JRC SCIENCE FOR POLICY REPORT

Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment

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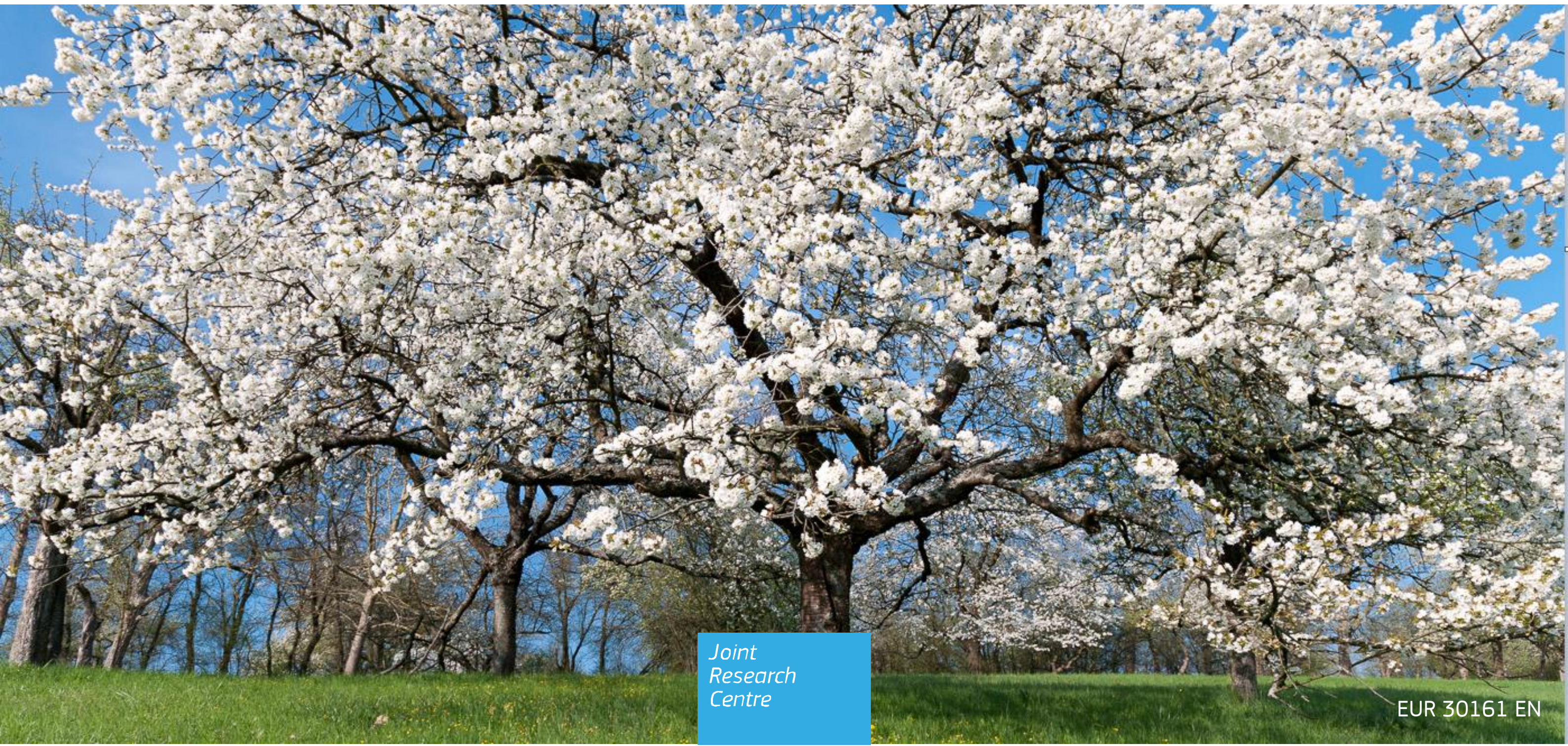
Joint Research Centre, European Environment Agency, DG Environment, European Topic Centre on Biological Diversity, European Topic Centre on Urban, Land and Soil Systems

2020



EUR 30161 EN

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EU Science Hub
https://ec.europa.eu/jrc

JRC120383

EUR 30161 EN

PDF ISBN 978-92-76-17833-0 ISSN 1831-9424 doi:10.2760/757183

Luxembourg: Publications Office of the European Union, 2020

How to cite this report:
Maes, J., Teller, A., Erhard, M., Condé, S., Vallecillo, S., Barredo, J.I., Paracchini, M.L., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A.M., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A.I., Ivits, E., Mauri, A., Rega, C., Czúcz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J.V., Spinoni, J., Cammalleri, C., Bastrup-Birk, A., San Miguel, J., San Román, S., Kristensen, P., Christiansen, T., Zal, N., de Roo, A., Cardoso, A.C., Pistocchi, A., Del Barrio Alvarellos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Robert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O., Santos-Martín, F., *Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment*, EUR 30161 EN, Publications Office of the European Union, Ispra, 2020, ISBN 978-92-76-17833-0, doi:10.2760/757183, JRC120383.

Contents

Abstract

This report presents an ecosystem assessment covering the total land area of the EU as well as the EU marine regions. The assessment is carried out by Joint Research Centre, European Environment Agency, DG Environment, and the European Topic Centres on Biological Diversity and on Urban, Land and Soil Systems.

This report constitutes a knowledge base which can support the evaluation of the 2020 biodiversity targets. It also provides a data foundation for future assessments and policy developments, in particular with respect to the ecosystem restoration agenda for the next decade (2020-2030).

The report presents an analysis of the pressures and condition of terrestrial, freshwater and marine ecosystems using a single, comparable methodology based on European data on trends of pressures and condition relative to the policy baseline 2010.

The following main conclusions are drawn:

- Pressures on ecosystems exhibit different trends.
- Land take, atmospheric emissions of air pollutants and critical loads of nitrogen are decreasing but the absolute values of all these pressures remain too high.
- Impacts from climate change on ecosystems are increasing.
- Invasive alien species of union concern are observed in all ecosystems, but their impact is particularly high in urban ecosystems and grasslands.
- Pressures from overfishing activities and marine pollution are still high.
- In the long term, air and freshwater quality is improving.
- In forests and agroecosystems, which represent over 80% of the EU territory, there are improvements in structural condition indicators (biomass, deadwood, area under organic farming) relative to the baseline year 2010 but some key bio-indicators such as tree-crown defoliation continue to increase. This indicates that ecosystem condition is not improving.
- Species-related indicators show no progress or further declines, particularly in agroecosystems.

