European ecosystem assessment — concept, data, and implementation

Contribution to Target 2 Action 5 Mapping and Assessment of Ecosystems and their Services (MAES) of the EU Biodiversity Strategy to 2020

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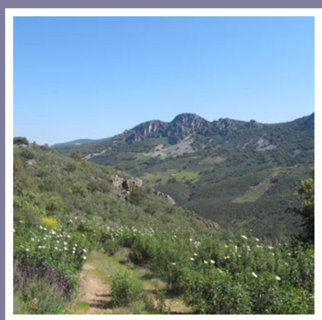

European Environment Agency

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Summary

This report summarises EEA contributions to Target 2 Action 5 'Mapping and Assessment of Ecosystems and their Services (MAES)' for the implementation of the EU Biodiversity Strategy to 2020 (EC, 2011), the Strategy of the EU to meet the global targets of the Convention of Biodiversity (UN, 2010). Europe is becoming greener (Fuchs et al., 2014) but, at the same time, losing biodiversity. At least one-out-of-three species in Europe is threatened with extinction (IUCN, 2011a-d). Many ecosystems are pushed towards the provision of one service — mainly food production — at the cost of the other services they usually provide. The EU Biodiversity Strategy to 2020 aims towards 'healthy' ecosystems that are rich in biodiversity and provide multiple services for human well-being.

Implementation is based on a common agreement between the EEA, the Commission Services (DG-ENV) and the Joint Research Centre (JRC), to share the work of European level assessment. As described in this report, the EEA is in the lead for mapping and assessing ecosystems and their conditions. The information, combined with the assessment of ecosystem services (JRC), will provide information about ecosystem conditions and their capacity to provide services on a European level.

First, the document provides an overview about the motivation to use an ecosystem-based approach, and the EU Biodiversity Strategy to 2020 as policy background.

The second chapter outlines specific aspects of addressing habitats and biodiversity in the context of ecosystems, ecosystem service assessments and natural capital, and describes the conceptual framework to map and assess ecosystems in more detail. It uses the DPSIR (Drivers Pressures State Impact Response) approach to put different elements of environmental information into coherent context. The Millennium Assessment (MA) identified a number of key drivers and pressures affecting ecosystems and their services that are essential for human well-being. For this study the pressures are grouped into five major blocks: habitat change, climate change, invasive species, land use management, and pollution and nutrient enrichment. These blocks reflect important processes affecting ecosystems at different scales (continental to local), and also the major policy efforts devised to cope with negative effects. Finally, the major elements for mapping pressures, ecosystem conditions and impacts, are outlined and explained — followed by a short summary of an extensive evaluation of existing European data.

In the third chapter, the mapping and assessment process is further explained. For each pressure, as well as for mapping and assessing ecosystem condition and its impacts on biodiversity, available data have been collected and summarised in a series of tables (Annex 2). The tables provide information about the mapping process, accessibility and the gaps identified. For each pressure, one example is shown, and data availability, as well as gaps, are addressed. Mapping ecosystem conditions comprises two major building blocks. First, a European ecosystem map was produced by linking Corine Land Cover (CLC) data with the European Nature Information System (EUNIS) habitat information. This map describes the distribution of ecosystem types across Europe. Secondly, the actual ecosystem conditions and the observed environmental changes have to be mapped by combining the ecosystem map with environmental monitoring data. Linking this information to the maps describing the environmental pressures provides a first overview on how pressures affect ecosystem conditions, habitat quality and biodiversity, and how pressures and conditions are changing over time. To assess the impacts of pressures on ecosystem conditions and habitat quality and biodiversity, the functional relationships, i.e. the so-called functional traits, have to be evaluated and described. The knowledge about these relationships triggers the quality of the impact assessment. Each of these steps is illustrated — using cropland and grassland as examples. In parallel, methods on how to combine information to map cumulative pressures and conditions are outlined in flow charts.

In the fourth chapter, the achievements of the Europe-wide ecosystem assessment are summarised, discussed, and set into context with the remaining challenges, for the provision of the relevant knowledge to underpin the quantitative targets of the EU Biodiversity Strategy to 2020 — mainly the 'no net loss' and the 'restoration and prioritisation framework'. Furthermore, currently available data need to be integrated with the new data available (mainly) from European environmental legislation and monitoring.

1 Introduction

1.1 Why ecosystem assessment

Ecosystems are defined in the Convention on Biological Diversity (CBD) as 'a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit' (UN, 1992). Ecosystems are multi-functional. Each system provides a series of services for human well-being either directly, e.g. as food and fibre, or more indirectly by e.g. providing clean air and water. Ecosystem assessment is an instrument for structured and targeted analysis of environmental change and its impact on human well-being. The structural and functional entities of ecosystems are key entry points for our understanding of how species interact with each other and their abiotic environments, and how these interactions are affected by human activities.

Ecosystems contain a multitude of living organisms that have adapted to survive and reproduce in a particular physical and chemical environment. Anything that causes a change in the physico-chemical characteristics of the environment has the potential to change an ecosystem's condition, its biodiversity and, consequently, its capacity to provide services. Any activity that removes or adds organisms can change the functionality of an ecosystem. An ecosystem assessment should evaluate all of the relevant factors affecting the ecosystem's structure and function.

Spatially-explicit mapping is required to capture different gradients and variations of the relevant components, in space and time, affecting ecosystem function (Maes et al., 2014). The assessment of ecosystem condition provides information about its capability to continuously provide services for human well-being. This knowledge is essential to document the on-going loss and degradation of ecosystems and their services, the subsequent socio-economic impacts, and the identification of pathways towards sustainable development, in order to maintain the delivery of services. As such, ecosystem assessments provide the input for decision-making by addressing and integrating basic information to sectoral policies, i.e. mainly, territorial planning, nature protection, agriculture, forestry, freshwater, marine, climate change mitigation and adaptation, and air pollution reduction.

This report outlines the concepts and methods to map and assess ecosystems and their condition on a European level, and the main sources of data needed to map and assess ecosystems at the European scale. It highlights the major pressures on ecosystems and outlines the expected results. It is targeted to describe the functional relationships between ecosystem condition, the quality of its habitats, and its biodiversity. The approach is also feasible for use in other environmental sectors, such as water, agriculture or forest management. It aims to support European policies with Europe-wide harmonised information, provide the baseline for assessing ecosystem services, and support the work of Member States on their national assessments.

1.2 Policy background

In May 2011, the European Commission and Council adopted the 'Communication for the Implementation of the Biodiversity Strategy to 2020' (EC, 2011), which also implies the time lines to meet the Aichi targets of the Convention of Biodiversity (EC, 2014a). The headline target for 2020 is 'halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss'. The Strategy translates this central objective into six specific targets, with 20 concrete actions to achieve them. The Common Implementation Framework (CIF) provides an overview of how these targets and actions are interlinked (see Figure 1.1).

The concept and methodology of the ecosystem assessment described in this report is triggered by Action 5 of Target 2. It is implemented by the Working Group MAES (Mapping and Assessment of Ecosystems and their Services) — a joint body of the European Commission and Member States with EEA participation. Action 5 states that '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.'

Box 1.1 Key terms and definitions

Assessment: The analysis and review of information derived from research for the purposes of helping someone in a position of responsibility to evaluate possible actions, or to 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: Biological diversity means 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 (UN, 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).

Ecosystems are defined in the Convention on Biological Diversity (CBD) as 'a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit' (UN, 1992).

Ecosystem assessment: A social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers (UK NEA, 2011).

Ecosystem condition/ecosystem state: The effective capacity of an ecosystem to provide services, relative to its potential capacity (MA, 2005). Capacity is triggered by the physical, chemical and biological condition of an ecosystem at a particular point in time, controlled by the natural condition and the anthropogenic pressures to which it is exposed.

Ecosystem function: Subset of the interactions between 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 (Maes et al., 2013).

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: An observed value — representative of a phenomenon to study. In general, indicators quantify information by aggregating different and multiple data. The resulting information is therefore synthesised.

Physico-chemical environment describes the physical and chemical conditions that control the existence and survival of species. Temperature, precipitation, humidity, soil structure and soil water content, slope, currents, and flooding are important physical parameters. Chemical parameters are determined by soil chemical conditions, bedrock weathering, nutrient supply including fertilisation, and air and water pollution.

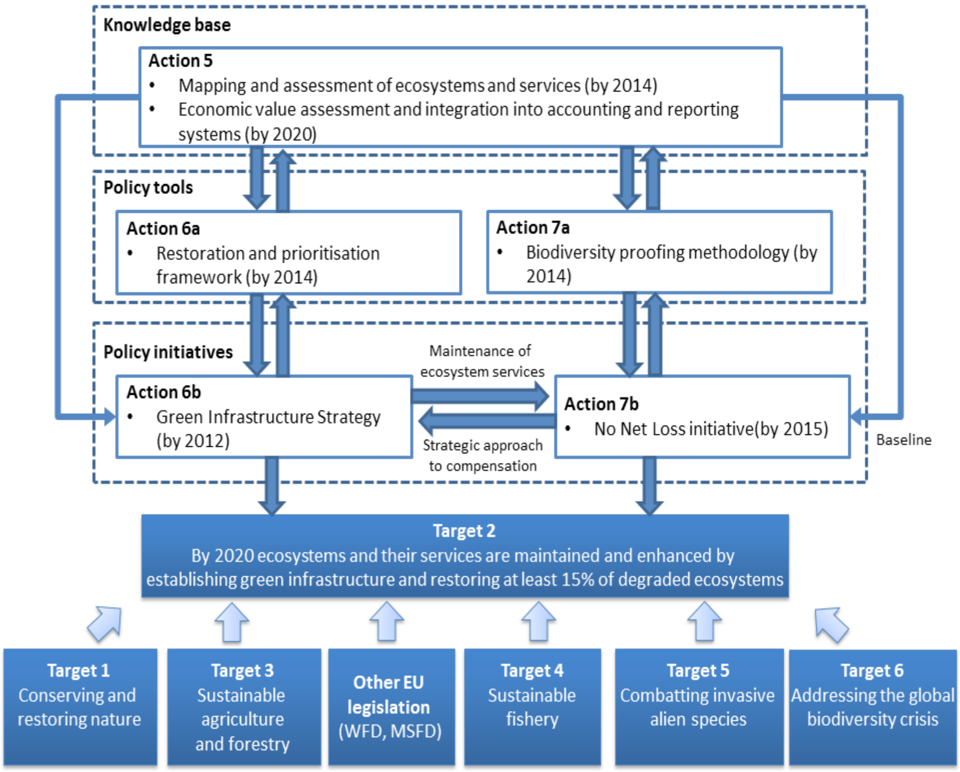
Source: Maes et al., 2013, updated.

The assessment and valuation of Action 5 is closely linked to the other actions of Target 2, i.e. Actions: 6a) Restoration and prioritisation framework, 6b) Green Infrastructure Strategy, 7a) Biodiversity proofing methodology and 7b) No Net Loss initiative. Links also need to be established to the other five Targets, i.e. 1) Conserving and restoring nature, 3) Sustainable agriculture and forestry, 4) Sustainable fishery, 5) Combatting invasive alien species, and 6) Addressing the global biodiversity crises. Giving an integrative view is important for use within decision-making processes and key to addressing synergies and trade-offs of policy impacts on ecosystems and their services.

The Strategy implies two timelines for their targets:

1. a medium term target: 'by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems';

Figure 1.1 Common Implementation Framework (CIF) of the EU Biodiversity Strategy to 2020



Note: Since January 2014 Action 6a) and 6b) are merged and implemented as a joint working group on Green Infrastructure and Restoration.

Source: Maes et al., 2013.

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

In September 2011, DG Environment (DG-ENV) of the European Commission, Eurostat, the Joint Research Centre (JRC) and the EEA, agreed to share the Europe-wide work for Action 5 in Target 2. The EEA committed to provide the building blocks to map and assess the condition of major ecosystems until 2014 — which is described in this report, i.e. steps 1 and 2 in Figure 1.2. In parallel, the JRC will map and assess the defined ecosystem services, i.e. step 3 in Figure 1.2.

Both organisations will closely cooperate to link and integrate activities based on an ecosystem/ecosystem service-matrix approach as outlined in the RUBICODE project (Vandewalle et al., 2010). This information, combined with the assessment of ecosystem services by the JRC, will provide detailed information about the ecosystem condition and its capacity to provide services on a European level, i.e. step 4 in Figure 1.2.

Between now and 2020, alignment of ecosystem service assessments with scenarios of future changes and the valuations of ecosystem services for baselines and scenarios will be integrated into environmental and economic accounting. Ecosystem assessments will provide the baselines for these activities.

Figure 1.2 A common assessment framework for ecosystems and ecosystem services

(1)
Map ecosystems

Urban
Cropland
Grassland
Woodland and forest
Heathland and shrub
Sparsely vegetated land
Wetlands
Rivers and lakes
Marine inlets and transitional waters
Coastal
Shelf
Open ocean

Land use land cover data e.g.
Corine Land Cover
Copenicus high resolution data
Elevation data
Seabed data
National datasets

Models for spatial delineating wetlands
or natural, unmanaged ecosystems

(2)
Asseess the condition of ecosystems

Indicators

Conservation status of habitats and species
Ecological status of water bodies
Environmental status of seas
Ecosystem status and biodiversity

Data

Art. 17 assessment

WFD assessment

MSFD assessment

Data including air pollutant concentrations, habitat connectivity, land use change soil degradation, etc.

(3)
Assess the ecosystem services delivered by ecosystems

Indicators

Supply indicators:
Indicators for stock and flow of ecosystem functions and ecosystem services

Demand indicators:
Indicators for the human demand for ecosystem services

Data and models

Different sources of environmental data and models

Different socio-economic statistics

(4)
Integrated ecosystem assessment

How does condition relate to service provision?
How do the various ecosystem types interact to provide their services?

Source: Maes et al., 2014.

2 Concept

2.1 Ecosystems, habitats, and biodiversity

Ecosystems, in more scientific terms, are communities of interacting organisms and the physical and chemical non-living components of their environment, e.g. water, minerals, soil and climate. These biotic and abiotic components are linked together through food-webs, nutrient cycles and energy flows (Odum, 1971). Ecosystems provide general and specific habitats for typical and atypical communities of species or taxa — from the smallest single-cells to the largest multi-cellular organisms, and for all stages of their life cycles.

Although this definition applies to all hierarchical levels — from a single water drop and its microorganisms, to Earth's major vegetation zones (biomes) — for the practical purposes of policy-relevant mapping and assessment at European level, and in view of the available information, ecosystems are considered here at the scale of land-cover-related units, e.g. urban, cropland, grassland, forests, rivers and lakes. These units represent the key elements for human management, e.g. in agriculture, forestry, fisheries and water management, to make the best use of their services. At the same time, this spatial scale also reflects the existing definitions of European environmental directives, namely the Habitats Directive (HD), Birds Directive (BD), Water Framework Directive (WFD), and the Marine Strategy Framework Directive (MSFD).

Habitats, the space where an organism or ecological community normally lives or occurs, are linked to species or groups of species/communities and their requirements to the physico-chemical conditions of their environment. For the purposes of EUNIS, a 'habitat' is defined as: 'a place where plants or animals normally live, characterised primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality, etc.) and secondarily by the species of plants and animals that live there'. Habitats are necessarily defined at a given scale. Some EUNIS habitats such as moss and lichen tundra or deep-sea mud may be of vast extent. Others such as cave entrances or springs, spring brooks and geysers are much smaller. Most — but not all — EUNIS habitats are in effect 'biotopes', that is to say 'areas with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms'. A few EUNIS habitats such as glaciers and highly artificial non-saline standing waters may be devoid of living organisms other than microbes. These features, although not strictly habitats, are included for completeness (Davies et al., 2004). As such, the definition includes both ecosystems and habitats *in sensu stricto*. Habitats and ecosystems can be considered as two different ways of perceiving the natural reality. The term 'ecosystem' is used for stressing structural interdependences between biotic and abiotic natural elements. The 'habitat' concerns particular spatial and physico-chemical natural conditions for a given level of living organisms (Tansley, 1935).

Biodiversity implies all dimensions of living organisms (see Figure 2.1), which comprises all species communities (i.e. of algae, plants and animals — from bacteria to big predators), including their variety, i.e. species richness; number of individuals, i.e. abundance; and genetic diversity. The abiotic factors triggering biodiversity are manifold. The main drivers of the presence or absence of species are light, temperature and water — including their short and long-term variations — all of which are summarised as 'climatic conditions', plus physical conditions including currents, chemical conditions, such as nitrogen, phosphorous concentrations or salinity, environmental heterogeneity, and disturbances (Pausas and Austin, 2001).

For Europe as a continent, three different aspects are important to steering biodiversity. First, species richness is generally increasing from North to South — a consequence of the natural climate variations, mainly the changes between ice ages and warm periods over the last million years.

The second important aspect is human land and sea use and their management. In most parts of Europe, the sea and land has been used by humans for many centuries or even millennia. Until the 19th century, human use of natural resources was nutrient-limited and energy-limited, and agricultural activities were based on managing small fields generating additional

Box 2.1 Typology of ecosystems

Member States, together with DG-ENV, the JRC and the EEA, agreed on a list of Europe-wide ecosystem types feasible for the aggregation of national and local data and the dis-aggregation of European data — also reflecting main policy areas and environmental reporting. A detailed description is available in Maes et al., 2013.

Major eco-system category (level 1)	Ecosystem type for mapping and assessment (level 2)	Description
Terrestrial	Urban	Urban ecosystems are areas where most of the human population lives. This class includes urban, industrial, commercial, and transport areas, urban green areas, mines, dumping and construction sites.
	Cropland*	Croplands are the main food production areas including both intensively-managed ecosystems and multifunctional areas supporting many semi-natural and natural species along with food production (lower intensity management). It includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics).
	Grassland*	Grasslands are 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, semi-natural and natural (extensively managed) grasslands.
	Forest and woodlands	Woodlands and forests are areas dominated by woody vegetation of various age, or they have succession-climax-vegetation types on most of the area, supporting many ecosystem services. Information on ecosystem structure, e.g. age group, species and diversity, is especially important for this ecosystem type.
	Heathland and shrub	Heathlands and shrubs 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 vegetation.
	Sparsely vegetated land	Sparsely vegetated lands often have 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 that support water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites.
Freshwater	Rivers and lakes	Rivers and lakes are the permanent freshwater inland surface waters. This class includes water courses and waterbodies.
Marine**	Marine inlets and transitional waters	Marine inlets and transitional waters are ecosystems on the land-water interface under the influence of tides and with salinity regimes higher than 0.5 ‰. They include coastal wetlands, lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments.
	Coastal	The coastal ecosystems include coastal, shallow, and marine systems that experience significant land-based influences. These systems undergo diurnal fluctuations in temperature, salinity and turbidity, and are subject to wave disturbance. Depth is between 50m and 70m.
	Shelf	The shelf refers to marine systems away from coastal influence and 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 200m deep.
	Open ocean	The open ocean refers to marine systems beyond the shelf break with very stable temperature and salinity regimes particularly at the deep seabed. Depth is beyond 200m.

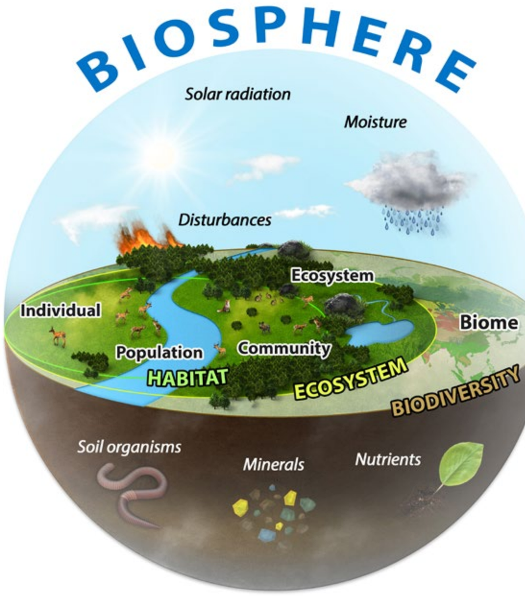
Note: * Croplands including permanent crops and actively managed grasslands are often summarised and reported under the term agro-ecosystems.

** The current zonal classification refers to the reporting units of the Marine Strategy Framework Directive (MSFD) and might be replaced by a more ecosystem-based approach in the future.

habitats for species in increasingly heterogeneous landscapes. This process is considered to have induced maximum biodiversity on European land about 200–300 years ago.

Many studies have found relationships between changes in species richness and nutrient availability (Kirkman et al., 2001). The typical response observed was a 'humped-back curve': species richness is low at low nutrient levels, increases to peak at intermediate levels and declines more gradually at high nutrient levels (Pausas and Austin, 2001). With industrialisation and its subsequent fast-growing human population, from the mid-19th century onwards, the availability of energy from fossil fuels, machinery, inorganic fertilisers and pesticides, the average field size, nutrient availability and pollutant load, as well as indirect pressures such as landscape fragmentation, air and water pollution and climate change, increased. However, at the same time, landscape/seascape heterogeneity reduced and put increased pressures on species and their habitats. In parallel, increasing land-take for settlements, industry, infrastructures and mining use, reduces the area of natural ecosystems, fragments their extension and creates new urban ecosystems. This process accelerated over the last 40 years. The structure of the world's ecosystems has changed more rapidly in the second half of the 20th century than at any time in recorded human history, and virtually all of Earth's ecosystems have now been significantly transformed through human actions (MA, 2005).

Figure 2.1 Ecosystems, habitats and biodiversity



Source: ETC/SIA 2015.

Finally, the third important aspect for biodiversity is rareness. Due to special environmental conditions, or specific land use, habitats such as bogs, mires and inland heathlands are present as important elements of the European ecosystem types. The number of species in these ecosystems can be low in e.g. bogs and mires, but the value of these ecosystems is high

Box 2.2 European land-use history and biodiversity 'in a nutshell'

Pre-industrial, i.e. before mid-19th century:

- small fields and more areas for agriculture increased species habitats in European landscapes;
- extensive use and nutrient limitation fostered species diversity;
- use of renewable energy (wood, hydropower) kept anthropogenic pressures on climate system limited;
- population growth is low and resource needs only slightly increased, which kept pressures on habitats and biodiversity limited.

Industrial after mid-19th century accelerating very much since second half of the 20th century:

- large fields and land abandonment reduce habitat diversity in European landscapes;
- intensive land use and the use of fertilisers and pesticides reduce species diversity;
- use of fossil fuels leads to additional pressures by anthropogenic climate change and air pollution, inducing spatial shifting of habitats, changing habitat quality, and creating opportunities for invasive alien species to expand their habitats;
- population growth and increasing average incomes enhance pressures on land and sea by land-take and the use of natural resources, creating new urban ecosystems, reducing natural habitats and fostering establishment of invasive alien species.

Box 2.3 Ecosystems, biodiversity, and habitats in the context of European ecosystem assessment

The Convention on Biological Diversity (UN, 1992; Article 2. Use of Terms) defines:

Ecosystems

'Ecosystem' means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Habitats

'Habitat' means the place or type of site where an organism or population naturally occurs.

Biodiversity

'Biological diversity' means 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.

These descriptions do not necessarily distinguish explicitly between the three terms 'ecosystems', 'habitats' and 'biodiversity'. The confusion between these definitions often hampers the process to address the causalities between human-induced environmental changes on the one hand and environmental conditions on the other. The overlapping definitions also make it difficult to assess the impacts of human-induced environmental change on biodiversity and at the same time to offer options for how to secure species presence and survival by improving the current environmental situation.

The ecosystem types as defined in MAES not only define functional entities (describing communities of species and their abiotic environment), they are also linked to major sub-national, national and European policy areas such as agriculture, forestry, nature protection or territorial cohesion. Moreover, the ecosystem types address a variety of scales, from the sub-national to the European. The MAES ecosystem definitions imply that habitats match ecosystems on a one-to-one basis or that habitats are part of these ecosystems. For example, deadwood in forest ecosystems is an important habitat for many insects, but deadwood represents only one element in forest ecosystem structure and functioning. Ecosystems are also part of larger entities. 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 for large mammals and birds — often cover more than one MAES ecosystem type for feeding and reproduction, requiring assessments on landscape scales and beyond.

Biodiversity implies all dimensions of living organisms (including algae, plants and animals — from microorganisms to big predators), their variety, abundance and genetic diversity. In the context of the MAES ecosystem assessment, its spatial and temporal scale, and the data available for assessments, the focus is on species diversity and abundance (which also indirectly implies genetic diversity even if not assessed explicitly in this context). Biodiversity is linked to the quality of the habitats species occupy and as such is linked to ecosystem condition. Protecting and managing ecosystems affects their condition, which is the key entry point for measures to improve habitat quality and subsequent biodiversity.

