 5, of the EU Biodiversity Strategy. A methodology for ecosystem service assessment (on the basis of ecosystem condition) has been proposed for marine ecosystems (Culhane et al., 2014), and the approach suggested here for terrestrial ecosystems is based on this. The overall aim of the methodology is to be able to use the information on current ecosystem condition and trends in pressures that is available from the implementation of EU environmental legislation (e.g. the Nature Directives, see Section 4.2) to determine whether the supply of ecosystem services can be sustained over time.

Step 1 would be to list, using the CICES classification, the ecosystem services that could be supplied by a given ecosystem type (Figure 8.1). If this list is very long, there might be a need to prioritise certain ecosystem services, such as those for which there is a high demand, or those that are particularly vulnerable to current pressures. However, this carries a risk that important services, or those that interact with important services via synergies or trade-offs, would be omitted (see also Raudsepp-Hearne et al., 2010). This highlights the importance of extending our knowledge on interactions between ecosystem services.

Step 2 would be to list the components of the ecosystem or ecosystem mosaics that would supply each service. Ecosystem components can include particular species, habitats, communities or functional groups (such as 'large trees' or 'pollinators'). For example, in woodland and forest ecosystems, the service of climate regulation through carbon storage would be provided by trees, soil, soil organisms, herbaceous vegetation and dead wood, but cultural services could be linked to particular iconic species, such as the pearl-bordered fritillary (*Boloria euphrosyne*) or nuthatch (*Sitta europaea*), or forest ecosystems would need to be assessed in the context of their spatial context with other ecosystem types as landscape mosaics.

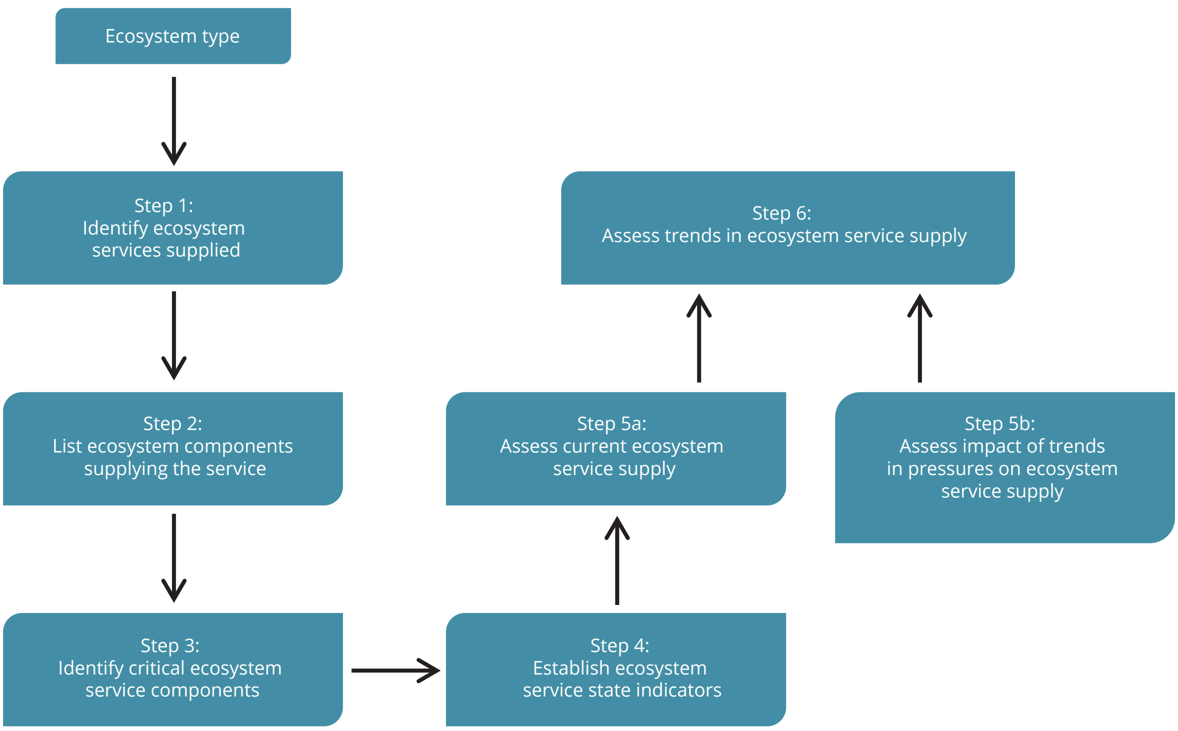
Step 3 is to identify those components that make the greatest contribution to the service supply (i.e. the critical ecosystem components). Sometimes (as shown by Harrison et al., 2014) the critical components for a given ecosystem service will be just one or two species, habitats, communities or functional groups, but often multiple components play a role. However, for a manageable assessment, it will be necessary to select just a few key components. For some services, there may be critical ecosystem components that are common across a range of ecosystem types. For example, soil will contribute to carbon storage in all terrestrial ecosystem types, but trees will be the most critical ecosystem component in most woodland and forest ecosystems.