The analysis of trends in ecosystem services concluded that the current potential of ecosystems to deliver timber, protection against floods, crop pollination, and nature-based recreation is equal to or lower than the baseline value for 2010. At the same time, the demand for these services has significantly increased. A lowered potential in combination with a higher demand risks to further decrease the condition of ecosystems and their contribution to human well-being.

Despite the wide coverage of environmental legislation in the EU, there are still large gaps in the legal protection of ecosystems. On land, 76% of the area of terrestrial ecosystems, mainly forests, agroecosystems and urban ecosystems, are excluded from a legal designation under the Bird and Habitat Directives.

Freshwater and marine ecosystems are subject to specific protection measures under the Water Framework and Marine Strategy Framework Directives. The condition of ecosystems that are under legal designation is unfavourable.

More efforts are needed to bend the curve of biodiversity loss and ecosystem degradation and to put ecosystems on a path to recovery.

The progress that is made in certain areas such as pollution reduction, increasing air and water quality, increasing share of organic farming, the expansion of forests, and the efforts to maintain marine fish stocks at sustainable levels show that a persistent implementation of policies can be effective. These successes should encourage us to act now and to put forward an ambitious plan for the restoration of Europe's ecosystems.

Acknowledgements

The authors wish to thank all the reviewers that commented on the first draft of this report. Their comments improved the quality of this report. This report could not have been made without the daily efforts of many colleagues and staff members of the European Commission and the European Environment Agency who collect, harmonise, analyse and make available high-quality environmental data on land, air, water, soil, ecosystems and biodiversity.

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On 19 September 2020 Prof. Georgina Mace passed away. Her research has deeply inspired this report. Her scientific ideas and excellence will continue to influence how we think about nature.

Executive summary

Background and context

Europe's ecosystems, on which we depend for food, timber, clean air, clean water, climate regulation and recreation, suffer from unrelenting pressures caused by intensive land or sea use, climate change, pollution, overexploitation and invasive alien species. **Ensuring that ecosystems achieve or maintain a healthy state or a good condition is thus a key requirement to secure the sustainability of human activities and human well-being**. This guiding principle applies for all ecosystems including marine and freshwater ecosystems, natural and semi-natural areas such as wetlands or heathlands but also managed ecosystems such as forests, farmlands and urban green spaces.

Knowledge about ecosystem condition, the factors that improve or decline that condition, and the impacts on ecosystem services, with the benefits they deliver to people, is key to effective management, decision-making and policy design. Such an understanding helps target actions for conservation or restoration and more broadly sustainable use.

The Biodiversity Strategy to 2020 includes the development of an integrated framework to monitor whether the actions undertaken are delivering on the ground. **This assessment presents the changes in pressures and ecosystem condition in the EU and its marine regions using the year 2010 as a policy baseline.** The following ecosystems are analysed: urban ecosystems, agroecosystems (croplands and grasslands), forests, wetlands, heathlands and shrub, sparsely vegetated lands, rivers and lakes, and marine ecosystems. The assessment is based on the best available European data. In addition, this report contains crosscutting assessments on climate change, invasive alien species, landscape mosaic, soil and ecosystem services.

General results

Marine ecosystems are the most extended ecosystem type in the EU (5.8 million km^2). On land (4.4 million km^2, according to the Corine Land Cover data 2018), forests (36%) and cropland (36%) are the dominant ecosystem types in the EU, followed by grasslands (11%), urban areas, (5%) heathlands and shrub (4%), rivers and lakes (2.5%), inland wetlands (2%) and sparsely vegetated land (1.5%). In terms of land cover changes, the extent of most ecosystem types has reached a rather stable value over the last 10 years apart from urban areas, which increased in size with a rate of 3.4% per decade. Agroecosystems, inland wetlands, heathlands and shrub slightly decreased since 2010 (<1% per decade).

Despite the wide coverage of environmental legislation in the EU, **there are still large gaps in the legal protection of ecosystems.** On land, 76% of the area of terrestrial ecosystems, mainly forests, agroecosystems and urban ecosystems, are excluded from a legal designation under the Bird and Habitat Directives. Freshwater and marine ecosystems are subject to specific protection measures under the Water Framework and Marine Strategy Framework Directives. **The condition of ecosystems that are under legal designation is largely unfavourable**. This conclusion is based on the data from recent reporting from the Member States on the conservation status of habitats, and the chemical and ecological status of water bodies. The share of habitats that reaches a favourable conservation status remains very low and varies between 3 and 25%. The share of freshwater bodies reaching at least a good chemical status is 36%, the share of freshwater bodies reaching at least a good ecological status is 39%.

The analysis of trends in pressures on ecosystems shows a mixed picture. Despite declining trends in land take, atmospheric emissions of air pollutants and critical loads of nitrogen, the absolute values of all these pressures remain high and further reductions are needed. Impacts from climate change on ecosystems are increasing. Of specific concern are the rising land and sea surface temperatures, the reduction in effective rainfall, the higher incidence of extreme drought events and the further acidification of marine ecosystems relative to the 2010 baseline values. Invasive alien species of union concern are observed in all ecosystems. Their impact is particularly high in urban ecosystems and grasslands. When considering habitats protected by the Habitats Directive, invasive alien species of union concern are most often reported by member states in coastal habitats, followed by forest and freshwater habitats. Pressures from overfishing activities and marine pollution are high, leading to degradation and loss of marine biodiversity and habitats. Despite downward trends of emissions of nitrogen and phosphorus to the environment, **the combination of these pressures and their possible**

interactions with climate change and the further spread of invasive alien species are causing serious threat to the EU's biodiversity and ecosystems.