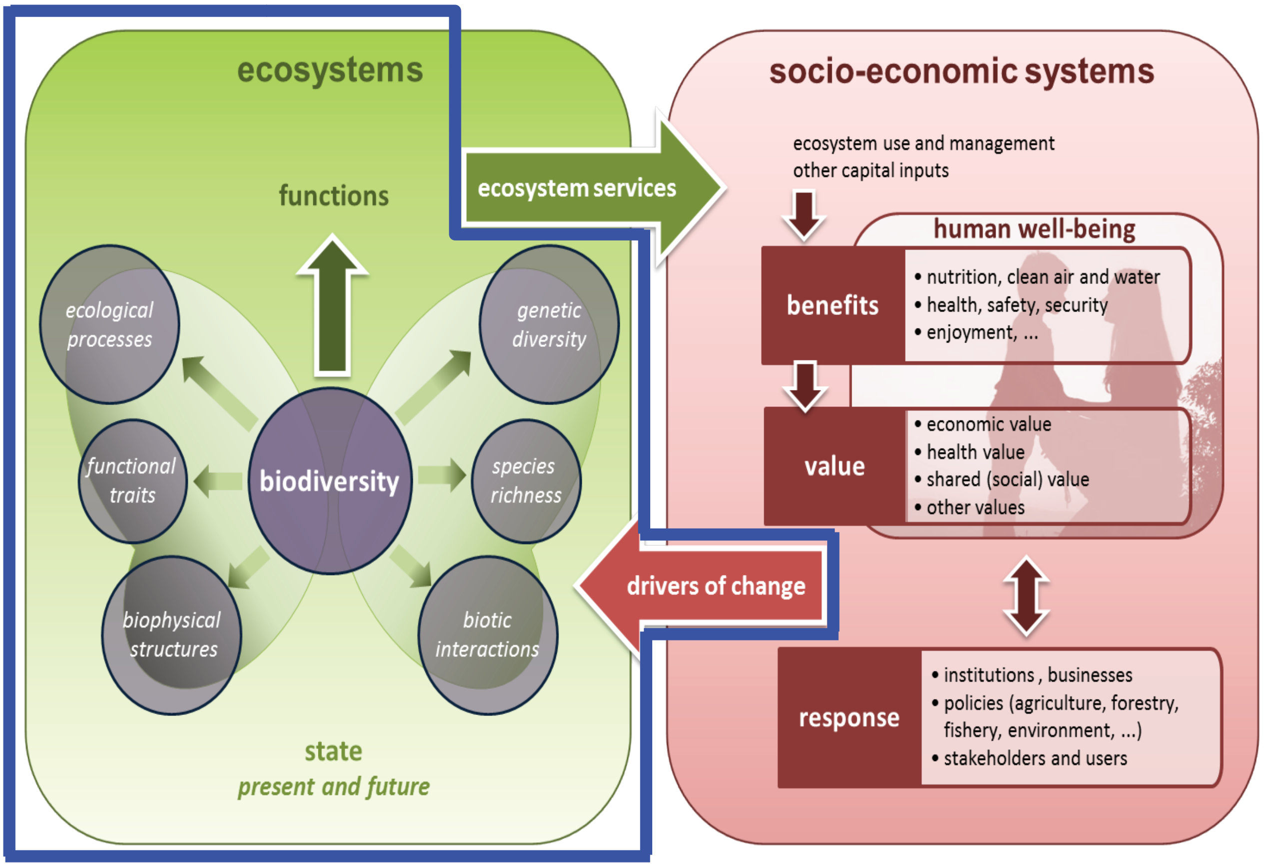
because they only appear in a few areas and they are often of special importance e.g. for migrating birds, or tourism. They are also important for the maintenance of the genetic variability of species. For their preservation, it is important to understand why these habitats exist, and how they should be managed and protected.

As outlined and illustrated in Figure 2.1, ecosystems, habitats and their biodiversity are closely linked to each other over space and time. To understand how species interact with their environment and are affected by human use, and how these processes have changed over space and time, as well as the functional relationships between ecosystems, habitats and biodiversity, is key to making sound and profound decisions for their preservation. As further outlined in the following chapters, it requires information about the spatial distribution and extension of ecosystems and the different pressures affecting their conditions. Both vary over space and time and can be combined to assess the impacts on ecosystem services and biodiversity. The outcomes allow an outline of possible responses to be drawn on how to mitigate negative impacts, or adapt and change ecosystem management, to improve ecosystem function, ecosystem service provision, and biodiversity conditions.

2.2 Ecosystems, ecosystem services and natural capital

Ecosystem services are defined as the benefits that people obtain from ecosystems (MA, 2005) contributing to human well-being (TEEB, 2010). The condition of ecosystems describes their effective capacity to provide these services. The ecosystem capacity is equivalent to actual ecosystem service capacity and consequently not dealing with the demand for human well-being as required by the definition. The effective use of ecosystem services depends on the demands, which, again, depend on social and economic factors and their distribution over space and time. Urban areas depend, notably, on ecosystem services for drinking water, clean air, food, flood protection, temperature regulation and recreation. Cities largely rely on their hinterland, which leads to very high demands for a wide variety of ecosystem services in these areas — from food and water provision to recreation, whereas the demand for services in rural areas can be rather low and may even be 'exported' to urban areas. Remote areas can provide numerous services that are important for the maintenance and regulation of our environment, but are not necessarily facing the same demand as urban periphery areas. The analytical framework of the MAES Working Group (Maes et al., 2013), illustrates the link between ecosystems, their biodiversity, their function, and their services (Figure 2.2). Ecosystem condition is not only affected by human use and management, but also by the use of the non-living parts of natural capital, which include abiotic components such as mineral resources, fossil fuels, land/sea take for settlements, industry and infrastructures — including land/sea areas used to produce renewable energy (Figure 2.3). Whilst the use of abiotic components does not rely on current ecosystem service capacity, the use of these abiotic components affects ecosystems directly by removing them — thus, taking them out of service, and indirectly increasing stress on ecosystems' functional capacities by air pollution, nutrient load and anthropogenic climate change, i.e. the consequences of using minerals and fossil fuels.

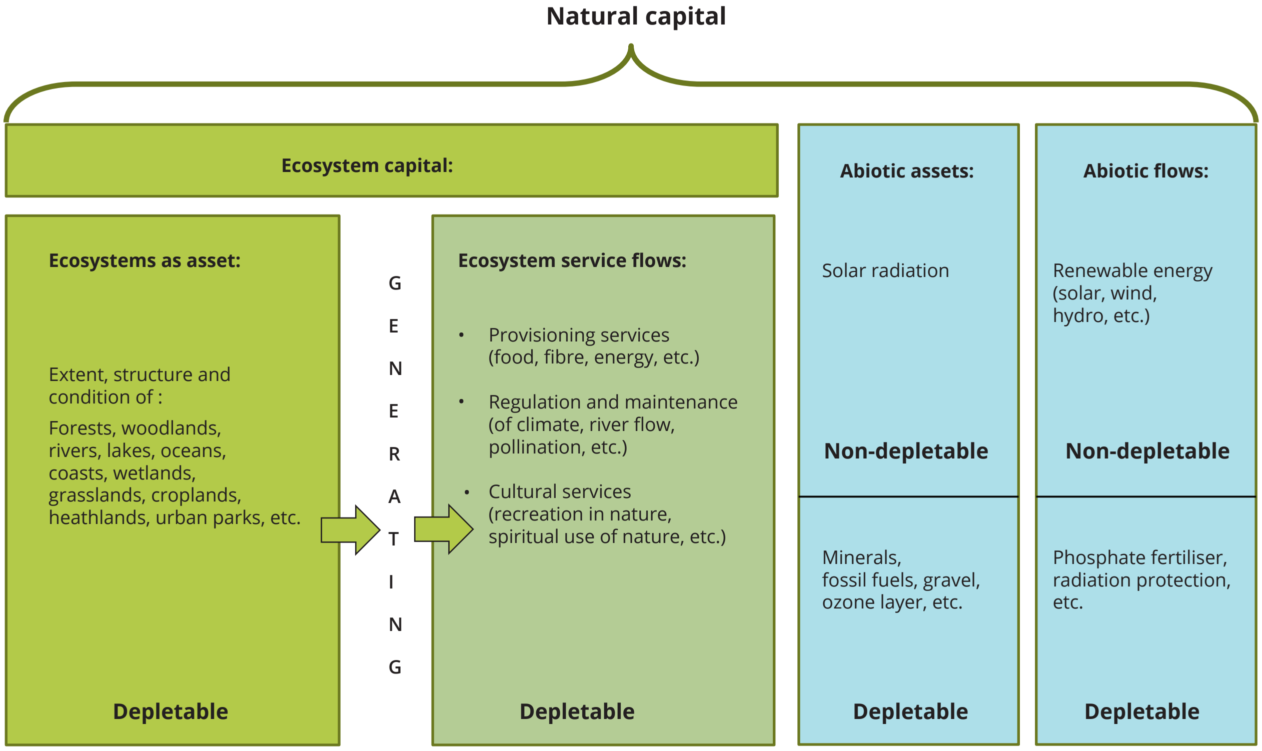
Figure 2.2 Conceptual framework for EU-wide ecosystem assessment and its link to ecosystem services



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

Source: Maes et al., 2013.

Figure 2.3 Link between ecosystems, ecosystem services and natural capital



Note: This graph presents the MAES working definition of natural capital.

Source: Petersen and Gocheva, 2015.

Many ecosystems are managed to maximise the provision of one service — mostly for food, often timber — at the cost of other services. The EU Biodiversity Strategy to 2020 aims towards 'healthy' ecosystems, which are rich in biodiversity and provide multiple services for human well-being. Safeguarding healthy, functioning ecosystems to deliver the range of ecosystem services required to meet the demands of our societies, guarantees that the condition of the environment, society and economy all work together and remain in good condition.

Reaching equilibrium between sustaining enough natural capital to deliver nature's ecosystem services, while supporting the demands of a growing global population, is a major challenge worldwide — not just in Europe. If properly managed, ecosystems provide multiple services that are vital to humanity, including the production of goods, e.g. food; life-support processes, e.g. water purification; life-fulfilling conditions, e.g. recreation opportunities; and conservation of options, e.g. genetic diversity for future use. So far, only a limited number of these services — mainly provisioning and some of the cultural services such as recreation — are quantified and valued, i.e. accounted. Most of these services are handled as 'free' public goods. Assessing the economic value of such services, and promoting the integration of these values into accounting and reporting systems at EU and national levels, will be the next steps in the implementation process of the EU Biodiversity Strategy to 2020.

2.3 Framework for European ecosystem assessment

Ecosystems contain a multitude of living organisms that have adapted to life in a particular physico-chemical environment. Anything that causes change in the physico-chemical characteristics of the environment has the potential to change the ecosystem and affect its habitats and biodiversity. Additionally, any activity that removes or adds organisms can change the ecosystem too.

Data and information for the assessment of the current environmental conditions, environmental changes, as well as the impacts and (policy) responses to cope with negative impacts, can be structured using the well-established Drivers, Pressures, State, Impact and Response (DPSIR) framework (EEA, 1999; Niemeijer and de Groot, 2008).

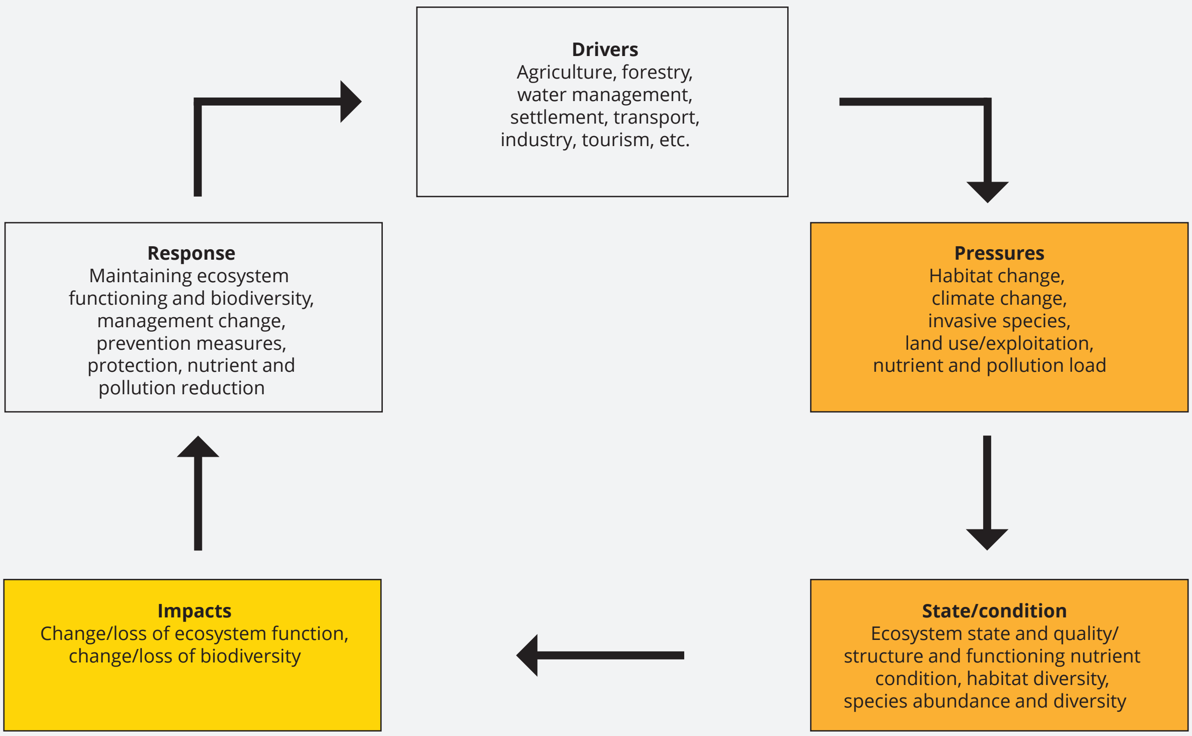
DPSIR is a theoretical framework used to systematically classify the information needed for the analysis of environmental problems, on the one hand, and to identify measures to resolve them, on the other hand (Turner et al., 2010). Drivers of change (D) exert pressures (P) on the state/condition of ecosystems (S) at one moment of time, affecting habitats and biodiversity (I) across Europe in all combinations of intensities, and consequently affecting the amount of services they can provide. If these impacts are undesired, policy-makers will put in place the relevant responses (R) by taking actions to tackle negative effects. See Box 2.4.

The DPSIR framework is independent from spatial and temporal scales and can be adapted and applied to any ecosystem type at any level of detail. It supports the structuring of the approach and helps to identify the relevant data needed to perform assessment in adequate temporal and spatial resolutions.

The Millennium Assessment (see Box 2.5), does not distinguish between drivers and pressures but uses the terms 'indirect drivers' and 'drivers' instead (Nelson, 2005). To adapt the terminology to the DPSIR framework applicable for the European policy framework, these drivers are labelled as pressures and conditions that can be grouped into two major blocks:

1. The natural, physical, chemical, and biological conditions triggered by climate, soil conditions, topography, evolution, extreme events and other

Box 2.4 The DPSIR framework for European ecosystem assessment



There is not always full clarity about the exact definition of environmental processes and where to place the different components in the DPSIR framework — it also depends on the objects to be addressed. In some cases, pressures in the context of a specific ecosystem assessment, e.g. terrestrial, might be considered as a condition in a different context, e.g. freshwater, or vice versa.

In any case, the contextual linkages should be visible and the DPSIR framework should help to put these linkages in the right place. In many cases, knowledge and data availability may determine which element of the DPSIR framework is used to describe the impacts to be investigated. Finally, the impact as the target of the assessment (in our case, the impacts of environmental change on biodiversity) triggers the overall design of the assessment.

Note: For 'state', the report uses the term 'condition' to avoid confusion with the term 'status' that describes the legal aspects.

Source: Turner et al., 2010, adapted.

environmental pressures. Within the time horizon of the Biodiversity Strategy-related ecosystem assessment, which covers years to several decades, the natural drivers of the Millennium Assessment are considered to be constant and are, therefore, part of natural conditions in the MAES DPSIR framework.

2. The pressures that ecosystems are exposed to due to human use are translated into five major blocks, i.e. habitat change, climate change (including inherent natural climate variations and extreme events, both of which cannot be separated from anthropogenic changes), invasive species, land use management, and pollution/nutrient enrichment. Human pressures are either direct, i.e. mainly from land use and management, or indirect, i.e. by air pollution or anthropogenic climate change.

The main pressures identified also reflect major policy areas but often feed also into different policy measures. Land cover change is mostly addressed by territorial cohesion policies. Climate change is linked to climate change mitigation and adaptation policies. Land-use and nutrient enrichment are part of agricultural and forestry-related policies but also affect nature protection and air-pollution mitigation. To address the relevant stakeholders, this requires a clear communication strategy and appropriate thematic mapping of pressures and subsequent ecosystem conditions.

Another important factor for mapping and addressing ecosystems and their condition is the change of pressures over time. The cumulative effects of observed changes in pressures are the reason for the current conditions of ecosystems. It describes the trends in pressures that ecosystems have been exposed to, so far. Time-series of observed changes in pressures are, therefore, important to analyse the causal connectivity between pressures and current condition for each ecosystem type and each spatial unit across Europe. The trend in pressures also provides a first insight into the expected changes in the near future. Decreasing observed trends may indicate further improvement of ecosystem conditions and vice versa, i.e. important information for decision-making about measures to mitigate and adapt to positive or negative effects. Consequently, ecosystem assessments always imply information on observed trends in the pressures that created the current conditions and trigger those in the near future. For the implementation of the EU Biodiversity Strategy to 2020, ecosystem assessments are focused on the functional relationships between ecosystem conditions, their service capacities, their habitat quality and related biodiversity. Taking into account existing and upcoming data and information, on a European level, as well as the targets defined in the Strategy, a Europe-wide ecosystem assessment requires the following building blocks (see also Figure 2.4):

Box 2.5 Pressures in MAES ecosystem assessment and drivers in Millennium Assessment

The pressures have been pooled into five major groups each representing main policy themes.

DPSIR MAES ecosystem assessment	Drivers Millennium Assessment	Comment
Pressure: habitat change	Changes in local land use and cover	Territorial cohesion: structural changes, land-take, fragmentation, land abandonment
Pressure: climate change	Climate change	Climate change mitigation and adaptation: changes in average values and extreme events (mainly temperature, precipitation, humidity)
Pressure: alien species	Species introduction or removal	Nature protection and EU Regulation on Invasive Alien Species (October 2014)
Pressure: land-use/ exploitation	Harvest and resource consumption and technology, adaptation, use	CAP, forestry: agricultural (including grazing) and forestry statistics — technological aspects are addressed, indirectly, via changes in land management, and the use of fertilisers and pesticides
Pressure: pollution and nutrient enrichment	External inputs, e.g. fertiliser use, pest control and irrigation	Air pollution prevention, CAP, nature protection: air pollution data, statistical data on fertiliser use, nutrients and pesticides
Condition: natural conditions as used for delineating ecosystems (ecosystem map)	Natural, physical, and biological drivers	Current average climate, soil conditions, elevation, slope, aspect, etc. considered stable within time horizon of the assessment (years to decades)

1. Spatially-explicit mapping of the key pressures of change, the direct pressures (e.g. land/sea use and management, harvesting, and land cover change) and indirect pressures (e.g. air pollution, eutrophication and climate change), and their different gradients and variations in space and time — altering the condition of ecosystems and consequently impacting their service capacities, habitat qualities, and biodiversity across Europe.

2. Spatially-explicit mapping of ecosystems to define their location and boundaries and assess their natural capacities — since no pan-European ecosystem map is currently available.

3. Combination of data sets to assess the current condition of European ecosystems, which also includes change-over-time pressures to identify if trends lead to less or more favourable conditions in terms of their habitat qualities and biodiversity, functioning, and their capacity to provide services.

4. Collection of profound and, if possible, quantitative information about the functional relationships between ecosystem conditions, service capacities, habitat qualities and their biodiversity.

5. Mapping impacts on ecosystem functions, habitats and biodiversity to provide information to meet the EU Biodiversity Strategy to 2020 targets and the related global Aichi targets of the Convention on Biological Diversity (CBD) (EC, 2014a).

The outcomes of the ecosystem assessment will feed into the subsequent assessment of their services and will provide input for valuing natural capital — as required in the Communication (EC, 2011).

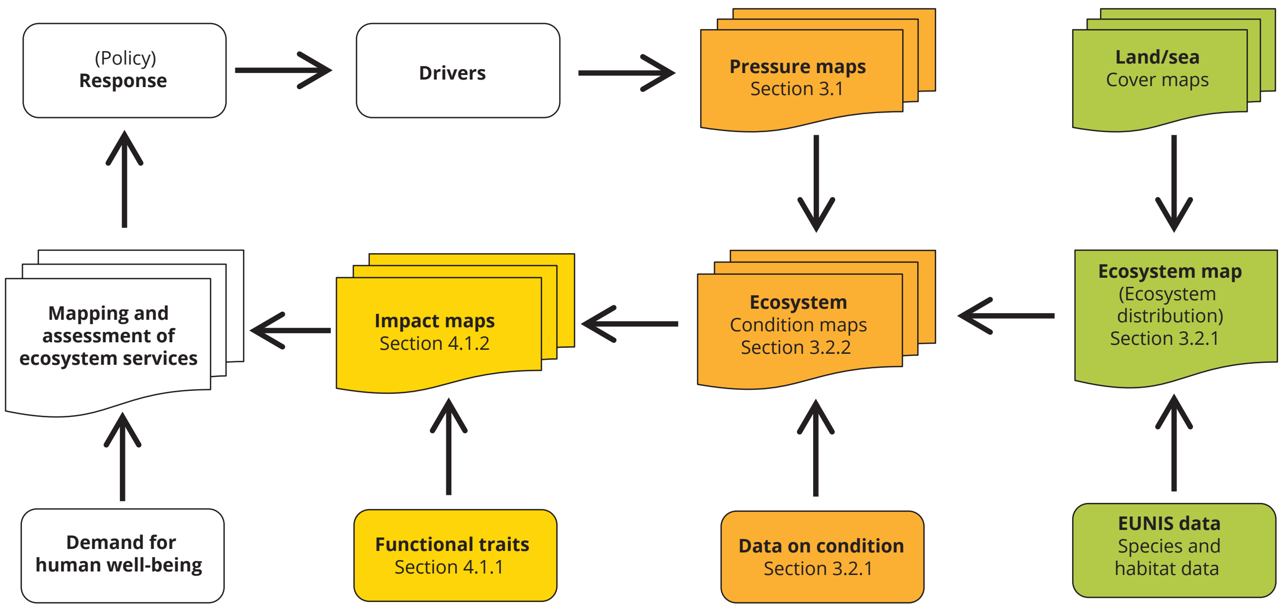
The interlinkages between different pressures, their relative importance for ecosystem condition, and the impacts on habitat quality and biodiversity, create a relative complex pattern of mutual interactions as illustrated in Figure 2.5.

The relevance of the pressures depends on the ecosystem type. While cropland ecosystems and managed grassland ecosystems are mostly influenced by direct management (including irrigation or drainage), semi-natural systems such as heathlands and shrubs are more affected by air pollution and climate change. Freshwater and marine ecosystems are additionally impaired by the condition of adjacent terrestrial ecosystems and the input of nutrients and pollutants of these systems into the waterbodies.

2.4 Data availability

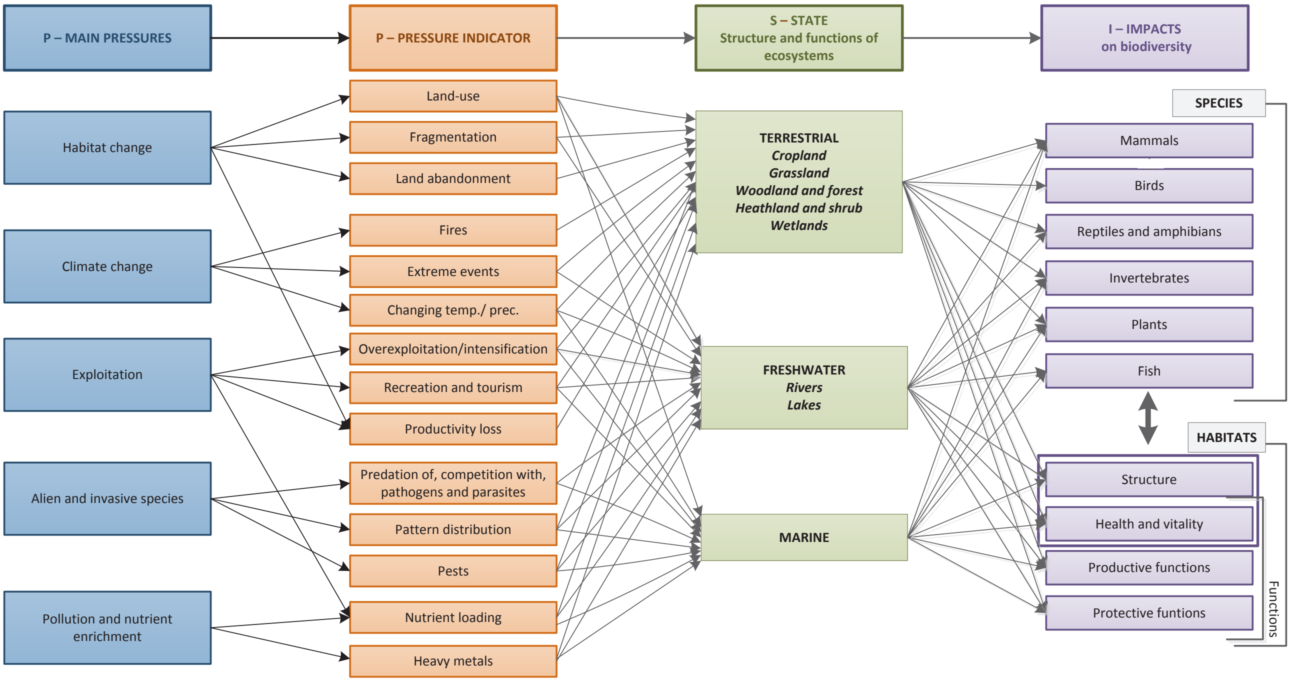
The implementation of the conceptual framework is triggered by the data available to assess and map pressures, ecosystem conditions, and impacts on their functional capacity across Europe for land, freshwater and marine areas. The assessment requires integration of a wide range of information, namely spatial data sets, indicators and statistics, and addresses different

Figure 2.4 Main building blocks for mapping and assessment of ecosystem condition and the impacts on biodiversity



Note: Ecosystem services, response, and drivers are not an object of this assessment — see Section 1.2.