Step 4 is to establish the relationship between the condition (state) of the critical ecosystem components and the supply of the service, which is important in selecting the indicators used to assess condition on the basis of data from statistics, environmental monitoring or reporting under EU environmental legislation. For example, 'trees' would be a critical ecosystem component in the case of climate regulation in woodland and forest ecosystems, where tree biomass is proportional to carbon storage. This stage would therefore look at how tree biomass per unit area, and so carbon storage per unit area, depends on the condition of woodland and forest ecosystems (e.g. described by age class distribution per species), leading to the identification of indicators of woodland and forest condition from the most appropriate sources. Establishing the ecosystem condition–service supply relationship is more important when there are several critical ecosystem components involved in the supply of a given service, as aggregating their condition into one 'service supply' is not necessarily a case of simply adding them together.

In most cases it may be difficult to find consistent quantitative indicators from the sources available and so qualitative indicators may have to be used. The choice of indicators will also be constrained by the available reporting data on habitats and species from EU environmental legislation, and, if these are inadequate, it would then be necessary to look at other sources of information available at the EU level. This applies to both condition (state) and pressure indicators (see step 6).

Step 5 is divided into two parts. **Step 5a** is the assessment of the condition of the critical ecosystem

Figure 8.1 **Methodology for assessment of ecosystem service supply**



components (i.e. ecosystem service supply) using the indicators from relevant EU environmental directives selected above. The 'status' assessments of these indicators are used to evaluate the ability of the critical ecosystem components to supply the ecosystem service of interest, in terms of whether the indicators 'pass' or 'fail' in meeting the objectives of the relevant directive (e.g. favourable conservation status). This would mean that the critical ecosystem component is in 'good' or 'bad' condition, respectively, and reflects its ability to supply the service of interest. In the example of carbon storage by trees, the main source of these status assessments would be the Habitats Directive for the condition of woodland habitats and tree species of interest (indicators), but often this information is incomplete, and other sources available at the EU level will have to be used, such as the EU Forest Strategy, although the sources chosen need to include some sort of target or status classification of ecosystem condition. **Step 5b** uses information on the pressures acting on ecosystems, the trends in those pressures and the link between pressures and condition to establish the potential impacts on the supply of the ecosystem service over time, at least qualitatively.

Combining these two steps (**Step 6**) and aggregating all the critical ecosystem components along the state-service relationship (from step 4) would result in an assessment of the ability of the ecosystem to supply the service.

This approach has been tested on three marine ecosystem service assessments (see also Box 7.2 in EEA, 2015c), and it could provide a practical approach for future assessments in other ecosystem types, but it is important to be aware of the limitations of this methodology, which are listed below.

1. This approach currently addresses individual ecosystem services in isolation. However, ecosystems are multifunctional and supply multiple ecosystem services, so it is crucial to understand how the different services interact with one another in terms of synergies and trade-offs.

2. Practical limits on the number of 'critical ecosystem components' that can be assessed are an important restriction. Ecosystem components interact in complex and often unknown ways, and these interactions determine both the current ability of the ecosystem to deliver services and, especially, its resilience to future change.

3. As mentioned throughout this report, data on the condition of ecosystem components available at the EU level from the implementation of EU environmental legislation is often incomplete, may rely on expert opinion, and is reported infrequently. This could affect the choice of indicators, including the need to find other sources of relevant information available at the EU level, which have to include targets or status classifications for ecosystem condition (to allow the 'pass' or 'fail' analysis in step 5a above and thus the transformation of 'condition assessments' into 'service supply assessments').