The analysis of trends in ecosystem condition delivers also a mixed outcome. In the long term, **air and freshwater quality is improving**. In forests and agroecosystems, which represent over 80% of the EU territory, there are improvements in structural condition indicators (biomass, deadwood, area under organic farming) relative to the baseline year 2010 but some key bio-indicators such as tree-crown defoliation continue to increase. This indicates that **ecosystem condition is not improving**. **Species-related indicators show no progress or further declines, particularly in agroecosystems.**

The analysis of trends in ecosystem services concluded that **the current potential of ecosystems to deliver timber, protection against floods, crop pollination, and nature based recreation is equal to or lower than the baseline value for 2010.** At the same time, the demand for these services has significantly increased. A lowered potential in combination with a higher demand creates risks of further eroding the condition of ecosystems and their contribution to human well-being.

<u>Results per ecosystem type</u>

Forests cover about 36% of the EU land area and are the most important reservoir of terrestrial biodiversity. Forest habitats protected under the Habitats Directive cover 28% of the total forest area. Within this area, only **14.1% of forest habitats are in a favourable conservation status**. Forests are exposed to major pressures. Changes in climate and forest cover loss (due to wildfire, storms, harvesting) have been increased notably. Likewise, pollutants remain a concern even if the trends point in the right direction. Invasive alien species and insect infestations are a serious concern. The **condition of forest is, on average, considered as degraded**. For example, one out of four trees (25%) shows defoliation levels indicating damage. Additionally, the trend in defoliation is upward, resulting in further degradation. Only **between 2% and 4% of forests are primary forests undisturbed by man.** The abundance of common forest birds did not show significant changes in the long-term. A 3% decrease was reported since 1990 and 4% since 1980. Some indicators point in the right direction: forest area, biomass (growing stock), productivity, and dead wood. The ratio between forest available for wood supply and protected forests in the EU is 6:1. So **for each square kilometre of protected forests there are six square kilometres of potentially productive forest land**.

Agroecosystems cover about 48% of the EU land area (36.4% cropland and 11.4% grassland). They include land area under agricultural management: annual and permanent crops cultivation, land temporarily fallow, horticulture, pastures, meadows and natural grasslands, as well as semi-natural habitats such as field margins, hedges, grass strips, lines of trees, patches of uncultivated land. Grassland habitats protected under the Habitats Directive cover 46% of the total grassland area. Within this area, **only 14.3% of grassland habitats are in a favourable conservation status and 83% of habitats dependent on adequate agricultural management are in inadequate conservation status. Pressures on agroecosystems are still high**. At EU level, gross nitrogen balance is stable at 50 kg/ha, pesticide sales remain at a constant but high level of 380 000 tonnes/year, the consumption of mineral fertilisers has increased by 15% in 10 years. Improvements are recorded in a diminishing atmospheric nitrogen deposition and nitrogen concentration in ground water but nutrient levels remain too high. The impact of climate change is multiple: longer growing season, increasing number of summer days, increasing frequency of drought events, increasing temperatures in winter. In summary, there is evidence of a northwards migration of agro-climatic zones (100 km in 10 years; replacement of West-Continental zone by the Atlantic Zone). Eighteen square meters of agricultural land is lost per second to urbanization in the EU. **Structural condition indicators** (landscape mosaic, crop diversity, share of dominant crop, high nature value farmland, and share of protected agroecosystems) **are stable**; organic farming has notably increased reaching 7.03% of the utilized agricultural area. **The farmland bird index and the grassland butterfly index show a further loss (long-term changes of -13.5% per decade and -21.6% per decade respectively).** Since the start of the observations in 1990, the farmland bird index declined with 33% and the grassland butterfly with 39%.

Heathlands and shrubs cover about 4% of the total EU land area; this is less than 10% of their estimated area in 1800. Almost 70% of the total area of heathland and shrub are habitats protected under the Habitats

Directive. **Only 14.3% of heath and scrub habitats and 21.2% of sclerophyllous scrubs habitats are in favourable conservation status.** In the most recent period, the level of pressures is slowing down. Land take mainly from construction and mining decreased with 68% relative to the baseline year 2010 (with 36% relative to 2000). Atmospheric nitrogen deposition dropped by 22%. However, a **low and chronic nitrogen input might still affect ecological functions as heathlands are very sensitive to eutrophication**. There is an increasing trend in fires (also used in management). The coverage of heathlands by protected areas remains stable with 41% of their area covered. The condition of heathlands and shrubs remains stable for 70% of their area.

Sparsely vegetated ecosystems (covered by bare or sparsely vegetated rock, lava, ice and snow of cliffs, screes, caves, volcanoes, glaciers and snow-fields, dunes, beaches and sand plains) cover about 1.5% or the total EU land area. Of this area, 54% coincides with habitats protected under the Habitat Directive. **25.4% of rocky habitats is in favourable conservation status.** Pressures are, on average, declining with notable less land take. Their level of protection is relatively high (53% of the area) while the condition remains largely unchanged.

Inland **wetlands** (peatlands and marshes) cover about 2% of the EU land area but an extended wetlands definition that also includes coastal wetlands and other wet ecosystems yields a percentage that is four times higher. **Wetlands represent the ecosystem with the worst condition in Europe**. Although all wetlands are protected by the Habitats Directive, only 10.7% of bogs, mire and fens habitats is in favourable conservation status**.** There is no evidence that pressures and condition are improving. For example, changes in precipitation and rising temperatures are contributing to declining wetlands condition and they impact their capacity to provide key ecosystem services, among others namely carbon retention and flood regulation.

Urban ecosystems cover about 5% of the EU land area but their immediate impact stretches well beyond their boundaries. Therefore, the system of functional urban areas, which cover 22.5% of the EU land area, was used in the assessment to analyse trends in pressure and condition. Urban ecosystems are experiencing increasing pressures. The trends in condition of urban ecosystems suggest degradation**. Urban expansion occurs at the cost of agroecosystems and natural areas such as forests**.

Rivers and lakes cover about 2.5% of the EU land area. Including riparian areas in the delineation of rivers and lakes results in a coverage of 7.5% of the EU land area. Of this extended area, 22% consists of freshwater habitats protected by the Habitats Directive. The share of freshwater habitats in favourable conservation status is 18.4%. Only 36% of water bodies is in good chemical status; 39% of water bodies is in good or high ecological status. **The resulting conclusion is that a large part of rivers and lakes are not in a good condition.** The assessment finds that while some pressures have decreased, showing the effectiveness of policy implementation, the level of anthropogenic pressures on aquatic ecosystems remains high, thus hindering their recovery. **In particular, riparian habitats are impacted by land take**.