Figure 2.5 Illustration of linkages between pressure and the condition of ecosystems



Note: Each main pressure is represented by one of several pressure indicators. For clarity, less important links are not presented.

Source: ETC/SIA, 2014a.

environmental sectors, including air quality, climate change, land cover, land/sea use, agriculture, forestry, water and marine, and nature protection. Additionally, reference data, e.g. climate, elevation and soil, are also needed in addition to data from other sources, namely from earth observation tools and modelling. The categories of information to be integrated include:

- data attributed to main land/sea cover and land/sea use classes, such as disaggregated statistical and other non-geo-referenced information;
- up-scaled, extrapolated, generalised local studies and experiments;
- process-based modelling results and extrapolated point measurements;
- quantitative and qualitative relationships between environmental pressures and ecosystem condition (indicators) and vice versa;
- expert-based quantitative and qualitative assessments mainly on the level of impacts of major pressures on ecosystem function.

Data sets usually have to be linked in order to produce indicators that, in their combination, provide information on the pressures affecting ecosystem conditions. The main types of data to use in the assessment are listed in Table 2.1. A major challenge remains the combination of spatial information of pressures, terrestrial ecosystem conditions, and the linear elements of waterbodies.

The availability of data sets and indicators has been evaluated by the European Topic Centre for Spatial Information and Analysis (ETC/SIA) and documented in two reports and reference documents, which provide more detailed information on data (ETC/SIA, 2013a) and methodology (ETC/SIA, 2013b). Part of this information has been integrated into the second MAES report (Maes et al., 2014). The summary table in Annex 1 provides a first overview about the data sets documented in these reports.

New data from environmental reporting schemes, published in 2015, will complement current information — in terms of improving the current baseline of information, as well as allowing assessments of trends. The new 'State of Nature' report under the Nature Directives, and the second water basin management reporting cycle of the Water Framework

Table 2.1 Typology of data sets required for the pan-European ecosystem assessment

DPSIR	Spatial data system	Data for assessment elements	Gaps/comments
Pressure	Air pollution, deposition	LRTAP, NEC, AQ Directive: atmospheric concentrations of $NO_2/NH_3/SO_2/O_3$, air pollutant deposition	Point measures and models
Pressure	Land use/land cover and agro-forestry	Land use/land cover (LUCL) change, land and ecosystem accounting (LEAC), imperviousness, high-nature value (HNV) farmland, HNV forest area index, naturalness indicator, Capri model outputs, fragmentation, high resolution (HR) layers, imagery, ecosystem map	Coarse minimum mapping unit, gap in identifying small linear features
Pressure	Urban and impervious	Urban Morphological Zone (UMZ), Urban Atlas, imperviousness, green infrastructure	Coarse scale data, lack of green infrastructure data
Pressure/ condition	Statistical data and models	FAO statistics on crops, demography, Eurostat data	Reliable temporally, some spatial gaps exist
Pressure/ condition	Weather and climate	Atmospheric conditions: Relative humidity, distributed climatic variable, heat (energy) and water, annual temperature and precipitation changes, floods, droughts	Lack of historical (long-term) data related to climate change effects on ecosystems
Condition	Monitoring reporting obligations	Habitats Directive, Birds Directive, Water Framework Directive, Marine Strategy Framework Directive	Extrapolated observations from sites, expert knowledge, river basin management plans, interpolated and modelled data sets
Condition	Freshwater	ECRINS, Waterbase — rivers, groundwater, Urban Waste Water Treatment Directive (UWWTD), biology in lakes, hydrogeological map	Integration of linear elements (rivers) and groundwater information Delineation of wetlands and floodplains, gaps mainly in groundwater information
Condition	Marine and Maritime	Seabed habitats, sea regions, sea uses, good environmental status, pressures on fishing stocks, aquaculture production, invasive species, catch per unit effort (CPUE), chlorophyll, hazardous substances	Unavailability of harmonised MSFD reported data — expected to be available in 2015 Spatial gaps in available European data sets, e.g. EU Sea map
Condition	Soil and bedrock	Land use functions, e.g. substrate, nutrients and water supply, carbon content, erosion risk, compaction	Lack of clear connection between soil functions and biodiversity Lack of comparability
Condition	Elevation	EU DEM, landforms, e.g. aspect, water and gravitation processes	Gaps and inconsistencies in EU DEM (coastal areas)
Condition	Reference layers	EEA reference grids, biogeographic regions, maritime boundaries, imagery	Gaps in spatial coverage, lack of consolidated reference of coastline features, gaps in the extended grid to cover the marine EEZ areas, gaps in detailed knowledge on certain rivers, inaccuracy in certain biogeographic regions (lower data resolution)
Condition/ Impact	Biodiversity	Natura2000, EU Sea map, Nature Directives Articles 17 and 12 reporting, Waterbase, nationally designated areas (CDDA), Red Lists of species, European Nature Information system (EUNIS), habitat types, species assemblages, forest map, Morphological Spatial Pattern Analysis (MSPA), fragmentation, high-nature value farmland and forest area, invasive species	Gap in coverage of reported species and habitat data

Directive (WFD), will be available and may allow a first assessment of how biodiversity of terrestrial and freshwater ecosystems and ecological status of waterbodies changes over time. The first baseline report of the Marine Strategy Framework Directive (MSFD) will be available in 2015, providing an approach on how to assess ecosystems in the marine environment. The new Copernicus continental land service data (Corine 2012, thematic High Resolution Layers 2012) will provide data on trends in land cover change (Corine Land Cover update, new high resolution layers for imperviousness and forest), and also first data sets for waterbodies, wetlands and grassland. The update of the SEBI 2010 (EEA, 2010a), together with the other environmental indicators as listed in EEA (2013), and the forest ecosystem assessment report, are other important sources for the implementation of ecosystem assessments on a European level.

3 Implementation

In this chapter and in Chapter 4, an overview of the current state of mapping pressures, conditions, and impacts on ecosystems is provided, together with one thematic map per main pressure and condition as an example. This illustrates how the concept can be implemented but cannot deliver a complete picture about available data for mapping and assessment.

Due to its mandate and data availability MAES related mapping focuses on EU-27 Member States. If possible EEA and its ETCs extended mapping and assessment to all EEA member countries and collaborating countries.

3.1 Mapping the pressures

3.1.1 Drivers and pressures

Drivers induce pressures that affect the health of ecosystems, their biodiversity and, consequently, the ecosystem services they provide for human well-being at different spatial and temporal scales. This makes both their assessment and their management complex. Climate change may operate on a global or a large regional spatial scale; political change may operate at the scale of a nation or a municipal district. Socio-cultural change, inducing pressure change, typically occurs slowly on a time scale of decades — although abrupt changes can sometimes occur, i.e. in the case of wars or political regime changes, while economic changes tend to occur more rapidly.

As a result of these spatial and temporal dependences of drivers, the pressures that appear to be most significant, at a particular location and time, may not be the most significant over larger (or smaller) regions or time scales. The pressures exerted impact ecosystems and their biodiversity differently. Some pressures are widespread, e.g. air and water pollution that can affect ecosystems and their habitats over thousands of kilometres from their sources (e.g. acid rain and eutrophication). Other pressures, such as overgrazing, agricultural intensification and timber extractions, have more local impacts, e.g. local, partial, or total loss of biodiversity. A variety of factors put pressures on ecosystems and their biodiversity, and most of these factors can be traced directly or indirectly to human activity. The effects of human activity seriously alter many basic ecosystem functions. These pressures are exerted differently on different ecosystem types. For each driver, a series of data sets are identified to be included in the development of indicators on pressures.

Table 3.1 provides a list of pressures caused by the major drivers of environmental change and affecting ecosystem types. In Europe, land-take, land fragmentation and land-use changes are direct pressures affecting all types of ecosystems — whereas other pressures are specific to certain ecosystems (e.g. the building of dams in rivers blocking water flow, or deep-sea resource exploitation in marine ecosystems).

From the five major groups of pressures, **habitat change** is the pressure causing direct degradation or loss of ecosystems and habitats at local levels. It primarily aims to address land cover change-related processes. Habitat change is considered the major cause of biodiversity loss, leading to total or partial destruction or removal of habitats and replacement by other habitat types (land-cover change). It also decreases habitat quality by increasing soil erosion and soil degradation, as well as land abandonment, which also replaces habitats and, consequently, further impacts biodiversity. In addition, ecosystem changes modify the structure and function of habitats, which increases the vulnerability of populations of plants and animals to local extinction — due to hampered migration and dispersal because of destruction, fragmentation or degradation of their habitats. The main drivers of habitat degradation and loss are land-take. Around half of Europe's land area is farmed, most forests are exploited, and natural areas are increasingly fragmented by other land use, i.e. mainly urbanisation and infrastructural development (EEA, 2010b).

Most of the relevant information for developing pressure indicators is available to support the development of ecosystem-specific indicators of the change in the extent of ecosystems and the changes in conservation status of species and habitats. The most important data set for habitat-related pressures at the European level is the operational Corine Land Cover

Table 3.1 Pressures of ecosystem change they exert on biodiversity

Ecosystem type	Major pressures of ecosystem change				
	Habitat changes	Climate change	Invasive alien species	Land/sea use or exploitation	Pollution and nutrient enrichment
Urban	Land-take, landscape fragmentation due to urban sprawl and roads around cities, channelling of rivers in urban areas	Extreme events: droughts, floods, fires, heat waves, sea-level rise in coastal cities	Expansion of alien species, introduction of exotic species in gardens	Non-intensive use of land due to low density populations and jobs, lack of appropriate management of recreation areas, gravel extraction around cities, over-exploitation of extraction of groundwater resource and freshwater	Contaminated soil by heavy metals due to industrial activities, air pollution and critical level of ozone, pollution of water caused by poor waste water management, sludge and waste
Cropland	Land-take, landscape fragmentation, agricultural intensification (structural changes)	Changes in monthly temperature and precipitation, extreme events, fires	Expansion of invasive alien species	Agriculture intensification, loss in cropland productivity, abandonment	Fertilisers and pesticides, critical levels of ozone, nutrient enrichment
Grassland	Landscape fragmentation, land abandonment, land-take, habitat loss	Changes in monthly temperature and precipitation, extreme events, fires	Expansion of invasive alien species	Agricultural intensification, (over-)harvesting, high irrigated land use, overgrazing, abandonment	Fertilisers, nutrient run-off, critical levels of ozone, heavy metals
Woodland and forests	Land-use change: conversion to agriculture, urbanisation, changes in forest pattern, fragmentation due to roads, land use changes — forest isolation, land-take	Changes in monthly temperature and precipitation, fires, extreme events, drought, frost, fires, floods, storms	Fast-growing invasive alien species, e.g. Phytophthora disease	(Over-)exploitation of timber and non-wood products, felling, recreation and tourism, game hunting and (over-) grazing	Nitrogen enrichment, acidification, air pollution and environmental contamination, heavy metals, critical levels of ozone
Heathland and shrub	Land-use change, landscape fragmentation, land-take, land abandonment	Extreme events, fires	Fast-growing invasive alien species, e.g. Phytophthora disease	Lack of appropriate site management, recreational and urban disturbance	Nitrogen enrichment, critical levels of ozone, water drainage, heavy metals
Sparsely vegetated land	n/a	n/a	n/a	n/a	n/a
Wetland	Land-take, fragmentation, drainage for agriculture, reed harvest	Extreme events, drought, floods, changes in rainfall	Introduction of invasive predatory fishes, non-predatory fish, plant species as Hydrocotyle ranunculoides and Azolla filiculoides	Blocking and extraction of water inflow, over-exploitation of groundwater resources, (over-)fishing, water extraction, reed harvest for biofuels, constructed wetland	Eutrophication, pesticides, acid rain, heavy metals, critical levels of ozone, plastic

Table 3.1 Pressures of ecosystem change they exert on biodiversity (cont.)

Ecosystem type	Major pressures of ecosystem change				
	Habitat changes	Climate change	Invasive alien species	Land/sea use or exploitation	Pollution and nutrient enrichment
Rivers and lakes	Modification of water courses, channelling, river regulation regimes, fragmentation (dams)	Changes in monthly temperature and precipitation, extreme events, average river flow, droughts, floods	Invasive alien fish farm species	Water extraction (including groundwater), overfishing, fish farms, gravel extraction	Pollution, acid rain
Marine ecosystems: marine inlets and transitional waters, coastal, shelf, and open ocean	Coastal land-take (tourism development)	Sea (surface) temperature, sea-level rise	Expansion of invasive alien species	Offshore activities, over-fishing, exploitation of oil and gas, aquaculture production	Eutrophication, heavy metals, fertilisers and pesticides, chemical pollution from industries and shipping

Source: ETC/SIA, 2013b.

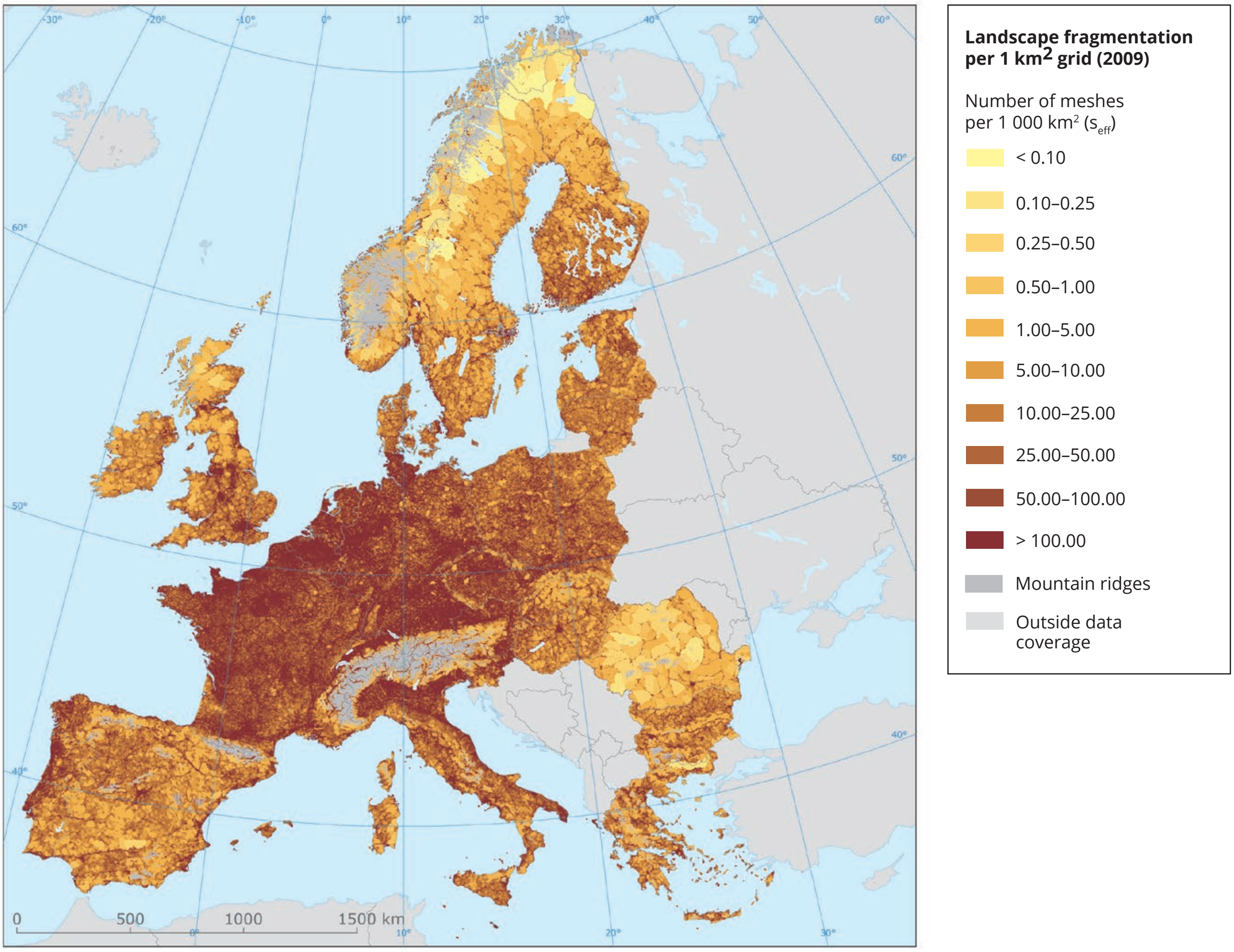
monitoring system for terrestrial ecosystems, which provides regular information about changes in land cover/land use including ecosystem size. Copernicus High Resolution Layers will provide more-detailed information on the changes in some land-cover classes, e.g. imperviousness and forest, and will improve the baseline for monitoring grassland, wetlands, waterbodies and riparian areas ([1]). In parallel, the information on trends in habitat quality from Art.17 of the Habitats Directive provides important information — which is not specific on structural changes only, but also covers a full spectrum of pressures for a selection of species and habitats. For terrestrial fragmentation, only a baseline data set and no change detection is currently available, which limits the assessment of fragmentation as pressure. Phenological data and indirect indicators, such as loss in soil production by land cover change, or pests and diseases, provide more information on habitat change.

For freshwater, data on dams and measures to increase flow rates in rivers, are the main source of information of habitat fragmentation and loss. Apart from freshwater dam data, other data especially for construction and regulation measures in river beds (hydromorphological data) is currently limited.

Marine sea use for energy production, aquaculture, mining, and the use of sediments are important pressures on water and seabed habitats, which currently are not mapped systematically for assessments on a European level.

([1]) http://land.copernicus.eu/pan-european.

Map 3.1 **Landscape fragmentation per 1 x 1 km² grid from human-made barriers for the year 2009**



Note: Data are missing for Iceland, the Balkan countries, Turkey, the Azores and Madeira.

Source: EEA/FOEN 2011.

An overview of the available data sets is listed in Annex A2.1, and Map. 3.1 show how fragmentation by infrastructure and other human-made barriers affect ecosystem structure and function across Europe.

Climate is an integrated part of natural conditions, and thus, directly, or indirectly, affects all dimensions of biodiversity. The second major pressure, anthropogenic **climate change**, causes changes in the life-cycles of many European plants and animals, including frog and fish spawning, bird nesting, the arrival of migrant birds and butterflies, and earlier spring phytoplankton blooms, pushing them to move northwards and uphill (EEA, 2012). It also creates risks of decoupling food-webs and changes in predator-prey interactions. Extreme events, such as floods, droughts, and fires, also change the health and characteristics of habitats and species.

Several indicators are available from various European institutes and projects, but the quality of the indicators is heterogeneous, especially for describing changes over time. Another issue is the quantitative attribution of observed climate change to its impacts on habitats and species. The ESPON Climate Project has developed a series of climate change indicators (ESPON Climate, 2011). The indicators of regional sensitivity to climate change provide information about the levels of: environmental sensitivity (e.g. protected natural areas; soil organic carbon content and the propensity of soil erosion and forest fires); economic sensitivity (e.g. climate sensitive economic sectors, namely forestry, agriculture, tourism, and energy production); physical sensitivity (e.g. settlements, roads, railways, airports, harbours, refineries, and thermal power plants); and social sensitivity (e.g. location, age, distribution, density and size of urban areas).

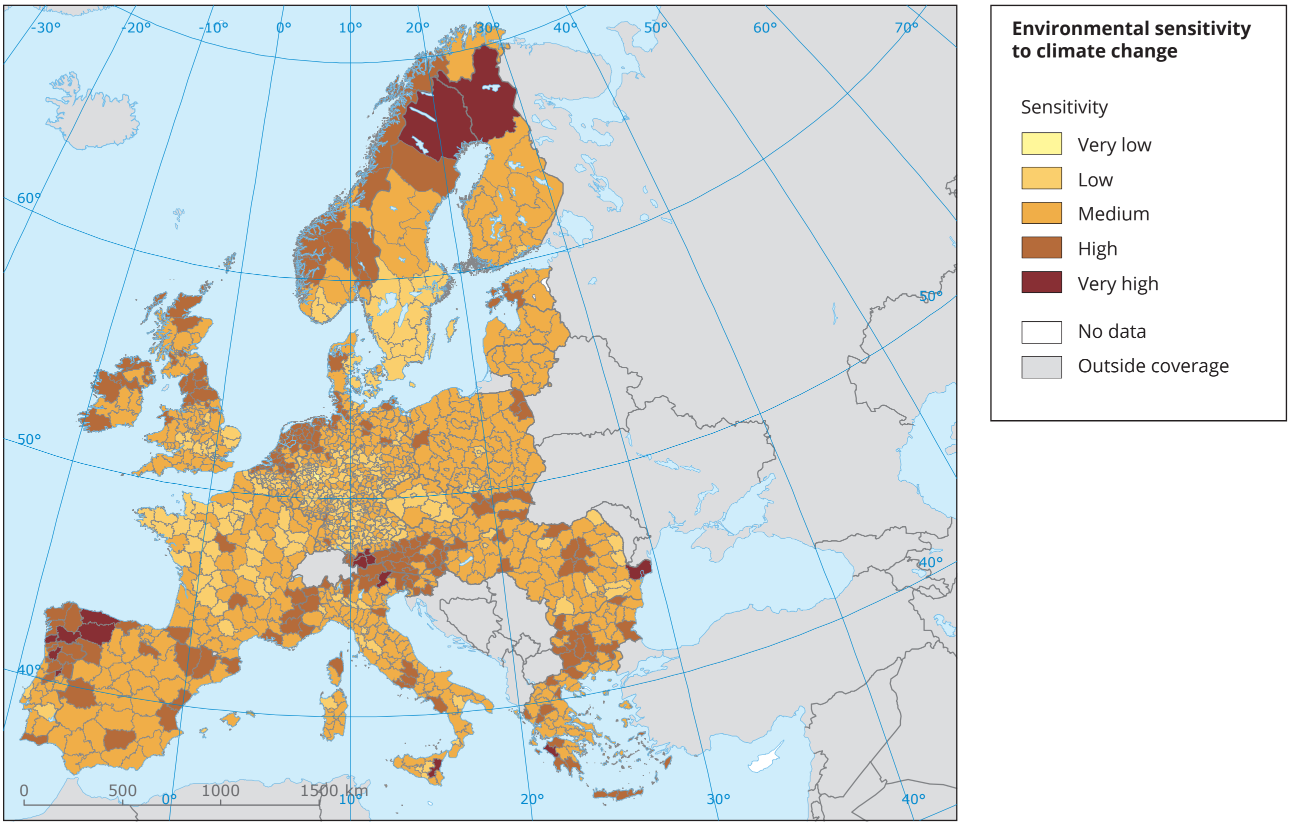
As ecosystem assessments currently address mainly impacts on biodiversity, the use of the ESPON climate indicator developed on environmental sensitivity of European regions to climate change, can be used in the assessments of terrestrial and freshwater ecosystems (Map 3.2). For certain ecosystems, additional information is available to produce ecosystem-specific indicators, such as the European Forest Fire Information System (EFFIS) database of the JRC ([2]) that provides observed temporal series on forest fire densities. Fire is not only linked to climate change but also partly to natural conditions, especially in the Mediterranean area, and is often induced by direct human impact. Other important data sets are coastal storms, floods and droughts as listed in Annex A2.2. Floods are important for both terrestrial ecosystems, mainly riparian areas, and the freshwater bodies. For marine ecosystems, sea surface temperature and acidification are important climate change-related pressures to consider in the further assessment.

Another approach to assess climate change impacts would be the direct use of climate data (EEA, 2012). In this case, it requires separate sensitivity analyses of habitats and biodiversity for temperature, precipitation and humidity impacts, in their various combinations, for changes in average and extreme events in time. The EEA hosts and maintains an overall list of currently 46 indicators related to climate change and its impacts on terrestrial, freshwater and marine ecosystems (EEA, 2013). It also includes impacts on cryosphere, soil, and covers aspects such as plant and fungi phenology, species interactions, and water requirements for irrigation.

Invasive alien species replace native species, occupying their habitats, often degraded, leading to change in their survival and abundance. Invasive alien species may drive local native species to extinction via competitive exclusion, niche displacement, or hybridisation with related native species.