4. Step 5a depends on the assumption that, if an ecosystem or species is, for example, in 'favourable conservation status', then it will be able to supply the ecosystem service. This is reasonable up to a point, but just because an ecosystem or species is not in 'favourable conservation status' does not mean that there will be poor or no ecosystem service supply — as, for example, in the case of food service provision from intensively farmed land. There may also be differences in what is considered 'good' between different EU directives, which would also influence the resulting ecosystem service supply, depending on which directive has been chosen if more than one was suitable ([12]). To improve this methodology, it would be essential to address the knowledge gap on the links between ecosystem condition and ecosystem service delivery that were identified in Figure 2.3 and Section 4.3.3.

5. There is a knowledge gap on the links among pressures, condition and ecosystem service supply that will make step 5b very challenging in most cases.

6. Much of the information available from EU environmental directives is not spatially explicit, so the test cases for marine ecosystems were not able to produce maps of ecosystem service supply. But, for many ecosystem service assessments, the spatial distribution of demand and supply is extremely important. For example, for flood prevention the service is created through upstream riparian ecosystems, whereas the demand and main beneficiary may live downstream in cities.

7. The above method is based on the 'supply-side' approach for assessing ecosystem services (linked to ecosystem capacity). It does not take into account

([12]) This may not be relevant for terrestrial ecosystems but note that the methodology also allows – following several assumptions - using information on ecosystem condition information from several EU environmental directives at the same time when assessing a given critical ecosystem component (EEA, 2015c).

the demand for ecosystem services. This would be challenging, but establishing the relationship between the supply side and the demand side is important, especially in terms of suitability and trends in ecosystem services, as many of the pressures identified, such as habitat changes and some pollution, are consequences of the high demands made on an ecosystem type.

For these reasons, the methodology described above has to be set into the wider context of the multifunctionality of ecosystems providing multiple ecosystem services that are often dependent on their spatial distribution and location and their interactions. This is especially important for valuation, as anticipated for the implementation of the EU Biodiversity Strategy to 2020 and addressed in Target 2, Action 5, of the Common Implementation Framework (see Section 1.1).

8.4 Improving the knowledge base delivering the EU Seventh Environment Action Programme priority objective on natural capital

This programme includes a commitment to 'work to integrate economic indicators with environmental and social indicators, including natural capital accounting'. Ecosystem assessment provides the basic information for accounting for their condition, which represents the capacity of ecosystems to provide services. Ecosystem accounts are a key pillar of the knowledge base required for developing a policy framework and making policy decisions that help protect and enhance our natural capital, as anticipated in the Seventh Environment Action Programme. A recent paper by Defra (2014) briefly reviews the role of ecosystem accounting in policy and its value in building an evidence base. This could include input in the following stages of the policy cycle:

- identifying a problem or opportunity (e.g. use in business cases);
- assessing and setting policy priorities (e.g. in informing strategic decisions, helping to optimise use of resources and funding);
- improving policy development (e.g. by providing the broader picture across thematic and sectoral policy lines);
- appraising policy options (e.g. use in impact assessments);
- improving policy or programme delivery (e.g. informing better resource management of delivery bodies; influencing behaviours by informing stakeholders through indicators).

One of the main conclusions of Chapter 7 was that there is little evidence of European initiatives integrating ecosystem services assessment and mapping into valuation and accounting. Looking to the future, the following steps will be important (Defra, 2014):

- early engagement with relevant decision-makers and stakeholders to manage expectations and identify policy needs;
- agreeing on an approach and then dealing with the specific data and methodological limitations;
- ensuring that accounts and the underlying data reflect changes in resource management or ecosystem condition in a timely way;
- ensuring that accounts build on existing forms of ecosystem service mapping.

Nevertheless, this process is not straightforward, and national experimentation will be crucial to making the approach work in practice.