Marine ecosystems outnumber terrestrial and freshwater ecosystem in terms of their extent. Nine percent of the EU marine regions is covered with coastal and marine habitats protected under the Habitats Directive but the number of habitats in favourable conservation status is particularly low (2.9%). Just over 70% of the habitats is in an unfavourable conservation status; the remaining share has an unknown status. Climate change is affecting all European seas. Data gaps limited the analysis of trends in the inputs of nutrients, contaminants and litter. EU fishing is becoming more sustainable, but many stocks are still overexploited. **Pressure from fishing activities is high in the Mediterranean Sea and Black Sea** while there is a decrease in the fishing pressure in the North East Atlantic Ocean and the Baltic Sea, with recovery of some stocks. There was insufficient monitoring data to infer conclusions about invasive alien species. The assessment of trends in ecosystem condition suffered from **substantial knowledge gaps** with respect to terrestrial and freshwater ecosystems. In particular, there was a significant disparity in knowledge and data availability (monitoring) for the North East Atlantic Ocean and Baltic Sea versus the Mediterranean and Black Sea.

Soils are estimated to cover 4,153,047 km2 of the EU's terrestrial ecosystems (or 94.4%). Organic soils, more commonly referred to as peatlands, account for around 6.5% of the soil area. The remaining 93.5% are mineral soils. Soils are under pressure from urban expansion (resulting in soil sealing and loss of function), intensive agriculture (resulting in compaction, loss of organic matter, loss of biodiversity, contamination, and increased soil erosion) and industrial pollution (from both local and diffuse sources). This assessment reports trends for two key soil indicators: soil erosion and soil organic carbon. The short-term soil erosion rates in 2016 show a limited decrease of 0.4% in all lands and 0.8% in arable lands compared to 2010. Long-term trends (2000-2010) report a stronger decrease in soil erosion by water, falling by 9% in all lands and 19% on arable land (driven largely by the implementation of erosion reduction measures under the common agricultural policy). However, **soil erosion by water across the EU** (2.45 tonne per ha per year) **is above accepted soil formation rates** (between 1.4 and 2 tonne per ha per year), **which means that the soil ecosystem will continue to degrade**. Mineral cropland soils exhibit the lowest soil carbon stocks of all land cover types apart from artificial areas and may already have reached a minimum equilibrium. **Croplands and grassland soils exhibit a slight decrease in soil organic carbon stocks between 2009 and 2015** of about 0.06% and 0.04% respectively, but with marked regional differences.

Next steps

More efforts are needed to bend the curve of biodiversity loss and ecosystem degradation and to put ecosystems on a recovery path. The progress that is made in certain areas such as pollution reduction, increasing air and water quality, increasing share of organic farming, the expansion of forests, and the efforts to maintain marine fish stocks at sustainable levels show that a persistent implementation of policies can be effective. These successes should encourage us to act now and to put forward an ambitious plan for the restoration of Europe's ecosystems.

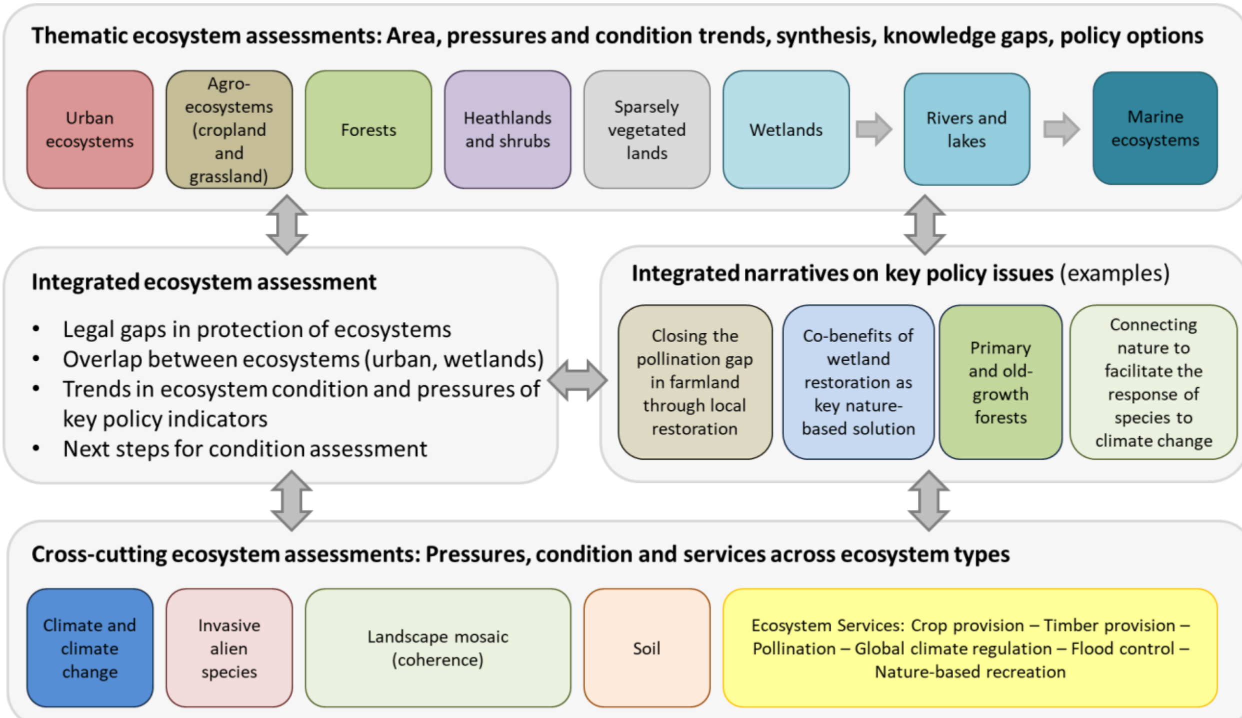
This report is a first but necessary step to better describe and understand the condition and trends of ecosystems. It delivers a basis for future assessments based on available European datasets. All indicators for which trends have been analysed are delivered with an indicator fact sheet and with the option to use the data for further work.