Therefore, alien species invasions may result in extensive changes in the structure, composition and global distribution of the biota, with severe impacts on habitats, leading ultimately to the homogenisation

Map 3.2 Environmental sensitivity to climate change in Europe



Source: ESPON Climate, 2011.

([2]) http://forest.jrc.ec.europa.eu/effis/about-effis/technical-background/european-fire-database.

of fauna and flora and the loss of biodiversity. This pressure affects all ecosystem types in Europe.

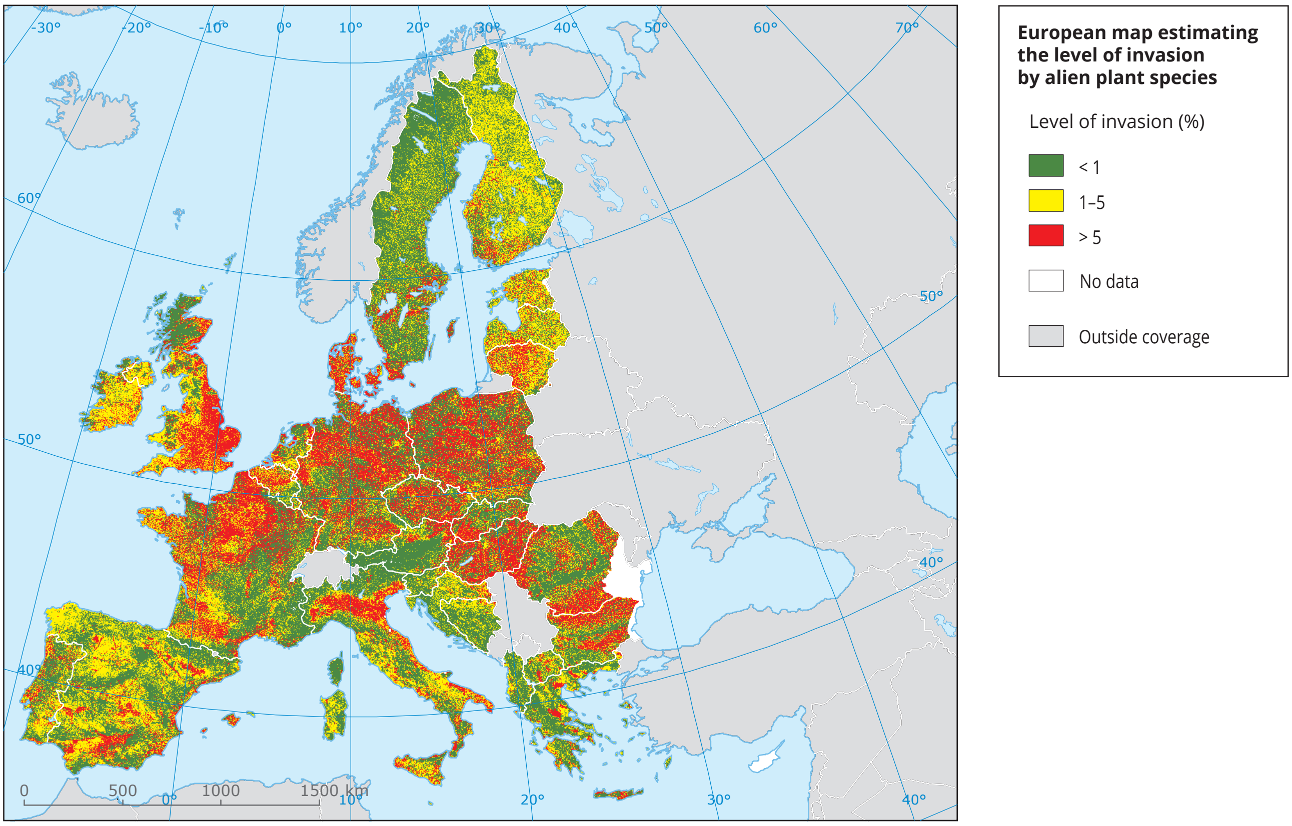
At the European level, Chytrý et al. (2009) developed a map estimating the level of invasion of alien plants in Europe. The level of potential invasion of plant species can be seen in Map 3.3 . It is based on observed alien species in vegetation plots distributed over different habitats. This information was extrapolated by relating it to the respective Corine Land Cover classes that are favourable for the alien species. This information is relevant for use as a risk assessment map of invasions from alien plant species in Europe.

The map shows that the predicted level of invasion is different across Europe, and it assigns high predictions in the temperate zone of Western and central Europe, mainly in agricultural and urbanised areas. The assessment is based on number of alien species and does not consider their abundance. For this reason, individual neophytic species, which are extremely successful in occupying new habitats are not well represented in this map. More information will be available due to the reporting scheme of the recently established EU Regulation on Invasive Alien Species (EC, 2014b) (see Annex A2.3).

Land/sea use or exploitation indicates the use of ecosystems mainly for the production of food and fibre. The intensity of land use by management has already severely impacted habitat quality and biodiversity. Together with habitat change, it is the most important pressure on biodiversity, mostly triggered by local management. Overexploitation is the result of unsustainable management practices that lead to irreversible depletion of natural resources, and is a major threat for biodiversity. It includes overgrazing grasslands, overharvesting forest ecosystems, and overfishing freshwater and marine ecosystems.

There is quite a variety of information accessible to map the pressures on ecosystems resulting from human management activities (Annex A2.4). A good amount of information is available to address terrestrial ecosystems, especially the use of croplands, grasslands, and woodlands. It comprises all harvesting data (agricultural and forest statistics) and land use/land management-related pressures such as irrigation and processes affecting soil quality. Map 3.4 provides an example of a composite indicator using yield statistics and nitrogen fertilisation as proxy to assess intensity of land use for croplands.

Map 3.3 European map estimating the level of invasion by alien plant species



Source: Chytrý et al., 2009.

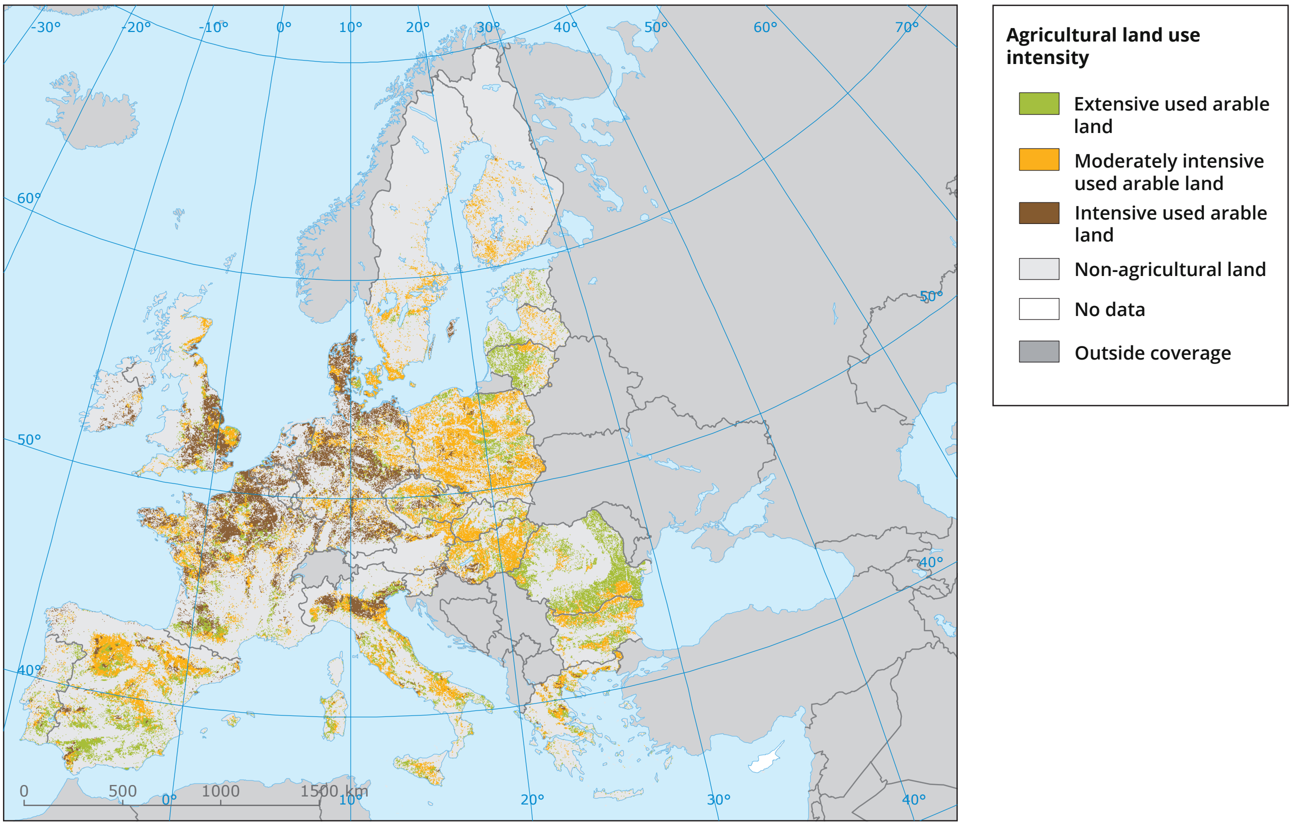
So far no adequate data seems to be available for freshwater on a European level, which would mainly include fishing, navigation, irrigation, water collection or energy production. The water exploitation index (EEA indicator CSI018/WAT 001 ([3])) together with information on quantitative status of ground water (WFD) will provide additional information on freshwater use.

Information available to assess overfishing in European seas is still scarce, as it is reported using different methods for different European sea regions. The use of available information is explored in a study on fish accounts (EEA work in progress).

Pollution and nutrient enrichment implies two main types of pressures. First, there are direct effects, mainly by agricultural and forest-related land use, and management effects comprising of fertiliser, manure and pesticide inputs for production, varying at local scales. The second major pressure is the intake of nutrients and pollution by air pollution, and deposition, with effects on regional and continental scales. Damages occur when excessively harmful components are introduced into an ecosystem, exceeding the capacity of the ecosystem to maintain its natural balance and, particularly, the effects of inputs of nutrients, pesticides, microbes, industrial chemicals, metals and pharmaceutical products, which ultimately end up in the soil, or in ground water and surface water (MA, 2005; EEA, 2010b). Pollution and nutrient enrichment change the characteristics of soils, thereby changing the biodiversity, i.e. habitats and species, causing biodiversity loss and ecosystem dysfunction, altered plant and animal communities, loss of species, and other harmful ecosystem changes.

Map 3.5 shows the exceedance of critical loads for eutrophication due to the deposition of nitrogen for the time period from 1980 until 2030, using the CSI indicator 005 (EEA, 2013; EEA, 2015). It can be used to assess the pressures on ecosystems from long-range air pollution. The critical load of the nutrient is defined as 'the highest deposition of nitrogen as NO_x and/or NH_y, below which harmful effects in ecosystem

Map 3.4 **Land management intensity of croplands derived from crop statistics and related nitrogen application**



Source: ETC/SIA, 2014a.

([3]) http://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources/use-of-freshwater-resources-assessment-2.

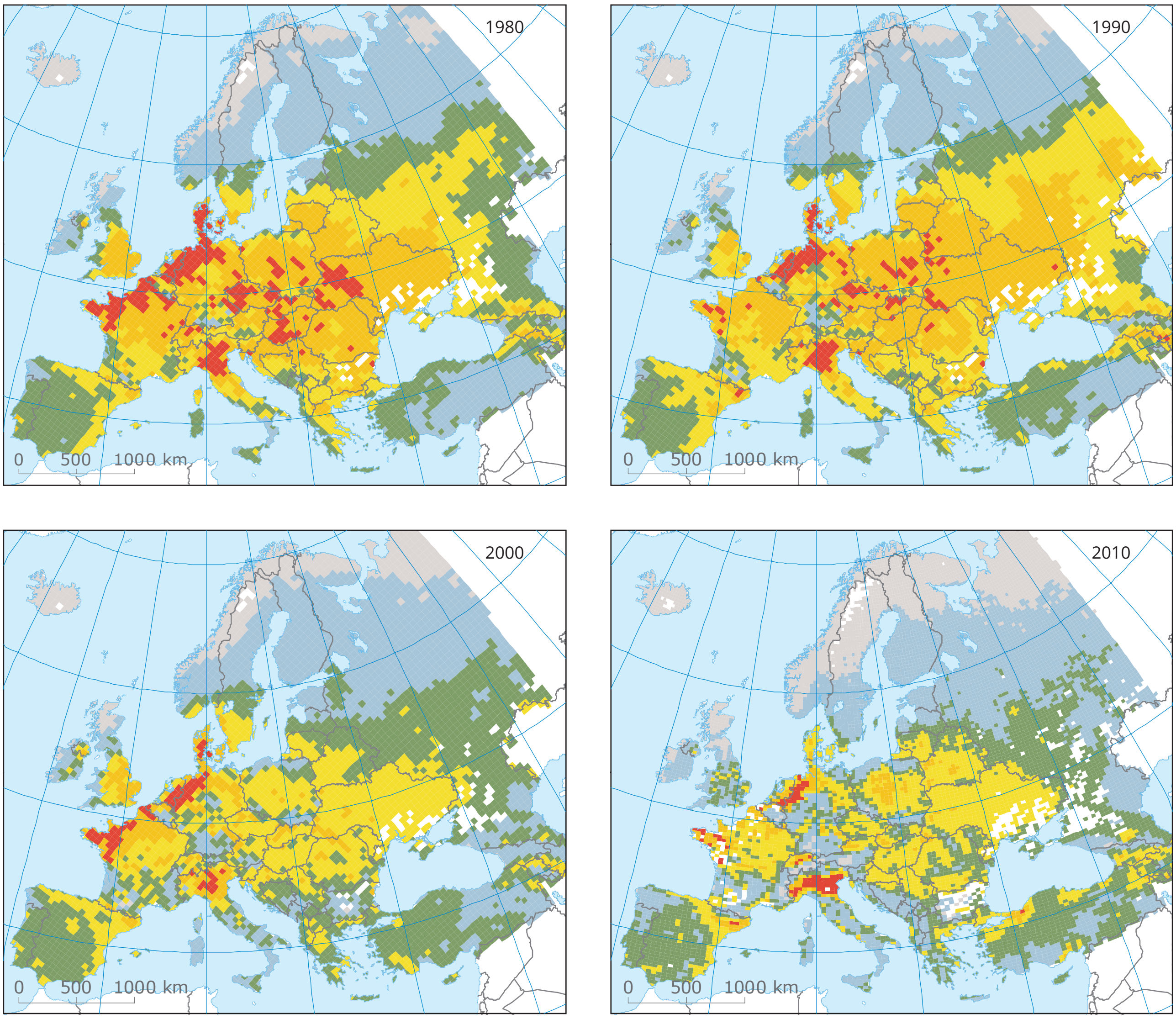
structure and function do not occur — according to present knowledge'. Statistical data for fertiliser and pesticide input, which are closely linked to land-use pressures, as well as data for other air pollutants, are available for mapping.

For freshwater and marine ecosystems, data for point sources are available from the Urban Waste Water Treatment Directive (UWWTD). Nutrient and pollution from non-point sources requires modelling of the very complex interrelationships between freshwater bodies and surrounding terrestrial ecosystems. Therefore, this pressure is assessed by water-quality monitoring, which is linked to conditions as described further below.

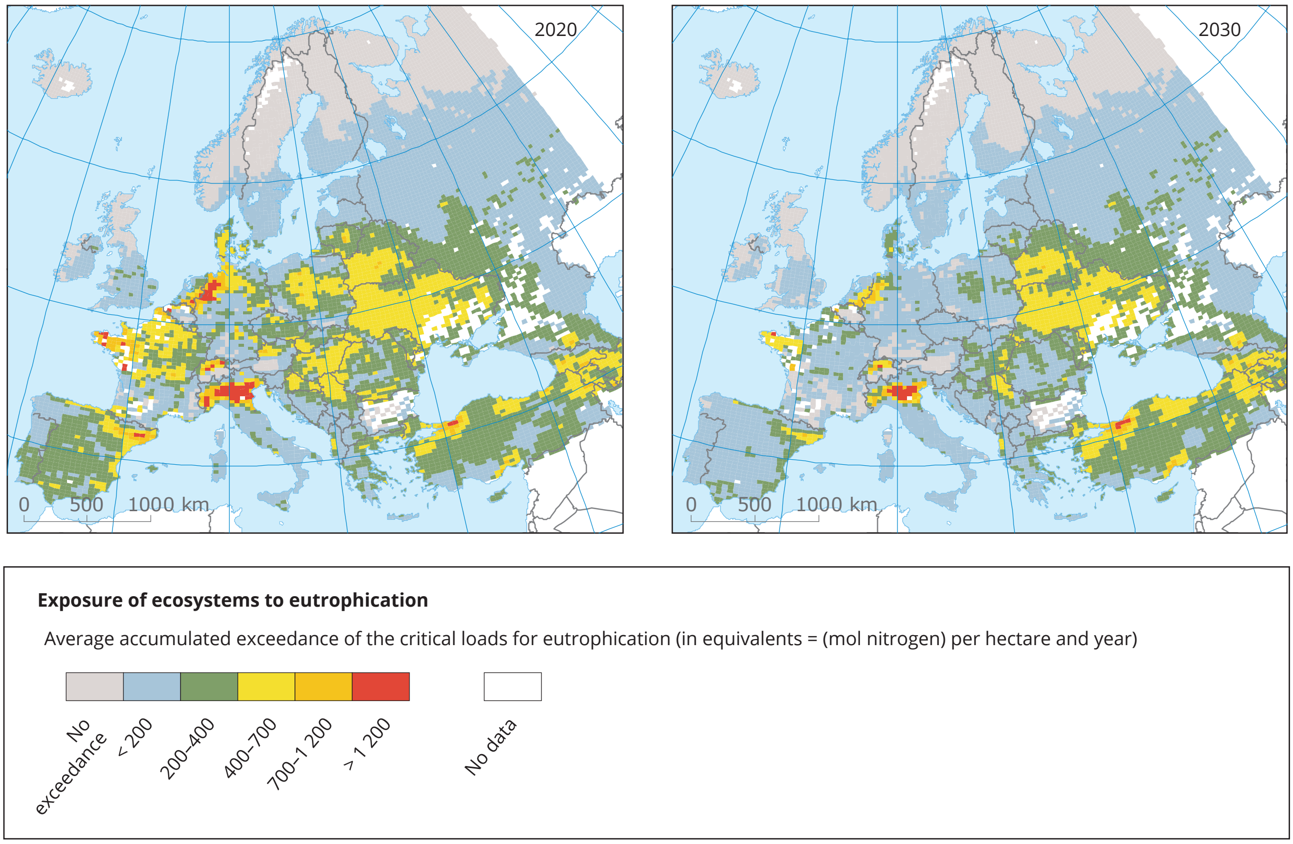
For marine ecosystems, additional data describing pollution from accidents (oil spills) and marine litter disposals are available. Information is summarised in Annex A2.5.

3.1.2 Mapping cumulative effects of pressures and

Map 3.5 Exceedance of nutrient critical loads for eutrophication due to the deposition of nitrogen for the time period 1980 until 2030



Map 3.5 Exceedance of nutrient critical loads for eutrophication due to the deposition of nitrogen for the time period 1980 until 2030 (cont.)



Note: Exceedance of critical loads for the most sensitive ecosystems provided by Coordination Centre for Effects (CCE).

Source: EEA, 2015.

trends

Different spatial and temporal gradients of main pressures (each represented by a number of indicators) result in a complex pattern of factors affecting ecosystems, their habitats and biodiversity. As outlined, the pressures can be mapped and assessed individually to reflect potential measures and policy areas, such as nature protection, agriculture, forestry and territorial cohesion.

Pressures of the same type, with the same units, can be simply added up as shown in Map 3.6 for croplands and managed grasslands (agro-ecosystems), even if the calculation of individual pressures is rather complex. In this case, nitrogen input was derived from the nutrient accounts (ETC/SIA, 2013b). The total nitrogen input to agricultural soils includes intentionally applied fertilisers (organic or mineral), manures from grazing livestock, biological nitrogen-fixation and atmospheric deposition.

In general, ecosystem assessment should provide information about changes over time, because it is very important to know the observed trend that led to the current condition, which is the baseline for decisions on measures to mitigate future trends.

If sufficient data are available, time series of observed trends of pressures can be mapped (as already indicated in Map 3.5 for critical loads of nitrogen), which allows spatially-explicit interpretations of the current conditions of ecosystems and expected trends in the near future. Map 3.7 provides an overview on the changing trends in nitrogen input in cropland and grassland ecosystems as average changes over 2000–2005, compared to the reference year 2000. The local patterns of changes, such as those illustrating positive and negative trends in areas that are geographically close to each other (e.g. the Po valley in Italy or the Galicia region in Spain), illustrate the importance of spatially-explicit mapping and assessment.

A second option is to combine pressures with different dimensions to show the cumulative effects and their variations across Europe. In this case, the values have to be re-scaled and combined, either by summing up, equally weighting, or weighting individual pressures according to their relative importance for ecosystem functioning. This method can be applied to map any combination of pressures, independent from their gradient and number, but only qualitatively at the cost of quantitative assessments. This assessment option requires the involvement of mostly regional expertise in the weighting process to be assigned for the individual pressures, depending on their relative contribution to the cumulative effects of pressures on ecosystems. Figure 3.1 illustrates the approach with a flow-chart on how to perform the assessment.

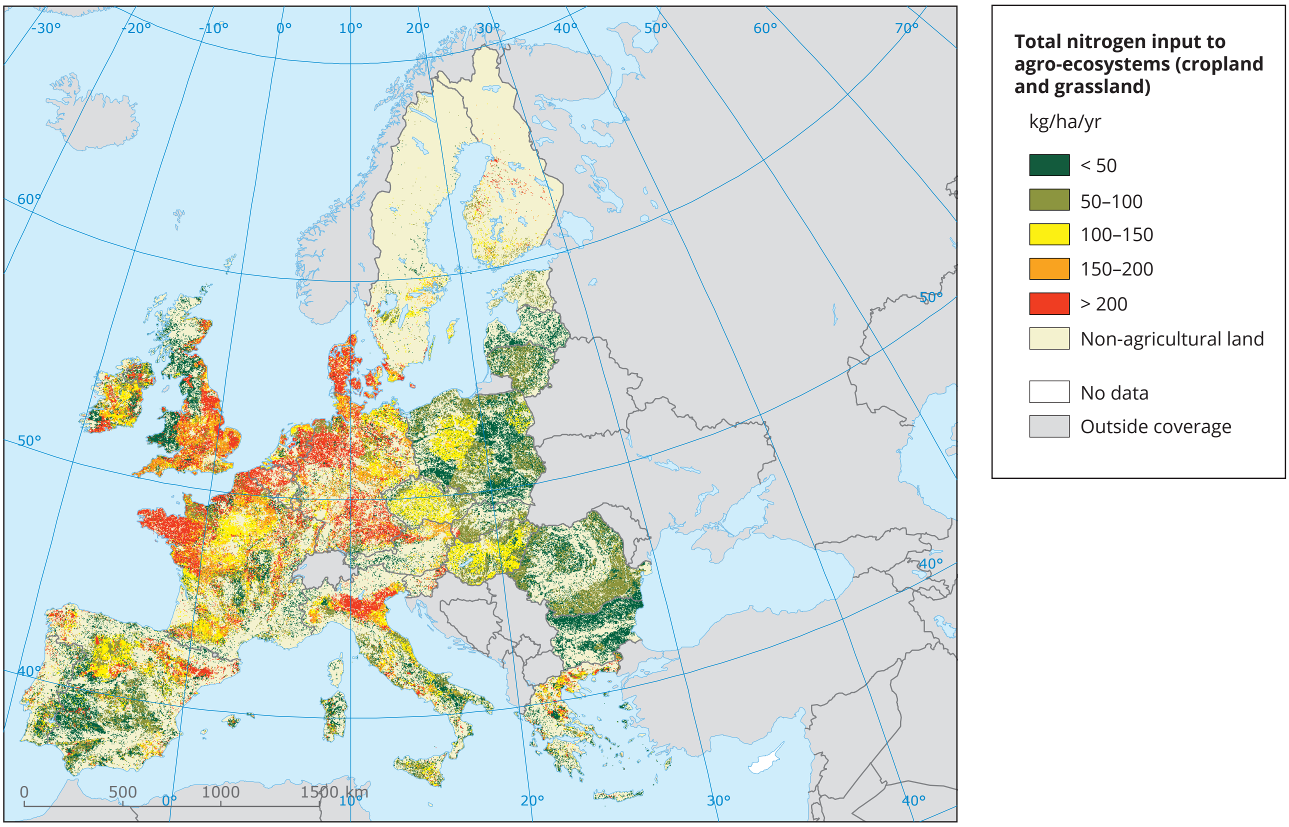
Map 3.8 provides an example of mapping cumulative pressures induced by land management for the ecosystem type 'cropland'. The basic assumption for indicator development is that arable cropping is only beneficial to biodiversity when it is implemented by low intensity management.