8.5 Conclusion

This report has provided a stock-take of the EEA's ecosystem assessment-related activities in the period 2012–2014 and has synthesised some of the key outcomes from these activities. It has shown the breadth of activities that ecosystem mapping encompasses, and the way in which assessment methods are developed to make the best use of the available data sources. It demonstrates how ecosystem assessment can be used to outline the causalities, the links between the different drivers of environmental change, the pressures they induce, the effects on ecosystem condition and the impacts on ecosystems' capacity to provide services and on their biodiversity. As such, the approach addresses the different policy lines and allows for more integrated policy responses across the sectors. It has also examined the contribution that ecosystem assessment can make to promoting green infrastructure and undertaking ecosystem capital accounting. This should provide a useful input to the follow-up of Mid-term review of the *EU Biodiversity Strategy to 2020* (EC, 2015c), helping the EU towards achieving Target 2, Action 5, through improving our knowledge of ecosystems and their services in the EU.

Glossary

Abiotic	Not living or recently living; used here to refer to ecosystem components such as rock, water, mineral parts of soils and climate.
Assessment	The analysis and review of information derived from research for the purpose of helping someone in a position of responsibility to evaluate potential actions or think about a problem. Assessment means assembling, summarising, organising, interpreting and possibly reconciling pieces of existing knowledge and communicating them so that they are relevant and helpful to an intelligent but inexpert decision-maker (Parson, 1995).
Biodiversity	The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (see Article 2 of the Convention on Biological Diversity, 1992).
Biophysical structure	The architecture of an ecosystem as a result of the interaction between the abiotic and physical environment and the biotic communities, in particular vegetation.
Biotic	Living or recently living, used here to refer to the biological components of ecosystems, that is, plants, animals, soil microorganisms, leaf litter and dead wood.
Conservation status (of a natural habitat)	The sum of the influences acting on a natural habitat and its typical species that may affect its long-term natural distribution, structure and functions as well as the long-term survival of its typical species (EC, 1992).
Conservation status (of a species)	The sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations (EC, 1992).
Drivers of change	Any natural or human-induced factor that directly or indirectly causes a change in an ecosystem. A direct driver of change unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy; an indirect driver of change operates by altering the level or rate of change of one or more direct drivers (MA, 2005).
Ecological value	Non-monetary assessment of ecosystem integrity, health or resilience (TEEB, 2010).
Ecosystems	Ecosystems are defined in the Convention on Biological Diversity (CBD) as 'a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit' (UN, 1992). In the same context, ecological science defines ecosystem as a complex of living organisms (biotic factors) with their non-living physical environment (abiotic) and their mutual relations (Christopherson, 1997).
Ecosystem assessment	A social process through which the findings of science concerning the causes of ecosystem change and their consequences for human well-being and management and policy options are brought to bear on the needs of decision-makers (UK-NEA, 2015).

Ecosystem condition	The physical, chemical and biological condition of an ecosystem at a particular point in time. The capacity of an ecosystem to yield services, relative to its potential capacity (MA, 2005). For the purpose of MAES, ecosystem condition is, however, usually used as a synonym for 'ecosystem state'.
Ecosystem degradation	A persistent reduction in the capacity to provide ecosystem services (MA, 2005).
Ecosystem function	A subset of the interactions among biophysical structures, biodiversity and ecosystem processes that underpin the capacity of an ecosystem to provide ecosystem services (TEEB, 2010).
Ecosystem service	The benefits that people obtain from ecosystems (MA, 2005). The direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). The concept 'ecosystem goods and services' is synonymous with ecosystem services. The service flow in our conceptual framework refers to the services actually used by humans.
EEA-39	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden, Switzerland, Turkey and the United Kingdom, plus the six cooperating countries: Albania, Bosnia and Herzegovina, Kosovo under the UN SCR 1244/99, the former Yugoslav Republic of Macedonia, Montenegro and Serbia.
Green infrastructure	Defined as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' (EC, 2013a).
Habitat	The physical location or type of environment in which an organism or biological population lives or occurs. Terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural.
Indicator	Observed value representative of a phenomenon under study. In general, indicators quantify or at least qualify information by aggregating different and many items of different data. The resulting information is therefore synthesised.
Pressures of change	Pressures alter the condition of ecosystems and, consequently, affect their service capacity, habitat quality and biodiversity across Europe.

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