This report used 2010 as a policy baseline against which changes in pressures and ecosystem condition are evaluated. However, **subsequent work is needed to set a reference condition to compare the past, current or future condition of ecosystem and to decide on a favourable target value**. Such an evaluation should ideally be based on a minimum set of key indicators which capture the full breath of ecosystem condition and which can be used to monitor ecosystems over time. It also requires a scientifically robust aggregation scheme or decision framework for aggregating different indicators into a single conclusion about the condition of ecosystems.

The capacity of the EU to **monitor biodiversity and ecosystems needs to be enhanced**. A better biodiversity and ecosystem monitoring system is essential not only to support possible legislation on ecosystem restoration but also to help implement existing legislations and better connect existing actions that are dependent on knowledge about key biodiversity and ecosystem parameters.

Increased monitoring of biodiversity and ecosystems requires an updated data infrastructure that allows access to a wide variety of information sources that produces regular updates on pressures, biodiversity, ecosystem condition and ecosystem services. An international framework for organizing ecosystem data is currently under revision and once ready can be used as a standard within the EU. The System of Environmental Economic-Accounting – Experimental Ecosystem Accounting defines an integrated statistical framework for organising biophysical data, tracking changes in ecosystem extent, condition and services and linking this information to economic and other human activities. This standard, which is relevant for both public and corporate accounting systems to facilitate sustainable investments, is essential to mainstream biodiversity and ecosystems in the reference scenarios and models used for policy and decision-making on climate, agriculture, energy, or transport.

How was the assessment organised? The ecosystem assessment is designed in four main parts: 1) thematic ecosystem assessments, 2) crosscutting assessments, 3) an integrated assessment and 4) integrated narratives on key policy issues. The thematic ecosystem assessments describe the trends of the condition of different ecosystem types. The crosscutting assessments feed the thematic assessments with specific datasets but also provide a stand-alone analysis on their topic. The integrated assessment presents a summary of the different assessments. Concrete examples or story lines (integrated narratives) show how the knowledge generated by this assessment can support policies and existing gaps emphasising need for action.



How were the trends in pressures and ecosystem condition analysed? The different thematic ecosystem assessments used indicators to analyse trends in the pressures on ecosystems and in ecosystem condition. Every pressure and condition indicator used in this assessment has been analysed for short-term (since 2010) and long-term trends (before 2010). The assessment teams investigated the presence of upward (improvement) or downward (degradation) or no trends (no change). The analysis was based on relevance of the change (changes higher than 5% over 10 years) and statistical significance. Each indicator was also subject of a confidence analysis, to determine how reliable the data lend themselves to making statements about the trends in ecosystems.

1 Introduction

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1.1 Context

1.1.1 The EU Biodiversity Strategy to 2020 and Action 5

In 2011 the European Union adopted a Biodiversity Strategy to 2020 (European Commission, 2011) with the aim to halt the loss of biodiversity and ecosystem services in the EU and help to stop global biodiversity loss by 2020. It reflected the commitments taken by the EU in 2010, within the international Convention on Biological Diversity (CBD). The strategy introduced an ecosystems framework to biodiversity policy under its target 2 complementing the efforts to conserve threatened habitats and species. Target 2 states 'by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems'.

Action 5 of the Strategy, better known as Mapping and Assessment of Ecosystems and their Services (MAES), states 'Member States, with the assistance of the Commission, to map and assess the state of ecosystems and their services in their national territory, 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'. The work formally started on 22 September 2011 with a stakeholder workshop in Brussels.

Assistance of the Commission as stated in Action 5 comprises a supplementary EU-wide ecosystem condition and service assessment, the objective of this report. Additionally specific actions were set up, together with the Member States, scientific experts and stakeholders to put the ambitions into practise and to ensure a better protection of ecosystems and their services. These actions include the Horizon 2020 research project ESMERALDA (Burkhard et al., 2018) to provide methodology and case studies for ecosystem service assessments and the Knowledge Innovation Project on an Integrated system of Natural Capital and ecosystem services Accounting in the EU (KIP-INCA) coordinated by Eurostat to develop an ecosystem accounting framework and pilot accounts.

In the same period, several countries were performing national ecosystem assessments using the framework of the Millennium Ecosystem Assessment (MA, 2005) or The Economics of Ecosystems and Biodiversity (TEEB, 2010). Importantly, also the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was founded in 2012. Clearly, all these initiatives could kick start the science and policy needed to develop a joint EU approach to policy relevant ecosystem assessment.

MAES has delivered several key outcomes. A first major outcome constitutes a series of reports that help Member States and stakeholders carry out a national ecosystem assessment (see references to the MAES reports) together with a first overview on pressures and conditions linked to the mid-term review of the Strategy (EEA, 2016). The main outcomes are an agreed analytical framework including standards and indicators for mapping ecosystem condition and ecosystem services. The conceptual framework is linking biodiversity to people and is used as a common integrated ecosystem assessment framework. Standards include a typology of ecosystems (including seven terrestrial ecosystem types, one freshwater type and four marine types) and a typology for ecosystem services, which allows for inclusion in accounting frameworks (i.e. CICES - the Common International Classification of Ecosystem Services). Guidance on indicators is available for assessing ecosystem condition and ecosystem services per ecosystem type.

A second achievement is the wide implementation of this guidance in all the Member States, despite its voluntary nature. Implementation in EU countries has been followed on a regular basis using a set of 26 indicators that measured progress on the scientific and policy developments of MAES at national level (European Commission, 2019). The level of implementation of Action 5, measured in September 2019, is over 70 percent overall.

A third key outcome has been the guidance on how to integrate ecosystem knowledge collected under Action 5 in different policies at EU and national level. More specifically, guidance has been developed to mainstream green infrastructure and ecosystem services into decision making (European Commission, 2019).

What is still missing is a final assessment of the state and trends of ecosystems at EU aggregated level using the MAES analytical framework as method to make this evaluation. They key question is how ecosystems have changed over the last decades as a response to pressures and how have these changes impacted people through the altered delivery of ecosystem services. This report fills this gap. This report is providing the evidence base for the final evaluation of the EU Biodiversity Strategy to 2020 at EU level due in December 2020, which will assess whether the foreseen actions have been effective and targets met.