To assess the intensity of arable land management, two main aspects are considered:

- the 'input' side (M1) of the management practices reflected by the use of fertilisers, the variety of crops and irrigation;
- the 'output' side (M2) represented by the yield produced on a particular area of land.

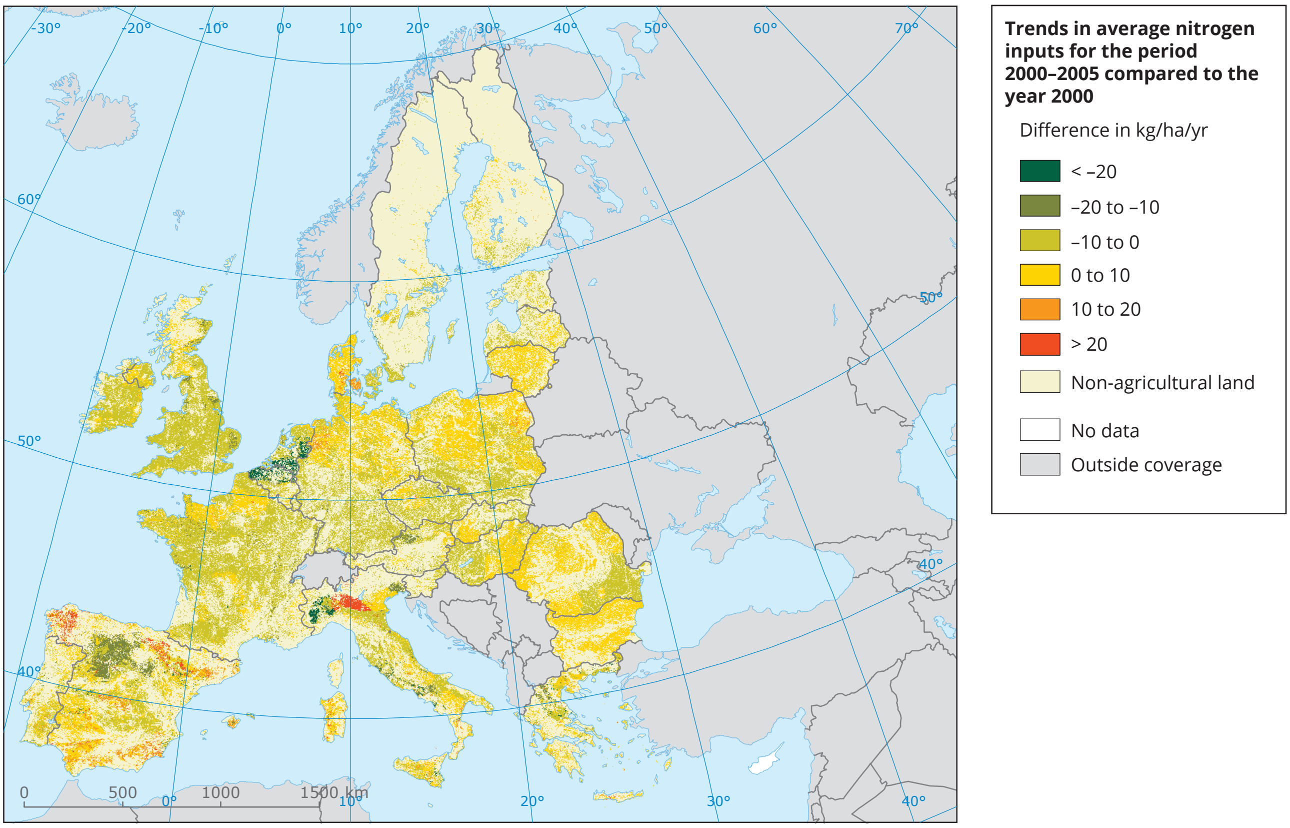
The arable crop index developed by the JRC (Paracchini and Britz, 2010), consists of two aspects — fertiliser input and diversity of crops, in one indicator. To measure farmland management intensities, the arable crop index uses the sum of manure and mineral nitrogen applied per hectare. Crop diversity contributes to the indicator with the assumption that the richer the crop composition and the more equal the shares, the better for biodiversity. The index ranges from 0 (highly-intensive management, e.g. mono-cultures and high fertiliser use) to 100 (biodiversity-friendly management, e.g. rich crop diversity and little fertiliser use).

Map 3.6 Total nitrogen input to cropland and managed grassland (agro-ecosystems) for the year 2010



Source: ETC/SIA, 2014a.

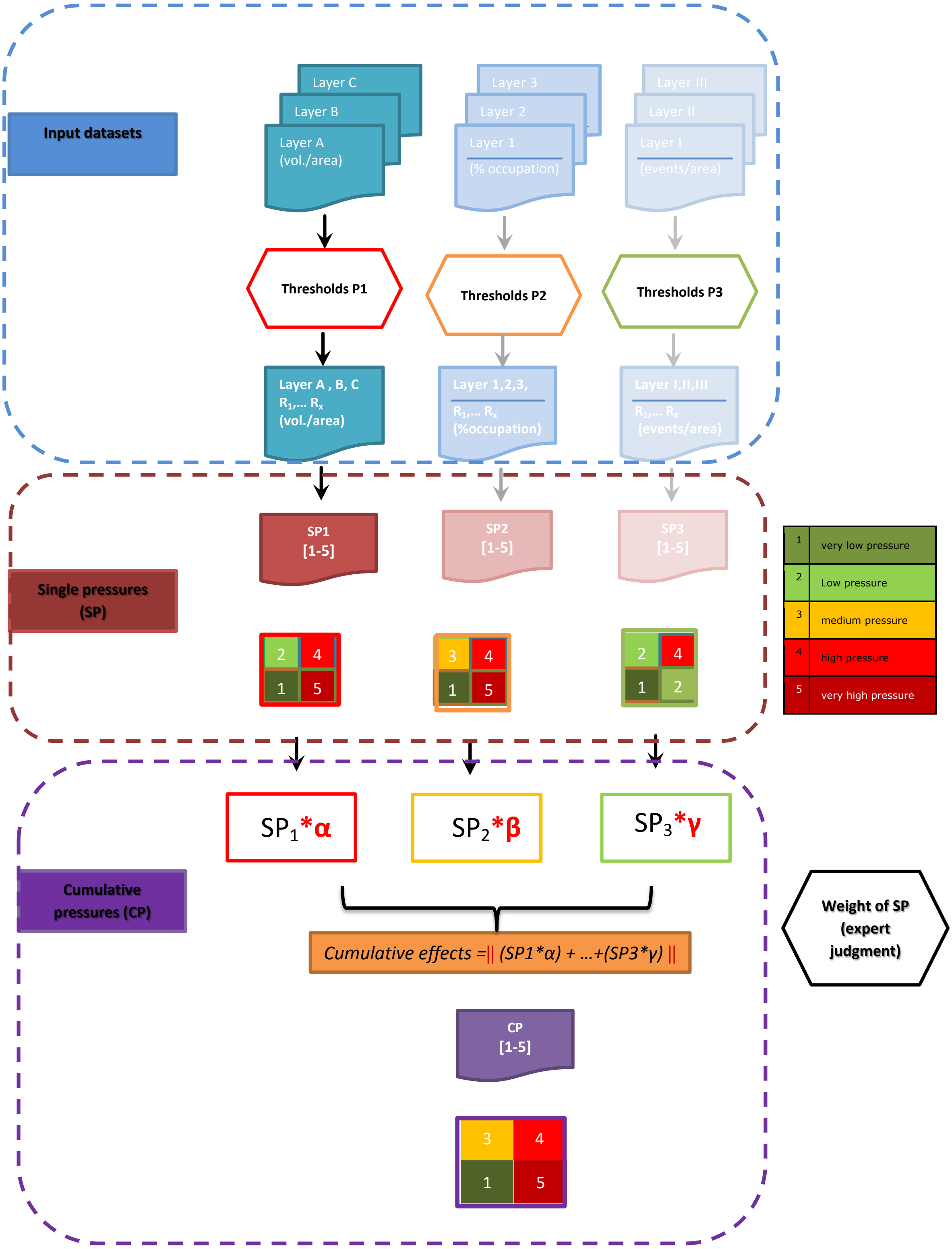
Map 3.7 **Trends in average nitrogen inputs to cropland and managed grassland (agro-ecosystems) for the period 2000-2005 compared to the year 2000**



Source: ETC/SIA, 2014a.

The arable crop index is then further combined with information on irrigation. According to the FAO (FAO, 2002), the highest crop yields that can be obtained from irrigation are more than double the highest yields that can be obtained from rain-fed agriculture. Therefore, the presence of permanent irrigation structures are also considered as an indicator of more intensive land-management practices. The arable crop index, combined with irrigation structures, is interpreted as the 'input' side of agricultural land-use management. The 'output' side of agricultural land use management is represented by crop yield averaged by crop type over a period of 11 years and normalised by biogeographic region, to account for the natural differences in absolute yield differences in different parts of Europe. The yield values are classified by quantile method into three classes (see Map 3.8).

Figure 3.1 **General approach used for the development of single pressure and cumulative pressure indicators based on input data sets to assess the major pressures affecting ecosystems under each driver of change**



Source: ETC/SIA 2014a.

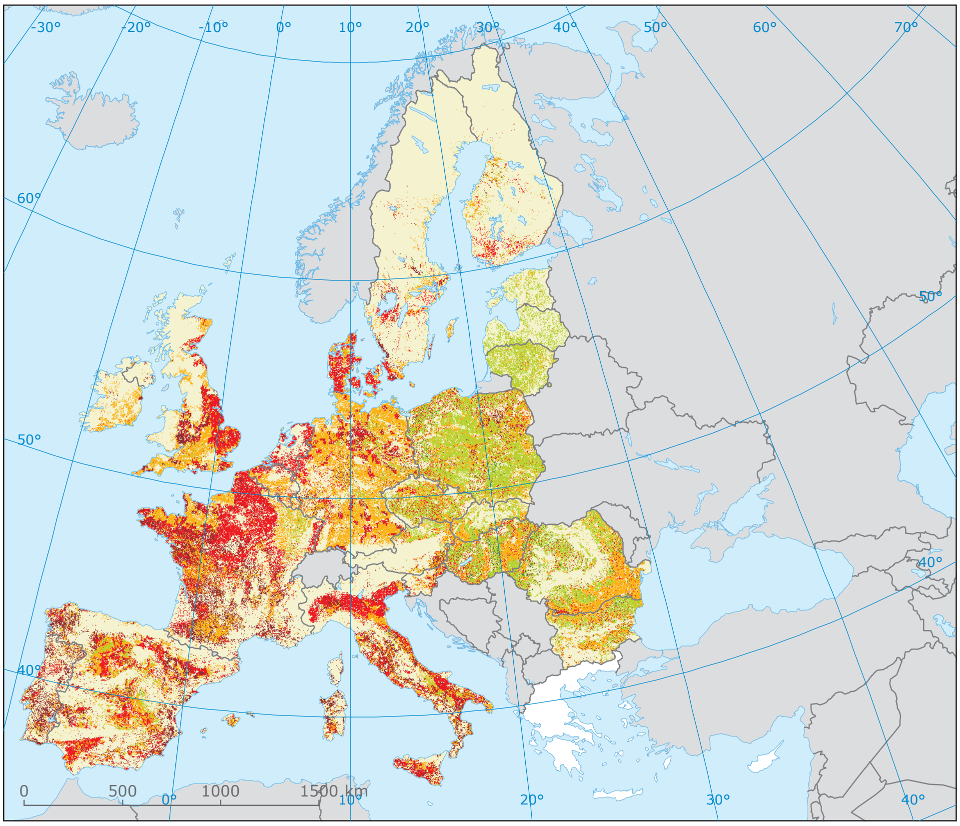
3.2 Mapping ecosystem conditions

Ecosystem condition is mostly the product of two major factors: the natural conditions and the anthropogenic pressures. Climate, soil, elevation, slope, aspect and other natural environmental parameters, determine the natural or potential conditions of ecosystems. Anthropogenic pressures, for example due to land use, management and air pollution, further affect ecosystem conditions. The combination of both the natural conditions and the anthropogenic pressures describes the effective capacity of ecosystems to deliver services, including their habitat quality and biodiversity.

3.2.1 Mapping ecosystem distribution

Ecosystems need to be mapped spatially and explicitly in order to develop an understanding about their natural condition and the pressures to which they are exposed. The definition and spatial delimitation of Europe's ecosystems is key for the identification of the condition and trends of ecosystems across Europe. Mapping ecosystems provides information about their delineation and distribution following an agreed ecosystem typology.

Map 3.8 Aggregated indicator for management intensity pressure on cropland (arable land) as combination of land management (fertiliser and irrigation) and crop yield



Note: The input and the output side are combined in a 3 x 3 matrix and classified in five classes:

- in dark green: very low input and output (very low management intensities and very low output)
- in light green: input lower than output
- in orange: combination of medium input and output
- in red: input higher or equal than output (medium to high management intensities)
- in dark red: input side higher than output (very high intensities but medium to low output)

11	12	13
21	22	23
31	32	33

1st character = input intensity (1 = very low)

2nd character = output intensity (1 = very low)

Source: ETC/SIA, 2014a.

The MAES Working Group agreed on a set of ecosystem types, combining Corine Land Cover (CLC) classes for spatially-explicit mapping with the non-geo-referenced European Nature Information System (EUNIS) ([4]) habitat-type categorisation. Such a typology allows the integration of national and local classifications that vary across Europe and, at the same time, make use of existing data to delineate ecosystems at European scale.

A practical approach to the 'spatial delimitation of an ecosystem' is to build up a series of overlays of significant factors: the location of discontinuities (e.g. in the distribution of communities of organisms); the physico-chemical environment (e.g. soil types, drainage basins, and depth of a waterbody); and the spatial interactions (e.g. home ranges, migration patterns and fluxes of matter). A useful ecosystem boundary is the place where a number of these relative discontinuities coincide. Ecosystems, within each category, share a suite of biological, geophysical and biochemical conditions, climatic conditions, species composition and interactions, and socio-economic factors — namely, the dominant uses by humans that tend to differ across categories.

The typology categorises the main EUNIS classes under three groups: terrestrial, freshwater, and marine ecosystems. It links MAES level 2 ecosystem types with EUNIS level 1 habitat classes (see Box 2.1) as the basis of the ecosystem mapping approach. When a better regional differentiation was possible, EUNIS level 3 was used. The typology development considers CLC classification (levels 1, 2, 3), and relates it to the EUNIS habitat types level 2 classification.

This typology was geometrically refined by enhancing the current CLC units using high resolution layers, and the European catchments and Rivers Network System (ECRINS ([5])) waterbodies. In parallel, a cross between the EUNIS and the CLC was created to relate their nomenclatures — where a CLC class may be linked to multiple EUNIS classes and vice versa. Thematic refinement was developed to link spatial environmental data sets with the highest possible accuracy in Europe, and to establish a set of knowledge rules to attribute at the level of each habitat.

The resulting map (Map 3.9) does not provide the exact location of habitats but informs about the spatial and thematic probability of presence of habitats across Europe. The detailed methodological approach for the development of the pan-European ecosystem map is documented in ETC/SIA (2014b).

The resulting cross-scheme is the basis for spatial re-aggregation of combined EUNIS land cover units into broad-scale ecosystems suitable for European ecosystem assessment at 1 x 1 km^2 grids in line with INSPIRE specifications. This spatial re-aggregation allows the integration of additional information on the presence, nature, and key quantitative values of ecosystems, from different sources, into each EEA 1 x 1 km^2 reference grid cell.

The typology includes urban, croplands, grasslands, woodland and forests, heathland and shrubs, freshwater (rivers and lakes), wetlands, coastal (including coastal lagoons and marine inlets and transitional waters) and marine ecosystems. However, urban ecosystems are not yet considered and are not included in this report but will be addressed in the MAES Working Group. Sparsely-vegetated land is not addressed either, as this type is not covered by specific data sets and is less relevant for ecosystem service assessments. The resulting map of ecosystem typologies (Map 3.9) is the baseline on which to proceed with assessing condition and pressures.

The terrestrial part of the current version of the ecosystem map is mostly based on Corine Land Cover data. Due to the specification of the map, especially the minimum mapping unit of 25 ha (EEA, 2007) Corine significantly underestimates rivers and small waterbodies. A special challenge remains to integrate the linear elements of the river network into an updated version of the ecosystem map.

The use of the ecosystem map for mapping and assessment of habitat conditions has only recently begun. A quick and easy example is the assessment of the protection status of habitats in Europe, which can be also further down-scaled to Member State level. It provides an overview on which type of habitat can be found in different parts of Europe, and how far these habitats can benefit from protection instruments (i.e. Natura 2000 network). As can be seen in Figure 3.3, natural ecosystems with little coverage mean high rareness i.e. bogs and mires are usually highly protected, in contrast to habitats which might be close to natural conditions but covering large areas such as forests. Exceptions are the highly artificial urban areas, which cover relatively small areas in Europe but are, of course, hardly protected.

([4]) http://eunis.eea.europa.eu.
([5]) http://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources/use-of-freshwater-resources-assessment-2.

Table 3.2 Typology of ecosystems and related EUNIS habitat classes

Ecosystem type	EUNIS Level 1		EUNIS Level 2		Total ecosystem coverage	
					Area (km²)	% area EUNIS level 2 per level 1
Urban	J	Constructed, industrial and other artificial habitats	J1	Buildings of cities, towns and villages	102 151	46.08
			J2	Low density buildings	94 150	42.47
			J3	Extractive industrial sites	6 453	2.91
			J4	Transport networks and other constructed hard-surface areas	16 100	7.26
			J5	Highly artificial man-made waters and associated structures	1 828	0.82
			J6	Waste deposits	998	0.45
Cropland	I	Regularly or recently cultivated agricultural, horticultural and domestic habitats	I1	Arable land and market gardens	1 243 168	99.18
			I2	Cultivated areas of gardens and parks	102 92	0.82
Grassland	E	Grasslands and land dominated by forbs, mosses or lichens	E1	Dry grasslands	9 330	1.35
			E2	Mesic grasslands	571 931	82.48
			E3	Seasonally wet and wet grasslands	55 771	8.04
			E4	Alpine and subalpine grasslands	21 128	3.05
			E5	Woodland fringes, clearings and tall forb stands	0	0.00
			E6	Inland salt steppes	3 043	0.44
			E7	Sparsely wooded grasslands	32 195	4.64
Woodland and forest	G	Woodland, forest and other wooded land	G1	Broadleaved deciduous woodland	487 970	28.29
			G2	Broadleaved evergreen woodland	49 248	2.86
			G3	Coniferous woodland	695 907	40.35
			G4	Mixed woodland	291 687	16.91
			G5	Lines of trees, small woodlands, recently felled woodlands, early stage woodland, coppice	199 784	11.58
Heathland and shrub	F	Heathland, scrub and tundra	F1	Tundra	0	0.00
			F2	Arctic, alpine and subalpine scrub	34 524	14.88
			F3	Temperate and mediterraneo-montane scrub	52 824	22.76
			F4	Temperate shrub heathland	691	0.30
			F5	Maquis, arborescent matorral and thermo-Mediterranean brushes	50 162	21.61
			F6	Garrigue	10 135	4.37
			F7	Spiny Mediterranean heaths	19 485	8.40
			F8	Thermo-Atlantic xerophytic scrub	3 233	1.39
			F9	Riverine and fen shrubs	140	0.06
			FA	Hedgerows	0	0.00
			FB	Shrub plantations	60 890	26.24
Attributed to sparsely vegetated land	B	Coastal habitats	B1	Coastal dunes and sandy shores	n/a	n/a
			B2	Coastal shingle	n/a	n/a
			B3	Rock, cliffs, ledges and shores, including supralittoral	n/a	n/a

Table 3.2 Typology of ecosystems and related EUNIS habitat classes (cont.)

Ecosystem type	EUNIS Level 1	EUNIS Level 2	Total ecosystem coverage Area (km²)	Total ecosystem coverage % area EUNIS level 2 per level 1
Wetlands	D Mires, bogs and fens	D1 Raised and blanked bogs	28 246	35.27
		D2 Valley mires, poor fens and transition mires	1 856	2.32
		D3 Aapa, palsa and polygon mires	44 981	56.16
		D4 Base-rich fens and calcareolus spring mires	590	0.74
		D5 Sedge and reedbeds, normally without free-standing water	4 373	5.46
		D6 Inland saline and brackish marshes and reedbeds	42	0.05
Rivers and lakes	C Inland surface waters	C1 Surface standing waters	92 690	87.66
		C2 Surface running waters	9 694	9.17
		C3 Littoral zone of inland surface waterbodies	3 356	3.17
Marine inlets and transitional waters, coastal, shelf, open ocean	A Marine habitats	A1 Littoral rock and other hard substrate	n/a	n/a
		A2 Littoral sediment	n/a	n/a
		A3 Infralittoral rock and other hard substrate	n/a	n/a
		A4 Circalittoral rock and other hard substrate	n/a	n/a
		A5 Sub-littoral sediment	n/a	n/a
		A6 Deep sea-bed	n/a	n/a
		A7 Pelagic water column	n/a	n/a
		A8 Ice-associated marine habitats	n/a	n/a

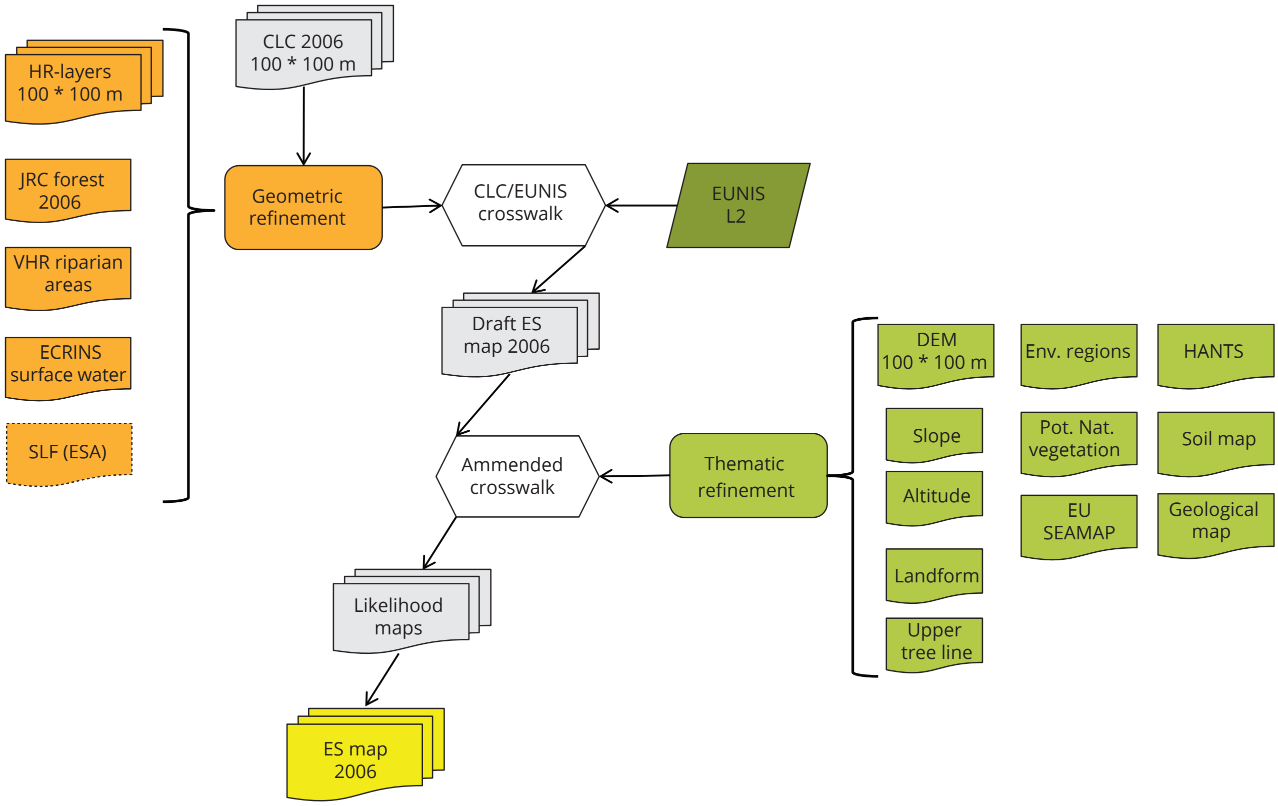
3.2.2 Mapping ecosystem conditions

The 1 x 1 km² ecosystem map is used as a base to be populated and validated with habitat quality and species assessments, to characterise the current conditions and map changes over time (Figure 3.4). For terrestrial ecosystems, most of the condition indicators either directly refer to habitat quality and biodiversity, or, as in the case of forests and woodlands, describe 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 terrestrial ecosystems is often lacking but indicated by the presence and absence of certain species, which can then be linked to the respective pressure maps and their changes over time. The chemical conditions, e.g. for freshwater and marine ecosystems, and the physical conditions, e.g. for rivers and seabeds, are important indicators for habitat quality and biodiversity. Here, data availability for mapping pressures is often insufficient (especially in the case of non-point pollution), so that mapping time series of conditions provides the most relevant information. The work flow in Figure 3.4 shows the steps in the mapping procedure. The integration of this information into the ecosystem map leads to a final indicator, and a map on the condition of European ecosystems.