1.1.2 What do we know about the state and trends of ecosystems in Europe?

Since 2010, new evidence on the state and trends of ecosystems in Europe and globally has been revealed. First and foremost, IPBES has carried out a series of global and regional assessments to understand the state of biodiversity and the ecosystem services it provides to society. A special report analysed the situation in Europe and Central Asia (IPBES, 2018) relative to a baseline situation in 1970. The authors concluded that the biodiversity in Europe and Central Asia is in continuous strong decline. The extent of natural ecosystems decreased, in particular of wetlands that suffered a decline of 50%. Also natural and semi-natural grasslands and coastal marine habitats have been degraded. Ecosystems have considerably declined in terms of species diversity. Landscapes and seascapes have become more uniform in their species composition and their diversity has been reduced.

The main driver of these processes is land/sea-use change as a result of more intense agriculture, forestry and fisheries and ongoing urbanisation. The impact of climate change on biodiversity and ecosystem services is increasing rapidly, especially in marine ecosystems and is likely to be one of the most important drivers in the future. Trends in natural resource extraction, pollution and invasive alien species have led to considerable declines in biodiversity and ecosystem services, and are likely to continue to pose considerable threats, particularly in combination with climate change (IPBES, 2018).

The dire picture on the state and trends of biodiversity and ecosystems is confirmed by other European assessments carried out as part of the obligations under several environmental EU directives. Member States have to report every six years the state of nature under the Birds and Habitats directives. The European Environment Agency collects and reports these assessments in a state of nature report (EEA, 2015). The assessments report for the period 2007-2012 assigns a favourable conservation status to only 16% of the habitats. 77% of the EU's most vulnerable habitats are in an unfavourable conservation status. Protected species score slightly better. 23% of 2665 EU regional species assessments (excluding birds) delivered a favourable conservation status. Bird species are considered in a separate assessment foreseen under the Birds Directive. Whereas 52% of bird species assessed have a secure population in the EU, still 17% are threatened and 15% a near threatened, declining or depleted population (EEA, 2015).

Freshwater ecosystems are not only covered by the Habitats Directive but are also the subject of dedicated legislation under the Water Framework Directive (WFD). The latest assessment results indicate that around 40% of surface waters (rivers, lakes and transitional and coastal waters) are in good ecological status, and only 38% are in good chemical status (EEA, 2018).

1.1.3 The European Green Deal and the EU Biodiversity Strategy to 2030

In December 2019 the European Commission proposed a European Green Deal (European Commission, 2019). It sets Europe to a path towards climate neutrality by 2050 and defines actions to reach that goal. Preserving and restoring ecosystems is central to the Green Deal. On 20 May 2020, the Commission adopted an EU Biodiversity Strategy for 2030 (European Commission, 2020). The strategy presents an ambitious agenda on bending the trend in biodiversity loss with increasing emphasis on ecosystem restoration. Ecosystems are seen as solutions, not only to protect biodiversity but also to enhance carbon uptake and contribute to climate change mitigation a well as to deliver essential benefits to people, agriculture, and the economy (Maes and Jacobs, 2017). The UN declared the next decade as the decade of ecosystem restoration. A key objective of the 2030 Biodiversity Strategy is to set up an EU Nature Restoration Plan. This plan proposes to carry out an impact assessment for legally binding EU nature restoration targets. These targets need to factor in baseline data and reference levels of the condition of ecosystems. The impact assessment will also look at the possibility of an EU-wide methodology to map, assess and achieve good condition of ecosystems so they can deliver benefits such as climate regulation, water regulation, soil health, pollination and disaster prevention and protection.

1.1.4 Why this assessment?

This ecosystem assessment extends and complements the knowledge we have about the state and trends of ecosystems reported under the EU environmental legislation, supplementary to the national assessments performed by the Member States as requested in Target 2 Action 5 of the EU Biodiversity Strategy to 2020. The conservation of habitats and species as well as the environmental ambitions on freshwater and marine ecosystems have a well-defined thematic and geographical scope. This assessment goes beyond covering the entire terrestrial and marine territory of the EU and in many cases provides more spatially explicit information. Ecosystems inside and outside protected areas such as coastal and inland wetlands and forests contribute to the wellbeing of people through ecosystem services. Despite their importance, they are often heavily impacted and bringing these systems back in a good condition is a key objective for a more sustainable planet, as reflected by the sustainable development goals (United Nations, 2019). But also human dominated ecosystems such as farmlands and urban green spaces are important providers of provisioning, regulating and cultural ecosystem services and can host remarkable levels of biodiversity that are at the basis of ecosystem services. These ecosystems should not be ignored when considering solutions to bend the curve of biodiversity loss (Mace et al., 2018).

Consequently, this assessment brings together for the first time EU wide and commonly agreed data sets that can be used to assess the state and trends of ecosystems and their services as well as the pressures and their trends they are exposed to. This is particularly important to understand where and how much ecosystems are degraded and threatened so as to guide priority and cost-effective restoration efforts.

1.2 Policy questions

This ecosystem assessment serves two main policy requests: (1) provide an evaluation of the headline biodiversity target of the EU Biodiversity Strategy to 2020 in general and of Target 2 in particular and (2) provide a baseline and trend, as well as support to the definition of good ecosystem condition for the EU Biodiversity Strategy for 2030.

Providing support to the above formulated policy requests requires specifying in more detail the questions that this assessment needs to address:

- What is the current condition of the different ecosystem types in the EU and how has this condition changed relative to the 2010 baseline?
- What are the different pressures that affect the condition of ecosystems in the EU and how have they changed relative to the 2010 baseline?
- What are the current levels of services provided by ecosystems; what is the use of these services and how have ecosystem service potential, use and demand changed relative to the 2010 baseline?
- What are possible synergies and trade-offs between ecosystem services and how can future policy decisions e.g. sectoral decision-making be informed to ensure optimal outcome to enhance biodiversity.

Providing answers to these questions required a joint approach with researchers, data-providers, stakeholders and policymakers at EU level. So regular science-policy meetings were held to ensure the policy relevance of the entire exercise and in particular the indicators and underpinning datasets that have been used to map and assess the pressures on ecosystems, ecosystem condition and ecosystem services. The involvement of stakeholders has also allowed for the operationalisation of methodological concepts and work.

It is important to stress again that this assessment will take full account of the data reported under the EU environmental legislation and be consistent with the outcomes of the related assessments of status and pressures under these reporting obligations (e.g. EU State of Nature, State of European Waters, State of European Seas).

The outcome of this assessment could contribute to ongoing assessments in support of the global Sustainable Development Goals (UN, 2019) and objectives in relation to a joint agenda on biodiversity and climate change.

1.3 Geographical coverage

The geographical coverage is the territory of EU-28 (EU and the UK) and the EU marine regions. The collection of datasets to map and assess ecosystem condition, pressures and ecosystem services as outlined in the chapters 3 to 5 of this report will cover this territory.

1.4 Outline of the report and timeline of the assessment

1.4.1 Outline

Following this introduction, Chapter 2 sets the assessment framework with definitions, the concept, the working approach and its limitations.

Chapters 3, 4 and 5 report the assessment results. The status and trends of ecosystems in Europe have been assessed using an indicator-based approach with indicators that are regularly updated from 2010 to 2020, underpinned by spatially-explicit or EU aggregated datasets collected at European scale, which were severe limitations to their selection. These chapters use a common reporting format and contain policy-specific messages that can be considered for the post 2020 biodiversity policy.

Chapter 3 (Thematic ecosystem assessments) delivers a set of in-depth assessments per ecosystem type. For each MAES ecosystem type, a separate assessment has been performed: urban ecosystems, agroecosystems (including croplands and grasslands), forests and other woodlands, heathlands and shrub, sparsely vegetated lands, wetlands, rivers and lakes and marine ecosystems. Every assessment reports changes in ecosystem extent, pressures and condition relative to 2010 or conditionally on data availability for a longer timeframe if respective information was available.

Chapter 4 (Cross-cutting ecosystem assessments) includes strategic reports on invasive alien species, climate change, landscape mosaic, and soil. These assessments are relevant for all ecosystems and are related to processes that can be assessed on a higher spatial scale than the scale at which ecosystems are assessed.

Chapter 5 (Ecosystem services) quantifies six ecosystem services at European scale and shows how the potential of ecosystems to deliver services, the demand for services set by society and the actual use of services have changed.

Chapter 6 provides an integrated assessment based on a synthesis of the findings in chapters 3 and 4. The chapter analyses the changes in ecosystem extent, pressures and condition comparing different ecosystem types.

Chapter 7 contains integrated narratives which provide concrete examples or story lines that show how the use of data collected under this assessment can support specific policies.

Chapter 8 contains the conclusions and key messages.

A separate supplement to this report contains additional metadata, data and analyses for the different indicators of this report.

1.4.2 Timeline

The starting shot for the EU wide ecosystem assessment was given on 25 September 2018 at the 16th meeting of the MAES Working Group with the presentation of a scoping paper (Maes et al., 2018). The first draft assessment chapters (Chapters 3, 4 and 5) were presented in Helsinki in December 2019 at a high level conference of the first EU wide ecosystem assessment organised by the Finnish Presidency of the Council of the EU. A scientific and policy review and the subsequent revision of these chapters took place during the first semester of 2020.

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2 A common framework for the assessment of the condition and trends of ecosystems and their services

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2.1 Introduction

This chapter describes the processes and working methods, implemented to ensure a consistent reporting of the condition of Europe's ecosystems and ecosystem services.

The EU wide ecosystem assessment evaluates the state of Europe's ecosystems and their services based on an analysis of available data. The assessment covers the whole EU-28 territory, including the EU marine regions.

The assessment is based on a list of policy relevant indicators for ecosystem condition and ecosystem services commonly agreed with key stakeholders from Member States and European Commission and is organised along a series of thematic assessments per ecosystem type and cross-cutting assessments across different ecosystems.

This chapter contains more details about the design of the assessment, the underlying analytical framework, and the practical implementation. In addition, it provides information about the common methods that have been used to derive conclusions about the state and trends of Europe's ecosystems.

2.2 Scoping

The ecosystem assessment was prepared with a scoping paper (Maes et al., 2018) which developed proposals and working approaches for a joint EU wide ecosystem assessment to be finalised by the end of 2019. This paper summarised the conclusions of the third Joint MAES INCA[1] Meeting in Ispra, Italy on 17 and 18 July 2018. The paper described the scope of the assessment, highlighted several scientific, technical and policy challenges that can be encountered in the assessment and made proposals for addressing these issues.

The scoping paper was presented and discussed with Member States and Commission services at the 16th meeting of the working group on Mapping and Assessment of Ecosystems and their Services (MAES) on 25 September 2018 in Brussels. A reviewed scoping paper and a more detailed approach to assess different ecosystem types were discussed at a reality check meeting: a meeting with different units of DG Environment giving the opportunity to policymakers to critically examine the proposals, raise comments and express possible concerns.

The following questions and requirements had to be addressed by the ecosystem assessment:

- What is the current condition of the different ecosystem types in the EU and how has this condition changed relative to 2010?
- What are the different pressures that affect the condition of ecosystems in the EU and how have they changed relative to 2010?
- What are the current levels of ecosystem services provided by ecosystems; what is the use of these services and how have ecosystem service potential, use and demand changed relative to 2010?
- What are possible synergies and trade-offs between ecosystem services and how can future policy decisions e.g. in sector areas be informed to ensure optimal outcome to enhance biodiversity?

[1] MAES: Mapping and Assessment of Ecosystems and their Services; INCA: Integrated system for Natural Capital and ecosystem services Accounting;

- The collection of datasets to map and assess ecosystem condition, pressures and ecosystem services needs to cover the territory of EU-28 and the EU marine regions.
- The first results of the assessment need to be available as of December 2019.
- The outcome of the ecosystem assessment needs to be relevant for Action 6 of the EU Biodiversity Strategy to 2020 which aims to set priorities for green infrastructure and ecosystem restoration.
- The data collected during this assessment have to constitute a baseline for the post 2020 biodiversity policy of the EU and its Member States.
- The assessment has to take full account of the data reported under the EU environmental legislation and be consistent with the outcomes of the related assessments of status and pressures under these reporting obligations. This is particularly evident for the assessments carried out under the Habitats Directive.
- The outcome of this assessment should contribute to ongoing assessments in support of the Sustainable Development Goals and objectives in relation to a joint agenda on biodiversity and climate change as outlined in the EU Biodiversity Strategy for 2030 (European Commission, 2020).