The acquired information is largely provided by the reporting obligations from European environmental legislation, as they are regularly monitored and

Figure 3.2 Work flow — ecosystem map development



Source: ETC/SIA, 2014b.

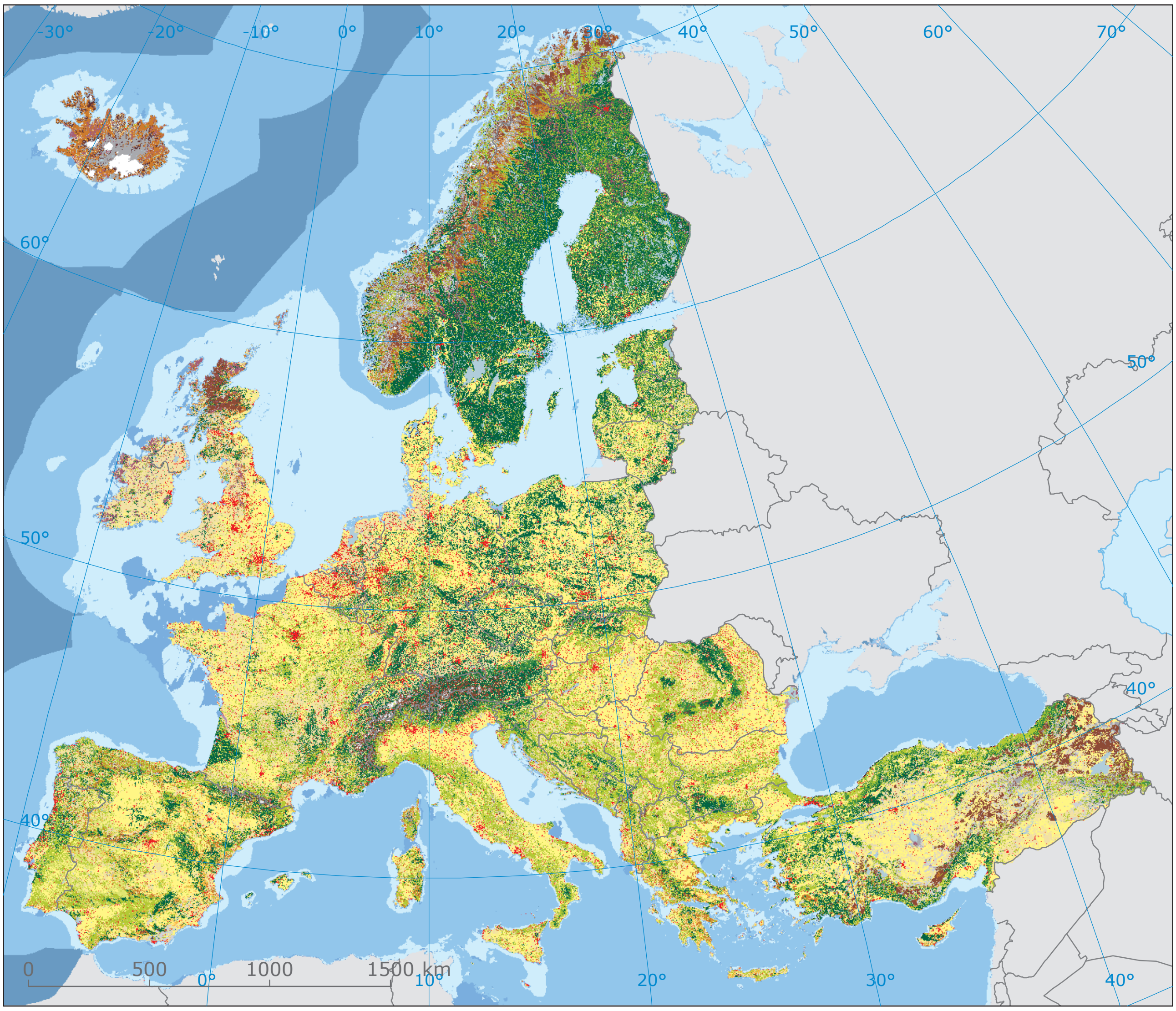
provide information on trends. The reports submitted by Member States make an important contribution to the mapping and assessment of ecosystems (see Annex 3).

The different European directives that can contribute to the condition assessment were developed for different purposes. This needs to be considered when data sets from reporting obligations are used in order to make adequate use of the information they provide.

In order to assess the condition of biodiversity in Europe, data sets from the Habitats Directive (HD) are key. Nevertheless, Article 17 of the Directive focuses on reporting on species and habitats considered to be most at risk across the European Union and, consequently, covering only parts of habitats and biodiversity. Therefore, the reported conservation status of these species and habitats does not provide a comprehensive overview about the condition of the MAES ecosystem types.

The Birds Directive covers all of the bird species that breed in the EU. There is also evidence from the literature to suggest that the status of bird species can provide a robust indicator of ecosystem condition (BirdLife International, 2004). The data, reported under Article 12 of the Birds Directive, may provide important insights for the mapping and assessment of ecosystems. However, this is the first time that Member States have provided comprehensive data on the state of bird species, and the assessment of data quality and coverage is still ongoing.

Map 3.9 **Ecosystem map version 2.1**



Ecosystem map (aggregated)

Marine waters
- European regional seas
- Open waters

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
- Sparsely wooded grasslands
- Broad leaved deciduous and evergreen woodland
- Mixed deciduous and coniferous woodland
- Coniferous and broad leaved evergreen woodland
- Mires, bogs and fens

Inland unvegetated or sparsely vegetated habitats
- Screes, inland cliffs
- Snow or ice-dominated habitats
- Miscellaneous inland habitats with very sparse or no vegeation

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

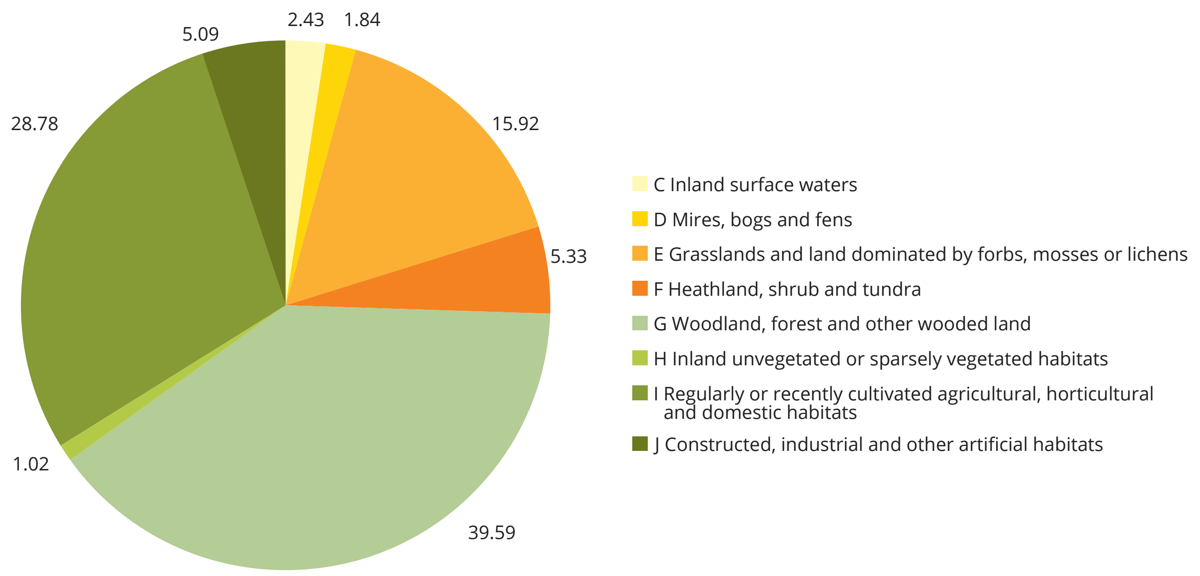
Non classified areas
- Unclassified areas
- Outside area of interest

Note: Legend has been aggregated (see Table 3.2).

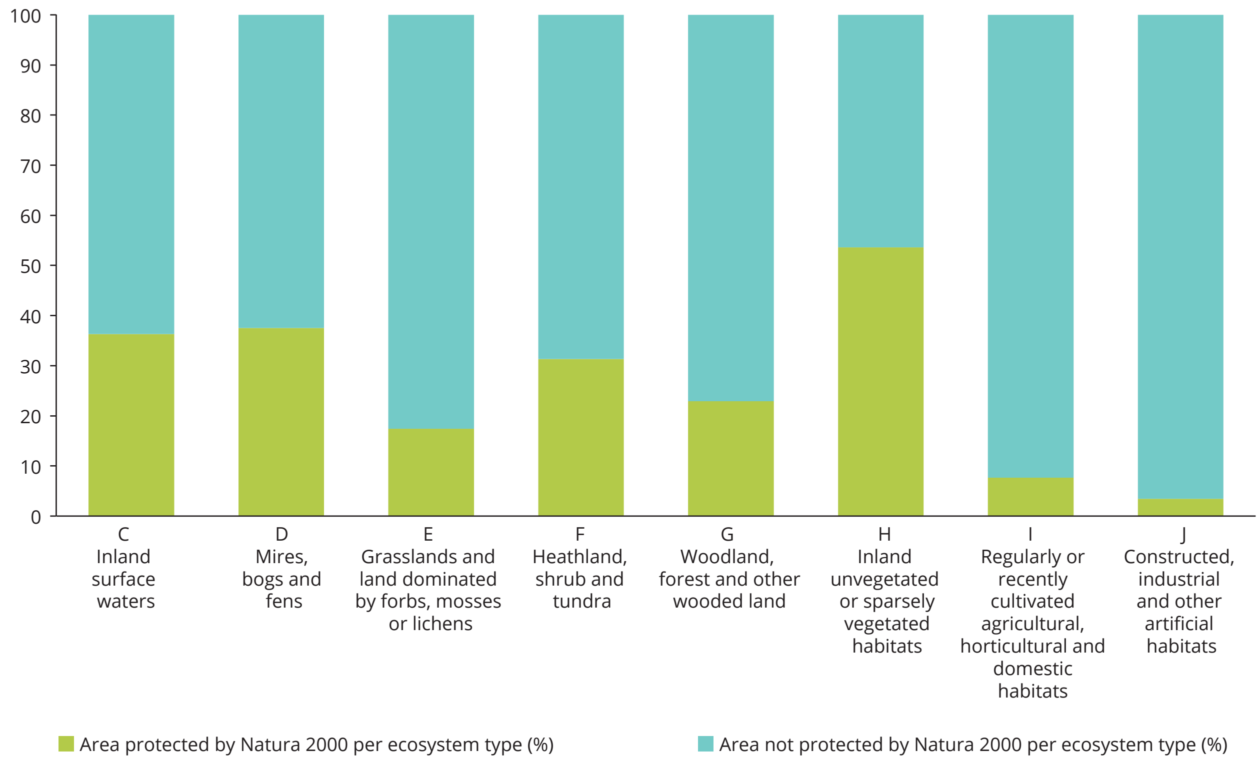
Source: ETC/SIA, 2014b.

Figure 3.3 **Percentage (%) of MAES terrestrial and freshwater ecosystem types in the EU-28, and their protection by Natura 2000 (%)**

Percentage of MAES ecosystem type in EU-28



Percentage (%) of area protected and not protected under Natura 2000 per ecosystem type



Source: ETC/SIA, 2014a.

The Natura 2000 network comprises special areas of conservation and special protection areas (SPAs), designated by Member States under the Habitats and Birds Directives, and provides information about the status of conservation of each habitat type and species.

Complementary to the reported information, additional data from the European IUCN 'Red List' assessment can also be integrated (IUCN, 2011a–d). So far, four taxonomic groups (corresponding to four IUCN data sets) include spatial information feasible for mapping: mammals, amphibians, reptiles and freshwater fish. The distribution maps from the IUCN European species assessment will need to link species to their preferred habitats and to their categories. In order to consider bird data in the assessment, additional global species maps from the global birds' assessment (BirdLife International, 2004), which relate the reported status of different species, can be added to the assessment of biodiversity conditions of ecosystems.

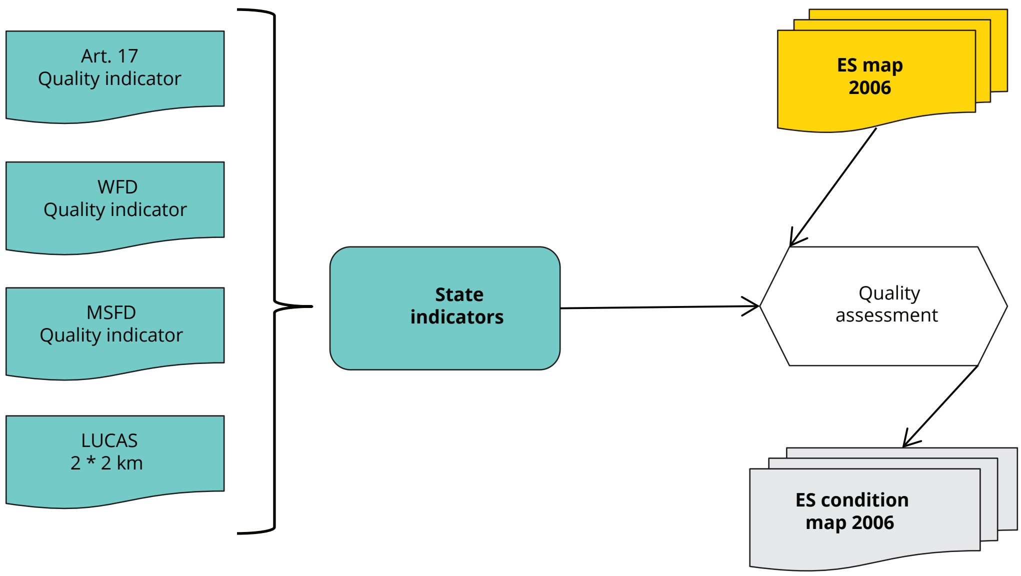
A link needs to be established between the reported data sets on habitats and species, additional regional assessments of species (i.e. IUCN and BirdLife data), and the ecosystems as defined by MAES. The EEA already produces a report concerning linkages between species and habitats covered by the Habitats and Birds Directives and the individual ecosystem types defined in the MAES process. The linkages provided by this report will allow assessment of biodiversity at the level of each MAES ecosystem type.

Map 3.10 demonstrates how to map ecosystem conditions, e.g. croplands and managed grasslands (agro-ecosystems), using relatively simple combinations of data. To refine the general ecosystem condition map for agro-ecosystems, the pan-European High Nature Value farmland map is used (Paracchini et al., 2008). The High Nature Value farmland map indicates areas that, historically, have been managed at low intensity and have not been converted to intensive farming. This area indicates high biodiversity in agricultural systems. They have one or more of the following characteristics:

- dominated by semi-natural vegetation;
- dominated by a mosaic of different low-intensity agricultural land uses, natural elements and structural elements;
- host rare species, or support a high proportion of their European or global populations.

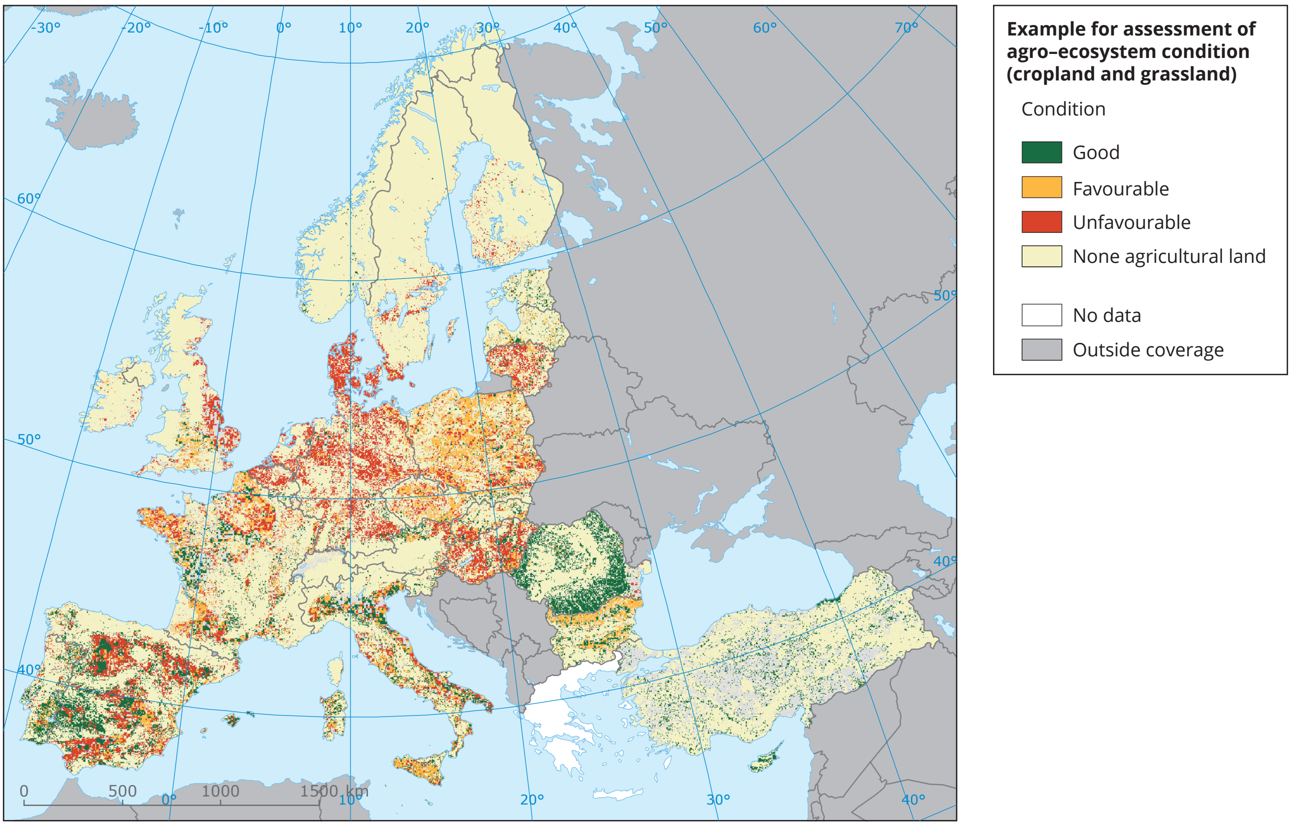
The HNV-farmland map is based on Corine Land Cover (CLC, 2006). The selection of HNV-relevant categories was based on the environmental stratification of Europe, expert rules (e.g. relating to altitude and soil quality), and country-specific information. To fine-tune the results, biodiversity data with European coverage were used (e.g. Natura 2000). The HNV-farmland map covers both farmed pastures and arable land with high nature values. To avoid overlap with grassland ecosystems, HNV pastures were excluded by overlaying the HNV map with the agricultural categories of the Corine Land Cover map of 2006. The resulting map marks the areas of High

Figure 3.4 **Work flow — mapping ecosystem conditions using the ecosystem map**



Source: ETC/SIA, 2014b.

Map 3.10 Example for assessment of cropland and grassland (agro ecosystem) condition



Note: The units are re-scaled (relative range 0-100, classified from unfavourable to good) because input consists of information in different units.

Source: ETC/SIA, 2014a.

Nature Value arable land. This information was used to refine the general condition map, in which areas in good condition (in terms of presence of indicator species) are highlighted.

As the arable ecosystem is the most intensively managed ecosystem type, the presence of species and biodiversity values within it are, in general, low. Therefore, it was decided that it will be sufficient to refine the condition map by only highlighting the areas in good condition, in terms of high nature value. No extra decision rules were used to distinguish between bad or moderate conditions.

The ecological status of freshwater and coastal waters is assessed under the Water Framework Directive (WFD). The WFD reports on water quality and 'ecological status' for rivers, lakes, groundwater, transitional water, and coastal water ([6]) (see Annex 3).

Information on non-point pollution should be linked with the pressure and condition data of the surrounding terrestrial ecosystems and point sources — as documented in the Urban Waste Water Treatment Directive (UWWTD). Additional information will be delivered from the water accounting exercise currently being finalised at the EEA. As mentioned in previous chapters, a pre-requisite for this is the geometric integration of the linear elements of the river network into the ecosystem map.

For marine ecosystems, the marine baseline report of the Marine Strategy Framework Directive (MSFD) with its ecosystem assessment approach will be the fundamental information base for further work in the MAES context. Besides the marine-related information from the WFD, the Bathing Water Directive and other additional data (e.g. chlorophyll concentrations) can also be used as indicators of water condition.

([6]) http://www.eea.europa.eu/themes/water/water-assessments-2012.

3.2.3 Mapping multiple factors of condition and trends

Assessment of the condition of ecosystems in Europe needs to be performed for each ecosystem type by integrating different biodiversity data sets as conceptualised in Figure 3.5. In this case, the assessment is mainly based on data collected under Article 17 of the Habitats Directive, Article 12 data of the Birds Directive and IUCN data. This is implemented by identifying the relationship between ecosystem types (in combination with the EUNIS information provided in the pan-European ecosystem map) and the condition of the biodiversity they host. Mapping needs separate attributions for different taxonomic groups, namely, mammals, fish, reptiles and amphibians, invertebrates, and plants, covering species reported under Article 17 and the IUCN.

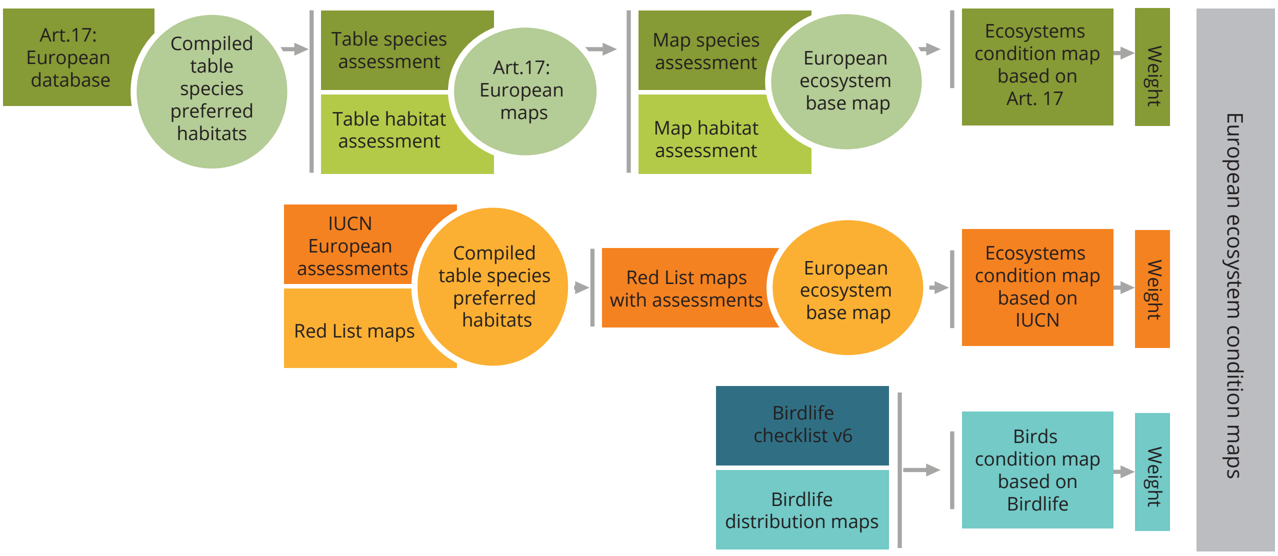
This relationship between species and preferred habitats — reported decreasing species trends and reported unfavourable and deteriorating habitats — gives an indication of the condition of species and habitats in pan-European ecosystems.

The ecosystem map produced by ETC/SIA, following the EUNIS (7) level 1 classification can be used since it directly correlates with ecosystem typologies defined for the Biodiversity Strategy (MAES ecosystem types level 2). This map can be used as a basis for population with different habitat qualities and species assessments included in the reported data of the Habitats Directive and additional species-related data, namely, the Red List assessment and the Birds assessment. The integration of this information leads to a final indicator and map on European ecosystem conditions.

The cross-link between species and habitat condition at the level of each ecosystem type is thereby developed. Evaluation of the condition of ecosystems is set through the identification of species and habitat distribution within each type of ecosystem, and the identification of its condition in each case. A cross table was created, linking species to their preferred habitat types and to the ecosystems where the different habitats occur. The input data used for the assessment of the conditions are: HD Article 17 for species and habitat conditions and trends, the global birds data sets (BirdLife International, 2004), and BD Article 12 reporting categories and criteria in the IUCN European assessment of the main taxonomic groups, including amphibians, butterflies, dragonflies and damselflies, freshwater fish, mammals, non-marine molluscs, reptiles, saproxylic beetles, and vascular plants.

At the level of each ecosystem type, the general condition indicator is linked to additional indicators characterising ecosystem specificities. The ecosystem-specific indicators build on the condition of biodiversity in general, and add indicators that are specific to each type of studied ecosystem that may affect and modify an ecosystem's state, e.g. livestock density, mineral fertiliser, forest fragmentation, and fish harvest.

Figure 3.5 Approach and workflow developed for the general condition assessment of ecosystems linking biodiversity condition data to the pan-European ecosystem map



Source: ETC/SIA, 2014a.

(7) http://eunis.eea.europa.eu/habitats-code-browser.jsp.

4 Impacts and response

4.1 Impacts on ecosystem function, habitat quality and biodiversity

Mapping and assessment of impacts of ecosystem conditions requires knowledge about the functional relationships between condition and the impact to be considered. Principally, all services need to be addressed in the assessment. Habitats and biodiversity require understanding of how ecosystem conditions affect habitat quality and biodiversity.

4.1.1 Functional traits of biodiversity

To map the impacts of ecosystem conditions on biodiversity, the functional traits of species in relation to ecosystem conditions or related habitat quality needs to be understood. If available, a direct link between pressures and biodiversity can also be used for impact assessment.

Under each driver of change, the impacts of pressures on ecosystems, their habitats, and their biodiversity are different. These relationships are currently collected to develop a knowledge base on the functional traits of species and habitats for each ecosystem type, in order to elaborate the impact of anthropogenic pressures, ecosystem conditions, habitat quality and biodiversity. Functional traits are those that define species in terms of their ecological roles, i.e. how they interact with the environment and with other species (Diaz et al., 2013).

The functional traits of species in a community include growth, tolerance and sensitivity to environmental conditions. Accounting for biodiversity functional traits and environmental gradients in the ecosystem assessment allows critical insight into how human pressures on the environment will affect the diversity and composition of species communities (McGill et al., 2006). Depending on existing knowledge, the relationships are described as direct impacts of pressures on species, or indirect indicators of ecosystem condition or habitat quality. The approach used to account for the main pressures and their impacts on the functional capacity of biodiversity, at the level of each ecosystem type, is the main descriptor for biodiversity capacity in ecosystems, i.e. the basic information to meet the targets of the EU Biodiversity Strategy to 2020.

4.1.2 Impact assessment

The impacts or the effects that pressures may exert on different ecosystem types, as well as on the functional traits of species and habitats, is diverse. In this report, the focus is on biodiversity, and therefore the approach to be used needs to combine impacts on species and habitats present in different ecosystems.

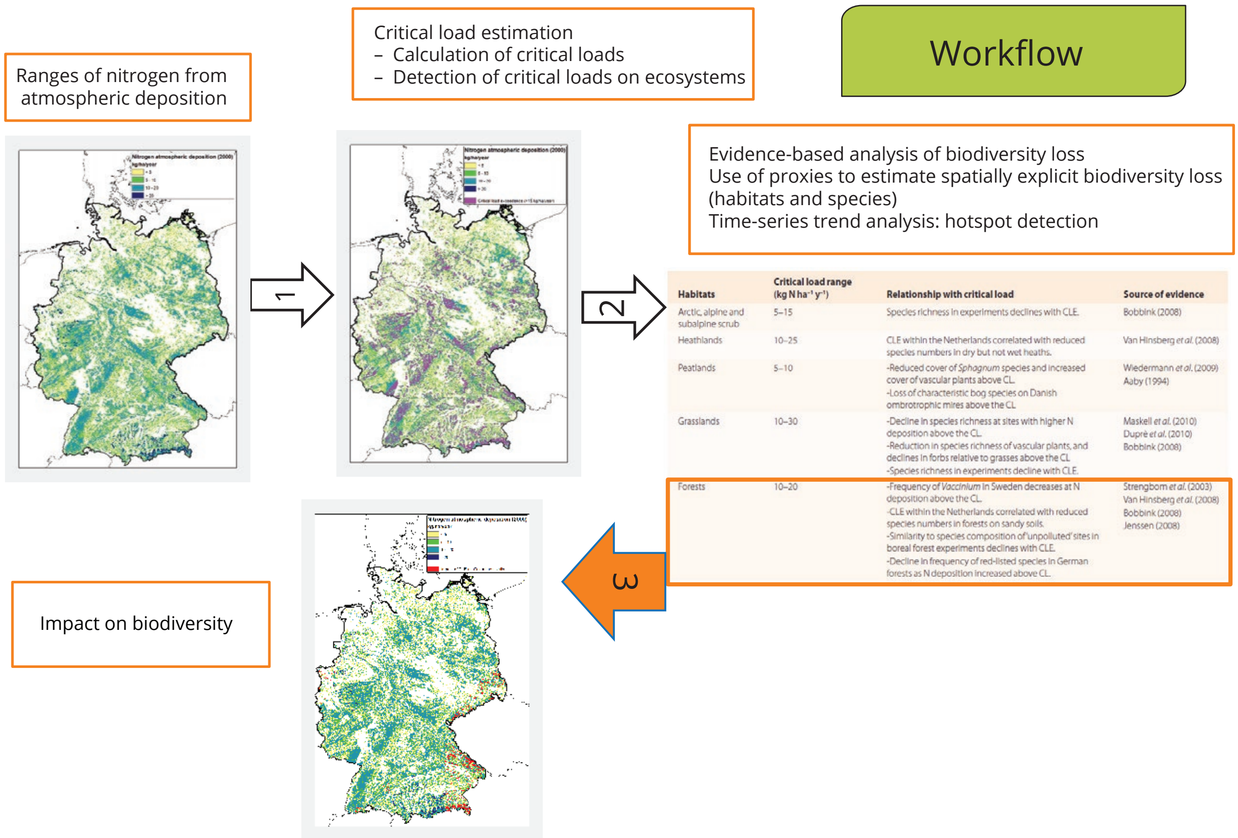
Using knowledge about functional relationships, and linking pressures with subsequent conditions, allows the impacts to be assessed — describing the sensitivity of habitats and different biodiversity components to pressures. Sensitivity can be estimated by using weighting scores for the pressures, which are based on experiments and expert knowledge.

Each of the weighted pressures impact habitats or species — depending on their spatial location in areas where these pressures occur and the combined strength of the pressures at this place. Species and habitats are usually impacted by several pressures, including their synergistic effects and antagonistic effects. A summary of the impacts of different pressures on specific habitat ranges or species distribution results in cumulative impact assessments, but does not necessarily address the full combined effect of pressures on species and habitats.

Figure 4.1 illustrates the different steps and the knowledge needed to perform a full impact assessment, using nitrogen deposition in Germany as an example. The nitrogen deposition map provides input for condition assessment: linked to information on functional traits (1), and linked to knowledge about how nitrogen conditions affect species and habitats (2). This attribution exercise results in a map describing the impacts of these pressures on species for each spatial unit (3).

The knowledge about impacts of pressures on ecosystem condition and biodiversity is still limited.

Figure 4.1 **Approach to address known evidence on the impacts of pressures on biodiversity using nitrogen deposition as an example**



Habitats	Critical load range (kg N ha^{-1} y^{-1})	Relationship with critical load	Source of evidence
Arctic, alpine and subalpine scrub	5–15	Species richness in experiments declines with CLE.	Bobbink (2008)
Heathlands	10–25	CLE within the Netherlands correlated with reduced species numbers in dry but not wet heaths.	Van Hinsberg *et al.* (2008)
Peatlands	5–10	-Reduced cover of *Sphagnum* species and increased cover of vascular plants above CL. -Loss of characteristic bog species on Danish ombrotrophic mires above the CL	Wiedermann *et al.* (2009) Aaby (1994)
Grasslands	10–30	-Decline in species richness at sites with higher N deposition above the CL. -Reduction in species richness of vascular plants, and declines in forbs relative to grasses above the CL -Species richness in experiments decline with CLE.	Maskell *et al.* (2010) Duprè *et al.* (2010) Bobbink (2008)
Forests	10–20	-Frequency of *Vaccinium* in Sweden decreases at N deposition above the CL. -CLE within the Netherlands correlated with reduced species numbers in forests on sandy soils. -Similarity to species composition of 'unpolluted' sites in boreal forest experiments declines with CLE. -Decline in frequency of red-listed species in German forests as N deposition increased above CL.	Strengbom *et al.* (2003) Van Hinsberg *et al.* (2008) Bobbink (2008) Jenssen (2008)

Source: ETC-SIA 2014a.

Impacts of air pollutants on European grassland ecosystems are summarised in EEA (EEA, 2014). The ecological status of waterbodies as monitored in the Water Framework Directive (8) comprises a fundamental understanding of the link between freshwater ecosystem condition and biodiversity, and can be directly used for ecosystem assessments. Limitations in impact assessment, knowledge about quantitative or qualitative relationships, and the cumulative effects of different pressures are addressed for marine assessments in HELCOM (HELCOM, 2010).

4.2 Link to response

To cope with negative impacts of pressures on ecosystems (affecting their conditions and habitat quality, as well as biodiversity) requires adequate responses by decision-makers. The outputs of the impact assessments should promote policies facilitating the transition from harmful or damaging behaviours, to more sustainable management of all natural resources. As such, impact assessments should encourage the adoption of more efficient practices, which should seek to resolve conflicts of interest in an equitable manner and/or pave the way for adapting by inducing major shifts in human interaction with the environment.

The pan-European ecosystem and ecosystem services assessment (Target 2, Action 5 of the EU Biodiversity Strategy to 2020) is connected to the overall goals of the Aichi targets of the Biodiversity Convention (CBD). In particular, the restoration and prioritisation framework (Action 6a.), and the connectivity and climate change mitigation under the Green Infrastructure Strategy (Action 6b), are benchmarks for impact assessments. Furthermore, assessments can be used to evaluate current scientific knowledge needs to increase the use of biodiversity offsetting (Action 7a.) and will support the European Commission in the initiative of ensuring no net loss by 2015 (Action 7b).

(8) http://ec.europa.eu/environment/water/water-framework/objectives/status_en.htm#_Assessment_of_water.

Responses can protect the environment from damage, or further harm, and encourage recovery through rehabilitation and remediation. Reforms in policies focus on improving the effectiveness of responses based on improved knowledge. The 2003 reform of the Common Agricultural Policy (CAP), with its focus on the Good Agricultural and the Environmental Condition (GAEC), provides an example of such a policy. The implementation of GAEC is a response to the abandonment of agriculture, assuring the minimum level of sustainability of farming practices, and recognising the strict link between agricultural activities and the management of land and landscape ([9]) (also considered in the EU Biodiversity Strategy to 2020 under Target 3: Sustainable agriculture and forestry). The Water Framework Directive already implemented the target of 'good ecological status', which refers to the functional links between water condition and biodiversity. The Water Framework Directive also allows for appropriate measures to meet the targets.

([9]) http://marswiki.jrc.ec.europa.eu/wikicap/index.php/Good_Agricultural_and_Environmental_Conditions_%28GAEC%29.

5 Conclusions and outlook

This report provides first approaches towards mapping and assessment of pressures, ecosystem conditions, and impacts on biodiversity, as part of the EEA's contribution to the implementation of the EU Biodiversity Strategy to 2020. It provides a first overview, in terms of data availability, demonstrates the development of indicators to support pan-European ecosystem assessments using a few examples, and explores the availability and shortcomings in knowledge for full implementation. For each ecosystem type, suitable data sets are identified and evaluated. Based on the most relevant information assessed, and the relevant indicators or proxies to be used to provide information on the condition of each ecosystem, the pressures, threats, and limitations encountered are identified. Indicators of land-use intensity are developed and can be used as operational tools for trend assessments. A first version of pan-European ecosystem mapping has been created, which allows spatially-explicit attributions of habitats and species information to ecosystem types, as the baseline for assessing conditions (Box 5.1).

Input data needed for the assessment is, to a large extent, based on the reporting obligations of European environmental legislation. New data sets are available in 2015, and are currently reported in the context of the Nature Directives, the water basin management reports of the Water Framework Directive (WFD), the first baseline report of the Marine Strategy Framework Directive (MSFD), and the new Copernicus continental land service data (Corine, 2012; High Resolution Layers, 2012). These data sets will further consolidate this approach in terms of data availability and quality for mapping pressures and conditions of European ecosystem types and related biodiversity. So far, a number of indicators have been developed, and examples have been presented for cropland and grassland ecosystems. Reports on forest and urban ecosystem assessments will provide complementary information, and the approach has been tested for the other MAES ecosystem types — except 'sparsely vegetated land'.

Analyses show the gaps to be addressed for full implementation of the approach. One of the most important gaps is the knowledge about the functional links between ecosystem conditions and biodiversity, and how ecosystem degradation affects habitats and species.

In addition, European data sets on the condition and trends of biodiversity are still not comprehensive. Specifically, data on marine species and habitats are scarcer than for terrestrial ecosystems. Information on the distribution of invasive alien species in Europe is not yet fully available, although it is considered as one of the main drivers of ecosystem change. Proxies can be developed for terrestrial ecosystems at risk from alien species invasion, and the EEA is developing indicators that can also be used for marine assessments.

European research has provided a wide range of data and indicators that can be used to overcome some of the gaps identified from reported data, but this knowledge is not equally distributed among ecosystems and the European territories. The terrestrial ecosystems seem to be the most widely covered, whereas freshwater ecosystems still contain

Box 5.1 Key achievements for a Europe-wide ecosystem assessment

1. Conceptual framework for ecosystem assessment developed and implementation tested against existing European data
2. Main pressures mapped and the method for mapping multiple pressures outlined
3. Operational data flow for land-use intensity established (nutrient accounts)
4. First version of European ecosystem map developed
5. First versions of ecosystem condition maps available

some serious gaps in validation, especially for groundwater. Marine ecosystems still suffer from scarce and fragmented information for ecosystem-based assessments, as well as from a lack of ecosystem-based mapping.

Within Europe, the quality of available data sets and indicators varies. Specifically, data sets resulting from reporting tend to be biased by administrative borders. Future challenges remain in improving the data quality of the monitoring programmes so that information can be updated and improved for robust trend detection. Further research in this sense is urgent (see Box 5.2) to cover the needs for implementation of the targets of the EU Biodiversity Strategy to 2020. Improved knowledge on the impacts of climate change on biodiversity is needed — in particular, assessing the vulnerability of species, habitats and ecosystems. In addition, modelled data sets are not frequent, but can be very useful for harmonising and filling data gaps on mapping pressures and conditions. Specific indicators need to be further developed to cover the five main categories of threats to biodiversity: habitat change, climate change, invasive species, land use management, and pollution and nutrient enrichment. In addition, specific indicators might be needed to complement the assessments, e.g. the drainage of wetland areas.

Other limitations are the spatial and temporal resolution of European data sets. The landscape fragmentation indicator, for example, has some limitations as it only considers major fragmentation at landscape level and does not reflect small changes on the local scale that might remain undetected using this indicator.

There is also limited knowledge of the impact of specific pressures, such as pollution or climate change, on biodiversity, and further research is required to better understand how different types of pollution influence different biodiversity components.

In terms of the conceptual framework, there is a wide range of linkages between drivers, pressures, ecosystem conditions addressing both structure and functions, and the services and benefits that ecosystems provide. The potential indicators and proxies for ecosystem conditions have been presented in the previous chapters. A second step calls for the definition of ecologically sound linkages between pressures and ecosystem condition, based on the identification of drivers of change, pressures, effects on condition, and impacts.

This report outlines the main drivers of change and the induced pressures to which different European ecosystems are exposed. Based on this list, the report identifies the main input data sets needed to develop indicators in order to assess the individual pressures to which each ecosystem is subjected. This knowledge will be used for the identification of a cumulative pressure gradient valid at European scale for each identified driver of change.

Box 5.2 Key challenges for a Europe-wide ecosystem assessment

Knowledge gaps:

1. functional relationships between ecosystem condition — habitat quality and biodiversity; the synergistic/antagonistic effects of pressures; and the interlinkages between terrestrial, freshwater and marine ecosystems;
2. functional relationships between ecosystem conditions and ecosystem services;
3. mapping multiple pressures and conditions;
4. interpreting EUNIS species data in the context of ecosystem pressures and conditions;
5. linking Europe-wide information with Member State assessments.

Data gaps:

1. missing information on green and blue linear features and their importance for biodiversity;
2. observed time series — especially for fragmentation, groundwater and marine environments, to interpret current condition and expected trends in the near future;
3. quantitative data for meeting the targets of the EU Biodiversity Strategy to 2020, especially the No Net Loss and Restoration Prioritisation Framework.

The activities outlined in this report have provided first results, and this document can only deliver a first insight using croplands and grasslands as examples. As shown, more data are available now (and more will be available in the near future) to further elaborate the relevant information for assessing pressures, ecosystem conditions, habitat quality and related biodiversity (see Box 5.3).

The next steps towards Europe-wide ecosystem assessment include: the integration of upcoming data from European monitoring and from instruments such as the Green Infrastructure Strategy; the integration of results from research activities such as OPERAs and OpenNESS projects; and on-going work to elaborate links between ecosystem conditions, biodiversity and ecosystem services, including efforts to improve our understanding of functional relationships.

Mapping and assessing ecosystem conditions at European scale also has limitations in terms of spatial resolution and level of detail. In particular, land use management and protection measures vary across countries, and bio-geographical areas are tailored for local measures — taking into account the social, economic, and environmental conditions in the respective areas. The link between Member State assessments and Europe-wide information will be another challenge for providing the relevant information required to meet the targets of the EU Biodiversity Strategy to 2020.

Box 5.3 European ecosystem assessment — the way forward

Cross-cutting	Integrate State of Nature report data for mapping and assessing ecosystem condition on European level (Art.12 and Art.17 data)
	Integrate new Copernicus data (Corine, 2012; High Resolution Layers, 2012)
	Integrate new fragmentation layer
	Link to green infrastructure
	Integrate update of EEA indicator data sets (SEBI, Agriculture, Climate etc.)
Urban	Integrate urban green infrastructure and other urban-related information
Cropland	Mapping pressures trends
Grassland	Grassland definition and mapping changes in pressures
Woodland and forest	Integrate information from forest ecosystem assessment report
Heathland and shrubs	Improve concept for heathland and shrubs
Wetlands	Improve concept for wetlands
Rivers and lakes	Integrate linear river network data into spatial ecosystem map, and use data from second reporting cycle of River Basin Management Plans
	Link terrestrial and freshwater ecosystem conditions
Marine	Integrate information from Marine Baseline Report with concept of marine ecosystem assessment
	Link with terrestrial and freshwater ecosystem assessments

List of acronyms

AQ	Air Quality
BD	Birds Directive
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CDDA	Common Database on Designated Areas (nationally designated areas)
CCE	Coordination Centre for Effects
CICES	Common International Classification of Ecosystem services
CIF	Common Implementation Framework
CLC	Corine Land Cover
CORILIS	Corine Lissage
Corine	Coordination of Information on the Environment
CPUE	Catch per unit effort
DEM	Digital Elevation Model
DG	Directorate General of the European Commission
DG-ENV	Directorate General of the European Commission-Environment
DPSIR	Drivers-Pressures-State-Impact-Response framework
EA	Ecosystem Assessment
EASIN	European Alien Species Information Network
EC	European Commission
ECRINS	European Catchments and Rivers Network System
EEA	European Environment Agency
EFFIS	European Forest Fire Information System
EFI	European Forest Institute
EFISCEN	European Forest Information Scenario database

EMEP	European Monitoring and Evaluation Programme
EMIS	Environmental Marine Information System
ESPON	European Observation Network for Territorial Development and Cohesion
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
EU	European Union
EUNIS	European Nature Information System
FAO	Food and Agriculture Organization
FAO-AGA	Food and Agriculture Organization's Animal Production and Health Division
FOEN	Swiss Federal Office for the Environment
GAEC	Good Agricultural and Environmental Condition
GFCM	General Fisheries Council for the Mediterranean
HANTS	Harmonic Analyses of NDVI Time-Series
HD	Habitats Directive
HELCOM	Baltic Marine Environment Protection Commission (Helsinki Commission)
HRL	High Resolution Layers
HNV	High Nature Value
IAS	Invasive Alien species
ICES	International council for exploration of the Sea
INSPIRE	Infrastructure for Spatial Information in Europe
IUCN	International Union for Conservation of Nature and Natural Resources
JRC	Joint Research Centre
JRC CCM	The Joint Research Centre Catchment Characterisation and Modelling (CCM)
LEAC	Land and Ecosystem Accounting
LRTAP	Long-range Transboundary Air Pollution
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MAES WG	MAES Working Group

MCPFE	Ministerial Conference on the Protection of Forests in Europe
MS	Member States
MSFD	Marine Strategy Framework Directive
NDVI	Normalised Difference Vegetation Index
NEC	National Emission Ceiling
OWL	Other wooded land
RBD	River Basin District
RUBICODE	Rationalising Biodiversity Conservation in Dynamic Ecosystems
SEBI	Streamlining European Biodiversity Indicators
SLF	Small linear features
TBFRA	Temperate and Boreal Forest Resource Assessment
TEEB	The Economics of Ecosystems and Biodiversity
UK NEA	United Kingdom National Ecosystem Assessment
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UWWTD	Urban Waste Water Treatment Directive
VHR	Very high resolution layer
VOC	Volatile organic compounds
WFD	Water Framework Directive
WISE	Water Information System for Europe

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Annex 1 Datasets and indicators available to assess the condition and drivers of pressures on pan-European ecosystems

Annex 1 synthesises the main datasets and indicators available to assess each ecosystem type at European level. Key drivers and pressures are separated in 5 major classes: (i) habitat change, (ii) climate change, (iii) land use specified as exploitation (management), (iv) invasive species and (v) pollution and nutrient enrichment.

The greenness from pale (low) to dark green (high) of each box indicates data availability for European wide assessments. The overview aims to be comprehensive with regard to at least terrestrial ecosystems, but its coverage is not exhaustive as it is data driven with a strong emphasis on the availability of spatial datasets.

	Ecosystem condition	Major drivers of ecosystem change				
Ecosystem type	**Condition**	**Habitat change**	**Climate change**	**Exploitation (management)**	**Invasive species**	**Pollution and nutrient enrichment**
Biodiversity level	– HD and BD reporting obligations – IUCN European species assessments – BirdLife International species assessments – Species and habitats accounts of European conservation importance – EEA's on-going fast track implementation methodology of biodiversity and species accounts (ecosystem accounting methodology) – Natura 2000 – Directive on Air Quality – Thematic high resolution layers	– HD and BD reporting obligations – IUCN European species assessments – BirdLife International species assessments – Species and habitats accounts of European conservation importance – Landscape fragmentation – Loss of accessibility for migratory fish due to dams in major European river basins	– ESPON climate – EFFIS	– HNV forest – AEI004 Indicator on Area under organic farming – AEI023 indicator on HNV farmland – Carbon accounts on timber extraction and grazing livestock – CSI032 Indicator on status of marine fish stocks – FAO fishstats	– SEBI010 Indicator on Invasive alien species in Europe – EASIN network – Trends and pathways of marine alien species (upcoming datasets: EEA)	– Air Quality Directive – Nitrates Directive – Exceedance of critical loads for eutrophication by nutrient nitrogen – Exceedance of pesticides in soils – Heavy metals input-output balance – Critical levels of ozone damage assessment
Cropland (including agro-ecosystems)	– Biomass harvested – Eurostat Statistics: crop production and land use change – CAPRI LU maps – Carbon accounts — crop production in arable land – Natura 2000 – Directive on Air Quality	– CLC – HANTS NDVI – AEI004 Indicator on area under organic farming – AEI023 indicator on HNV farmland – CSI014, Land take indicator – Landscape structure: fragmentation, ecotones, linear features – Presence of greenhouses – EU Agricultural census	– ESPON climate – EFFIS	– Nutrient accounts – Carbon accounts on grazing livestock and arable land – AEI004 Indicator on Area under organic farming – AEI023 indicator on HNV farmland – High irrigated land usage – CLC – SoilProd model: spatially explicit results – SPOT VEGETATION1 – LUCAS – HSMU database – SENSOR Project	– SEBI010 Indicator on Invasive alien species in Europe – EASIN network	– Air Quality Directive – Nitrates Directive – SEBI009 indicator on critical load exceedance for nitrogen — critical levels of ozone damage assessment – Nutrient accounts — methodology development for N and P accounts per ecosystem type – Heavy metals
Grassland	– HD and BD reporting obligations – CLC – HR layer on grassland – LEAC tools – FAO livestock map – JRC nitrogen map – Eurostat Livestock statistics – Grazed biomass – Natura 2000 – Directive on Air Quality	– HD and BD reporting obligations – CLC – HR layer on grassland – HANTS NDVI – Landscape fragmentation – Carbon accounts – HNV farmlands – AEI004 Indicator on Area under organic farming – IUCN European species assessments – BirdLife international database	– CLC – ESPON climate – World Fire Atlas – HANTS NDVI – EFFIS	– HNV farmlands – AEI004 Indicator on Area under organic farming – Nutrient accounts – Carbon accounts on grazing livestock	– Invasive alien species in Europe (SEBI010) – EASIN network	– Air Quality Directive – Nitrates Directive – SEBI009 Indicator on critical load exceedance for nitrogen – Critical levels of ozone damage assessment – Nutrient accounts — methodology development for N and P accounts per ecosystem type – Heavy metals

	Ecosystem condition	Major drivers of ecosystem change				
Ecosystem type	**Condition**	**Habitat change**	**Climate change**	**Exploitation (management)**	**Invasive species**	**Pollution and nutrient enrichment**
Woodland and forest	– HD and BD reporting obligations – CLC – JRC forest type map 2006 – HNV forest area, Naturalness – Pan-European map on growing stock – EFI dataset, EFISCEN database – UNECE/FAO/Forest Europe statistics – CORILIS radius 0, NDVI – Forest fires (EFFIS) – 2 upcoming indicator – (FISE): Pan-European map of forest living biomass, Pan-European map of forest biomass increment – Natura 2000 – Directive on Air Quality	– HD and BD reporting obligations – CLC – JRC forest type map 2006 – HANTS NDVI – JRC forest pattern, fragmentation and connectivity – SEBI013 Indicator on fragmentation of natural and semi-natural areas – IUCN European species assessments – BirdLife international database – On-going JRC work on Mediterranean forest and forest Natura 2000, CC and biodiversity.	– CLC – Natura 2000 database – World Fire Atlas – JRC Eurosoil – OEROK 2011, – JNCC 2010 – HANTS NDVI – ESPON climate – EFFIS – Maps on impacts of CC on tree species distribution (FISE/EFDAC).	– HNV forest – Nutrient accounts – SEBI017 Indicator on forest (growing stock, increment and felling) – NFI datasets 2005 – Carbon accounts on timber extraction and grazing livestock – Timber provision (JRC, based on AFOLU and EFISCEN) – Pan-European map on growing stock – Forest productivity (forest biomass) – JRC Forest Pattern, Fragmentation and Connectivity – Forest mapping – Private forest ownership map	– SEBI010 Indicator on Invasive alien species in Europe – EASIN network	– Air Quality Directive – Nitrates Directive – SEBI009 Indicator on Critical load exceedance for nitrogen) – Critical loads exceedance of eutrophication due to the deposition of nutrient nitrogen – Critical levels of ozone damage assessment – Nutrient accounts — Methodology development for N and P accounts per ecosystem type – HAIR2010 – Heavy metals – E– PRTR
Heathland and shrub	– HD and BD reporting obligations – CLC – LEAC – Biogeographical regions layer – Natura 2000 – Directive on Air Quality	– HD and BD reporting obligations – CLC – HANTS NDVI – EFFIS – Landscape fragmentation – IUCN European species assessments – BirdLife international database	– CLC – ESPON climate – World Fire Atlas – HANTS NDVI – EFFIS	– HANTS NDVI	– Invasive alien species in Europe (SEBI010) – EASIN network	– SEBI009 Indicator on critical load exceedance for nitrogen – Nutrient accounts — Methodology development for N and P accounts per ecosystem type
Rivers and lakes	– WFD – ECRINS – River Basin Districts (RBDs) – CLC – JRC MARS – ETR Evapotranspiration – EEA ORNL's Landscan – FEC – WISE – Waterbase – Natura 2000 – Directive on Air Quality	– CLC – ECRINS – Waterbase databases – Loss of accessibility for migratory fish due to dams in major European river basins – IUCN European species assessments – BirdLife international database	– ESPON climate	– ECRINS – Loss of accessibility for migratory fish due to dams in major European river basins – Waterbase databases	– SEBI010 Indicator on Invasive alien species in Europe – EASIN network	– Air Quality Directive – Nitrates Directive – Urban Waste Water Treatment Directive (UWWTD) – WFD: Mean annual nitrates in rivers reported by Member State – SEBI009 indicator on critical load exceedance for nitrogen)

	Ecosystem condition	Major drivers of ecosystem change				
Ecosystem type	**Condition**	**Habitat change**	**Climate change**	**Exploitation (management)**	**Invasive species**	**Pollution and nutrient enrichment**
Wetlands	– HD and BD reporting obligations – WFD – CLC – LEAC – HRL wetland – Satellite imagery – Ramsar layer on wetlands – Natura 2000 – Directive on Air Quality	– HD and BD reporting obligations – CLC – LEAC tools – HRL wetland – IUCN European species assessments – BirdLife international database – Loss of accessibility for migratory fish due to dams in major European river basins – Wetlands inventories and land use/land cover layers	– ESPON climate	– Multi– temporal satellite imagery – Wetland indicators developed by ETC-SIA (section 3.6.2.1. of the EA Methodology report) – Wetlands inventories and land use/land cover layers	– SEBI010 Indicator on Invasive alien species in Europe – EASIN network	– Air Quality Directive – Nitrates Directive – Urban Waste Water Treatment Directive (UWWTD) – WFD: Mean annual nitrates in rivers reported by Member State – SEBI09 indicator on critical load exceedance for nitrogen
Marine	– HD and BD reporting obligations – MSFD (upcoming datasets) – CLC – Art. 17 Species distribution – Art. 12 Birds conservation status – Ecosystem map (ETC/SIA 2013) – Directive on Air Quality – WFD 'transitional' and 'coastal' waters – Natura 2000 — marine protected areas – EU Sea map – Waterbase – Fish abundance [Capacity] – Commercial and artisanal fish and shellfish landing (t/a) [Flow] – Aquaculture: Harvested fish and shellfish (t/y) [Flow] – Fibers and other material from plants Abundance/ biomass (t/a) [C] – Commercial and artisanal landing (t/a) [F]	– HD and BD reporting obligations – MSFD (upcoming datasets) – WFD 'transitional' and 'coastal' waters – IUCN European species assessments – BirdLife international database – Loss of accessibility for migratory fish due to dams in major European river basins	– ESPON climate – EMIS portal and data	– Common Fisheries Policy (CFP) – MSFD (upcoming datasets) – CSI032 Indicator on Status of marine fish stocks – CSI034 Indicator on Fishing fleet capacity – FAO fishstats – CSI033 Indicator on Aquaculture production – Biomass surveys and analysis of commercial catch per unit effort (CPUE)	– SEBI010 Indicator on Invasive alien species in Europe – Trends and pathways of marine alien species (upcoming datasets: EEA) – MAS (upcoming 2 indicators per MSFD area by EEA (expected 2014)	– Air Quality Directive – Nitrates Directive – WFD 'transitional' and 'coastal' waters – CSI021 Indicator on Nutrients in transitional, coastal and marine waters – CSI023 Indicator on Chlorophyll in transitional, coastal and marine waters – MAR001 Indicator on Hazardous substances in marine organism – Regional Sea Conventions monitoring networks

Annex 2 Datasets and indicators available to assess the pressures on pan-European ecosystems

Table A2.1 Main pressures threatening ecosystems caused by habitat change and the measures used to assess their effects

			Habitat change							
Pressure	**Indicator**	**Datasets**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
Habitat quality change according to Habitat Directive & Natura 2000	Conservation status of habitats of European conservation importance	Article 17, article 12 coverage trends, assessment conclusion (FV, U1,...) Natura 2000 level of habitat conservation, threat level (H,M,L)	*	*	*	*	*	**	*	2001–2006
Species quality according to Habitat Directive & Natura 2000	Conservation status of species of European conservation importance	Article 17, article 12, population trends, assessment conclusion (decreasing, stable, decreasing) N 2000 level of species conservation, threat level (H,M,L)	*	*	*	*	*	*	*	2001–2006
Human activity related to habitat change pressure	Degrees of impact of human managed areas vs. conservation	HD and BD reporting obligation. Natura 2000	**	**	**	**	*	*	**	2006–2012
Changes in species distribution and number	Species threat and trends	IUCN European assessments	**	0	0	0	*	*	*	2008–2011
Changes in species distribution and number	Bird species threat and trends	BirdLife international database	**	0	0	0	*	*	*	2008–2011
Changes in land use	Assessment of Land cover change	CLC 2000, 2006 and LEAC tools	**	**	**	**	*	**	--	2000, 2006
Changes in land use	Land cover change	CLC 1990, 2000 and 2006, and upcoming 2012	*	**	*	*	*	*	--	1990, 2000, 2006, 2012 (upcoming)
Changes in land use	Phenological changes — change appreciation in specific ecosystems	HANTS NDVI 2000–2012	**	*	0	*	*	--	--	2001–2012, 16-day period
Level of fragmentation	Grid size; Grid density; Distance to other grids	Landscape fragmentation map (EEA), Forest fragmentation (JRC), Land accounts, land use change (in time), land take	**	**	**	**	**	--	--	2006, 2009, 2012

Table A2.1 Main pressures threatening ecosystems caused by habitat change and the measures used to assess their effects (cont.)

			Habitat change							
Pressure	**Indicator**	**Datasets**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
Fragmentation	Forest fragmentation or forest connectivity change	Forest Landscape in Europe: Pattern, Fragmentation and Connectivity	--	--	**	**	**	--	--	1990–2000 –2006
Farming sustainability	Organic farming	IRENA 7	*	--	--	--	--	--	--	1997–2011
Loss in soil quality	Loss of agriculture/ soil quality (related to management)	Annual per capita and total national losses of cropland productivity potential in EU Member States expressed in wheat yield equivalents (2000–2006).	*	--	--	--	--	--	--	2000–2006
Pressure on biodiversity in farmland	HNV farmland being an estimation of the distribution patterns on the basis of land cover and biodiversity data.	IRENA 26	**	0	--	--	--	--	--	2000
Land take proportion	Land take	CSI014, Land take indicator	**	0	0	**	*	--	--	2000-2006
Land abandonment/ lack of management	Surface /NUTS 2 affected Land cover formation /loss in time per km2	Risk of farmland abandonment (JRC), probability of occurrence, land use change (in time) CLC Land cover flows (1990-2000-2006-2012)	**	**	*	**	0	--	--	1990–2000-2006–2012
Pests and diseases	Area damaged flora/fauna	EFI , forest inventories	--	--	0	0	--	--	--	1950–2010
Physical characteristics e.g. structure of rivers (meandering, etc.)	River Fragmentation	WFD, ecological quality status/altered habitats could be used as proxy for pressures from river fragmentation, EEA major dams, loss of accessibility to migratory species due to dams in major European river basins	--	--	--	--	--	**	--	1860, 1910, 1960, 2010

Note: * = data available but not mapped; ** = mapped; 0 = no data; -- = not relevant/not applicable.

Table A2.2 Main pressures of climate change impacts on ecosystems and the data used to assess their effects

			Climate change							
Pressure	**Indicator**	**Datasets**	**Cropland**	**Grassland**	**Woodland and forest**	**Heath-land and shub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
Climate change	Temperature	Global and European temperature EEA indicator CSI012	**	**	**	**	**	**	**	Since 1850
Climate change	Precipitation	Mean precipitation EEA indicator Clim002	**	**	**	**	**	**	**	Since 1960
Extreme events	Precipitation extremes	Precipitation extremes EEA indicator Clim004	**	**	**	**	**	**	0	Since 1960
Regional sensitivity to CC effects	Level of degradation due to climate change	Environmental sensitivity to climate change — ESPON climate	**	*	**	*	**	*	**	2010
Coastal storm	Change in exposure to coastal storm surge events (ESPON CC)	Inundated areas due to coastal storms	0	0	0	0	0	*	*	2071–2100
Floods	Human induced floods (e.g. climate change, canalisation)	Change in exposure to river flooding,	0	0	0	0	*	*	0	2071–2100
Fires — extreme events	Human induced fires (e.g. climate change, human related) Forest frequency (area affected by recurrent fires/ time)	Pot. impacts on forest fires (ESPON CC), Average of forest fire density (n of fires/yr./1km²) fires history data — EFFIS), Seasonal severity index (JRC) SSR future projection (2071–2100) (JRC) http://forest.jrc.ec.europa.eu/effis/	--	--	**	**	0	--	--	2000–2100
Drought — extreme events	Induced droughts (e.g. climate change, overexploi-tation)	Pot. Impacts of climate change on soil organic carbon content	**	*	**	*	0	--	--	2071–2100
Increase in sea-surface temperature	SST	ESaTDOR — ESPON (NOAA-OI-SST)	0	0	0	0	0	0	**	1981–2011
Sea-level change	Predicted sea level change (mm / year)	EEA-hydrodynamics and sea-level rise	0	0	0	0	0	0	**	2005
Ocean acidication	Changes in ocean ph	N ceas	--	--	--	--	--	--	*	n/a

Note: * = data available but not mapped; ** = mapped; 0 = no data; -- = not relevant / not applicable.

Table A2.3 Main indicators available to assess the pressures caused by invasive species threatening ecosystems and the measures used to assess their effects

			Invasive species							
Pressure	**Indicator**	**Datasets**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
Invasive alien species	Number of invasive alien species/ country	Invasive alien species in Europe (SEBI010)	*	*	**	0	*	*	*	< 1900–2008
Invasive alien species	Proportion of alien species; pressure on native species	Alien species in Europe level of invasion of Alien plants in Europe (Chytrý et al., 2009)	*	*	**	0	**	0	*	1970–2008
Presence of alien species	Several indicators on presence (number) of alien species in terrestrial, freshwater and marine ecosystems	Number of alien species in terrestrial, freshwater and marine ecosystems in Europe — European Alien Species Information Network (EASIN) (terrestrial, freshwater, marine)	*	*	**	*	**	*	**	2000–2014
Marine alien species	2 indicators on marine alien species (MAS)	EEA is working currently developing 2 Invasive alien species (marine) MAS between 1960's and 2012 about trends in: 1) MAS (showing decadal cumulative n. of species per MSFD region 2) pathways of MAS (showing total n. of species per major pathway of primary introduction	--	--	--	--	--	--	**	1960s–2012
Marine Invasive species	Number of invasive species by shipping (10 km^2)	Number of invasive species per grid (NCEAS-ESaTDOR (ESPON))	--	--	--	--	--	--	*	n/a

Note: * = data available but not mapped; ** = mapped; 0 = no data; -- = not relevant/not applicable.

Table A2.4 Main pressures resulting from land use intensity and their threats on ecosystems and the measures used to assess their effects

			Land use/exploitation							
Pressure	**Indicator**	**Datasets**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
Forest use	Overexploi-tation of timber and non-wood products	C accounts on timber extraction	--	--	*	0	0	--	--	2000–2010
	Non-sustainable forest management	SEBI indicator 017	--	--	*	0	0	--	--	1990–2005
	Pan-European map on growing stock	Growing stock and above-ground woody biomass for coniferous and broad leaved forests	--	--	*	0	--	--	--	2000
	Average age; age groups; max. age of forest	Ancient forest data	--	--	0	--	--	--	--	Several years
Ecosystem use	Pressure on agriculture, forest and grassland ecosystem	Carbon accounts on grazing livestock	*	**	**	0	--	--	--	2000–2010
	Proportion of total population harvested	C accounts on timber extraction (ETC-SIA), Utilization rate of forests (NFI), annual felling as % of annual increment	**	**	*	0	0	--	--	2000–2010
Agricultural land use	Average grazed biomass/time	HNV farmland, HNV forest area indicator	0	**	*	0	0	--	--	2006
	Agricultural productivity/ year	Carbon accounts — arable land	**	0	--	--	--	--	--	2000–2010
	IRENA 7 Area under organic farming	Share of agricultural land under organic farming.	**	0	--	--	--	--	--	Mandatory delivery from 2008
	Agriculture intensification	High irrigated land usage	**	0	--	--	--	--	--	1990–2006
Mono-dominance	Species abundance	HD — species diversity MSFD — Biological diversity, WFD — conservation status of species in fresh, coastal and transitional waters,	**	0	*	0	*	*	0	2000–2012
Mono-dominance	Biodiversity friendly farming practices	CAPRI Arable crop index, diversity of crops, fertilizer input	**	--	--	--	--	--	--	2009
Crop yield	Maximum yield category/pixel	Average crop values [by crop type] in time in tonnes/ km^2 (ETC-SIA)	**	--	--	--	--	--	--	2000–2012
Intensive crop production — land management	Irrigation share	CAPRI irrigation share (JRC) Irrigation share (EEA) — CLC 212 Irrigation share — permanent irrigation structures (FAO)	**	0	--	--	--	--	--	2006
Loss in soil functionality	Vulnerability to loss in soil functionality	Natural capacity to support farming practices (JRC)	**	--	--	--	--	--	--	n/a

Table A2.5 Main pressures resulting from land use intensity and their threats on ecosystems and the measures used to assess their effects

			Land use/exploitation							
Pressure	**Indicator**	**Datasets**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
Loss of soil organic content	Level of soil organic carbon content	Topsoil organic carbon content (OC_TOP) — (t/ha)	0	0	*	*	0	--	--	Several years
Soil erosion	Vulnerability to soil erosion	Database of Hydraulic Properties of European Soils (HYPRES)	*	*	*	*	0	--	--	Several years
Soil hardening	Soil hardness/ compactness	Susceptibility of soil compaction in Europe (JRC) (low, high)	*	*	*	*	0	--	--	N7a
Loss in soil drainage capacity	Soil water content	Soil data (ISRIC-WISE), soil drainage class	*	0	*	0	0	--	--	n/a
Aridification	Water flow efficiency -> drainage	WFD water flow capacity	--	--	--	--	**	*	--	2006
Distortion hydrological cycle	General status hydrological cycle	EEA major dams — loss of accessibility, WFD % of classified water bodies impacted by hydromorphological pressures FW, transitional, coastal waters	--	--	--	--	0	*	0	1700–2000
Sea use	Proportion of total population harvested	FAO fishstat, proportion of fish stocks outside safe biological limits (EEA)	--	--	--	--	--	--	*	2000–2010
Excess harvesting of marine fish	Overfishing	Regional fish stock assessments status of marine fish stocks (CSI032)	--	--	--	--	--	--	**	2008–2009
Intensity of marine use	Intensity of maritime shipping	Density of shipping lanes, freight transport by direction, cruise traffic (CEAS-Eurostat — GISCO)	--	--	--	--	--	--	**	2004–2008
Catch intensity	Total catch in ICES and CFCM fishing regions in Europe	Total catch in ICES and GFCM fishing regions of Europe	--	--	--	--	--	--	**	2002–2009
Martitime impact on population	Population density impacted by maritime activities:	Share of the population of the EU regions living in maritime service areas (Eurostat).	--	--	--	--	--	--	*	2006
Marine aquaculture production	Marine aquaculture production relative to coastline length	Volume (tonnes) per km	--	--	--	--	--	--	**	2008

Note: * = data available but not mapped; ** = mapped; 0 = no data; -- = not relevant / not applicable.

Table A2.6 Main pressures resulting from air pollution and nutrient enrichment change threatening ecosystems and the measures used to assess their effects

			Pollution and nutrient enrichment							
Pressure	**Indicator**	**Datasets**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
Air pollution	Concentration of NO_2/ NH_3/SO_2/O_3, eutrophication, acidification	Air Quality Directive, NEC Directive, LRTAP Exposure of ecosystems to acidification, eutrophication and ozone EEA indicator CSI005	**	**	**	**	**	0	0	1980, 1990, 1996–2011
Ozone levels	Critical levels of ozone	Damage assessment to forests, crops, natural vegetation, soils, surface and groundwater	*	*	0	0	0	0	--	n/a
Soil nutrient enrichment	N,P content	N, P accounts (ETC-SIA) : change in N/P deposition in ecosystems in time (kg/h/year) ISRIC-WISE → N content	**	**	**	**	**	--	--	2000–2010
Pesticides content	HAIR2010 — Harmonized Environmental Indicators for Pesticide Risk	Exceedance of pesticides in soils	*	0	0	0	0	--	--	Depending on input data
Heavy metals content	Heavy metals (changes in soil metal content are model based)	Concentration of heavy metal components in arable land and grassland (ETC-SIA)	**	**	--	--	--	--	--	2000–2050
Soil salinization	Salinity	Soil salinisation map of Europe (JRC), concentration	*	*	--	--	--	--	--	2009
Emission of heavy metals	Emissions of mercury and cadmium to water	Based on E-PRTR reporting of 2007 data — Member State reporting (Art. 7)	--	--	--	--	--	*	--	2007
Hazardous substances	Hazardous substance levels in biota, sediments, and sea water	EEA waterbase/WFD	--	--	--	--	--	--	*	1998–2010
Inorganic marine pollution	Volume of contamination	Total kg of contaminants per year	--	--	--	--	--	--	**	2006
Organic pollution	Volumes of organic contaminants	Total kg of pesticides per year	--	--	--	--	--	--	**	n/a
Water pollution	Point sources of water pollution	Urban Waste Water Treatment Directive (UWWTD) http://www.eea.europa.eu/data-and-maps/data/waterbase-uwwtd-urban-waste-water-treatment-directive-3					*	*		Since 2009
Maritime accident density	Proxy to pollution in the sea	Number of accident density in the seas around the EU (EMSA)	--	--	--	--	--	--	*	2009
Marine pollution	Oil spill pollution	Location and quantity of the major oil spill incidents (EMSA /ITOPF)	--	--	--	--	--	--	*	2012

Note: * = data available but not mapped; ** = mapped; 0 = no data; -- = not relevant / not applicable.

Annex 3 Datasets and indicators available to assess the condition of pan-European ecosystems

Table A3.1 Main datasets and indicators to be used in the assessment of ecosystems condition and trends

			Condition and trends							
Ecosystem	**Indicator**	**Datasets/indicator**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
General	Habitat Directive Article 17	Population category and trend (species) Coverage category and trends (habitats)	*	*	**	*	*	*	*	2000–2012
General	Birds Directive Article 12	Status of conservation of wild bird species naturally occurring in the Union	*	*	*	*	*	*	*	2012
General	Natura 2000	Status of conservation of natural habitats and wild fauna and flora	**	**	**	**	**	--	*	2000–2012
General	IUCN European species assessment	Status of conservation and trends of plants and animal species in Europe	*	--	--	--	--	--	--	Several years
Surface	Ecosystem size	Pan-European ecosystem map (EEA, ETC-SIA)	**	**	**	**	**	*	--	2006, 2012
Ecological quality status/ surface (ha)	Ecosystem quality (if data only available at level of ecosystem type)	Pan-European ecosystem condition map (EEA, ETC-SIA)	*	*	*	*	*	*	*	2006
Agro-ecosystems	CAP — Good Agricultural Ecological condition (GAEC)	Minimum soil cover, appropriate machinery use, use of adequate rotation crops, level of protection of permanent pasture, level of water protection against pollution, level of unwanted vegetation in agricultural land	*	*	--	--	--	--	--	n/a
Woodland and forest ecosystems	Forest biomass	Forest quality, Forest growing stock (Gallaun, et al., 2010)	--	--	*	--	--	--	--	2009
FW, transitional, and coastal waters	WFD — Ecological status	% classified less than GES surface water bodies in Europe	--	--	--	--	--	**	*	2000–2012
Woodland and forest ecosystems	Naturalness of forests	HNV forest area Biogeographical regions, Tree species maps (EFI) Forest type suitability map (JRC)	--	--	**	--	--	--	--	2009

Table A3.1 Main datasets and indicators to be used in the assessment of ecosystems condition and trends (cont.)

			Condition and trends							
Ecosystem	**Indicator**	**Datasets/indicator**	**Cropland**	**Grassland**	**Woodland and forest**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Marine**	**Reference year**
FW, transitional, and coastal waters	WFD — Nitrogen and phosphorous concentrations in rivers	Waterbase WFD: mean annual nitrates in rivers reported by Member State SEBI009 indicator on critical load exceedance for nitrogen	--	--	--	--	*	**	--	2000–2012
FW, transitional, and coastal waters	WFD — Chemical status	% of water bodies not achieving good chemical status in transitional and coastal waters (WISE-WFD)	--	--	--	--	*	**	*	2000–2012
FW, transitional, and coastal waters	WFD — Nitrate concentrations in groundwater	WFD	--	--	--	--	--	*	--	2000–2012
FW, transitional, and coastal waters	WFD — Phosphorous concentrations in lakes	WFD: annual mean phosphorous and nitrate concentration in water bodies	--	--	--	--	--	*	--	2000-2012
FW, transitional, and coastal waters	WFD — Nitrate and phosphate concentrations in coastal water	WFD: trends for nitrogen and phosphorous concentrations in open marine, coastal and transitional waters MSFD: The MSFD pressure analysis will define how widely the land-based pressures namely nutrient loading from rivers and atmospheric deposition of nitrogen are impacting the marine environment.	--	--	--	--	--	--	*	2000-2012
FW, lakes, transitional, and coastal waters	WFD — % of natural, heavily modified, artificial and unknown status for river, lake, transitional and coastal water bodies	% of classified heavily modified and artificial bodies	--	--	--	--	--	*	--	2000-2012
Coastal and marine	Bathing water quality — Bathing water Directive	Water quality during bathing season reported by Member State	--	--	--	--	--	--	**	1990-2014
Marine ecosystems	MSFD — Biological diversity	Quality and occurrence of habitats, abundance of species, low levels of non-indigenous species	--	--	--	--	--	--	**	2012
Marine ecosystems	Flagship species abundance (EMODNET biology)	Species density per ecoregion	--	--	--	--	--	--	*	2002–2011
Marine ecosystems	Diffuse attenuation coefficients (JRC-EMIS)	Transparency of the water column	--	--	--	--	--	--	*	2002–2012
Marine ecosystems	Chlorophyll concentration (JRC-EMIS)	Annual average chlorophyll concentration based on satellite observations (EOS MODIS-A (NASA GSFC))	--	--	--	--	--	--	*	2002–2012

Note: * = data available but not mapped; ** = mapped; 0 = no data; -- = not relevant / not applicable.

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