Meeting these requirements needed a joint approach with researchers, data-providers and policymakers at EU level. Whereas these questions can be addressed independently, a common synthesis and an integrated assessment are mandatory to make this exercise relevant for different policies.

2.3 Design of the ecosystem assessment

The scoping phase resulted in an assessment design as presented in Figure 2.1. This design has been changed a number of times during the scoping phase and has been further fine-tuned during the assessment phase. The ecosystem assessment is structured around four main parts: thematic ecosystem assessments, cross-cutting assessments, an integrated assessment and integrated narratives addressing key policy issues.

The thematic ecosystem assessments describe the state and trends of the condition of different ecosystem types using a set of indicators that were selected in agreement with key stakeholders (fifth MAES report).

The thematic ecosystem assessments produced statistics at EU aggregated level as well as spatially explicit results. Note that the marine ecosystem assessment is not presented at EU aggregated level but per marine region with outcomes for the Baltic Sea, the North East Atlantic Ocean, the Mediterranean Sea and the Black Sea.

The cross-cutting assessments feed the thematic assessments with specific datasets but also provide a stand-alone analysis of the impact of invasive alien species and of climate change as key pressures on ecosystems. Two more cross-cutting assessments describe the state of soil in the EU and analyse the condition of ecosystems at a higher spatial scale by looking at the spatial patterns of ecosystem distribution on landscape level.

Both the thematic and cross-cutting assessments are delivered by the end of 2019 and feed an integrated ecosystem assessment that compares the different ecosystem types with respect to pressures and conditions. Driving questions for the integrated assessment are to understand the level and spatial distribution of ecosystem condition, the key pressures affecting condition, the subsequent impacts on ecosystem services and how the collected information can help to set targets and priorities for ecosystem restoration.

An integrated assessment means describing how the interactions between pressures, ecosystem condition and ecosystem services are relevant for policymaking and the implementation of measures to improve their condition. Concrete examples or story lines (integrated narratives) demonstrate, how the use of data collected under this assessment can support specific policies.

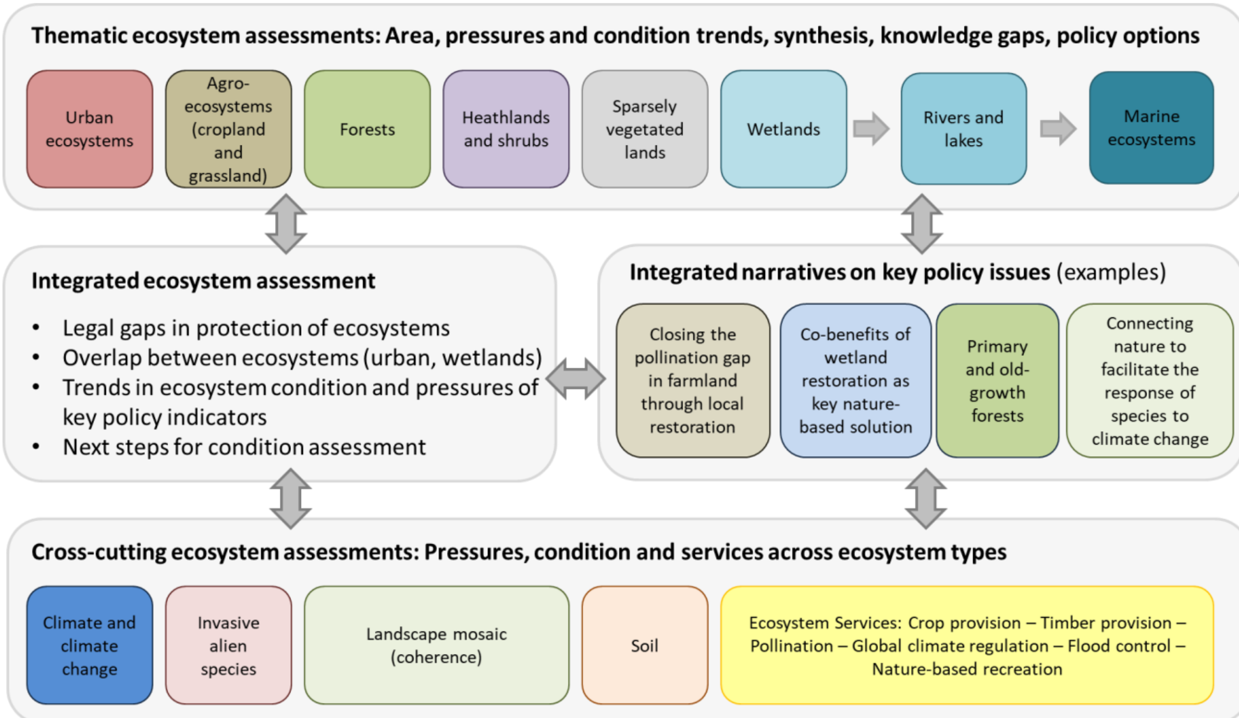

Figure 2.1. Final design of the EU wide ecosystem assessment.

2.4 Operational framework for the ecosystem assessment

This assessment is entirely based on an operational framework developed by the MAES Working Group in collaboration with policymakers and researchers. The framework is described in a series of MAES reports and scientific articles published in the international literature as further specified in this section. The framework was further enhanced and tested by ESMERALDA, a coordination and support action funded under the Horizon 2020 programme for research and innovation (Burkhard et al, 2018a, 2018b).

The MAES operational framework includes the following elements:

- A **conceptual frame** for linking ecosystems and biodiversity to people through drivers of change and ecosystem services (first MAES report, page 16). This concept constitutes a conceptual basis for the integrated ecosystem assessment. Particularly, it assumes how pressures, condition and services are interrelated and these assumptions can be tested within and across ecosystems using the data collected under this ecosystem assessment.

- A **common assessment framework** that describes the different steps of ecosystem assessment from mapping ecosystems, to assessing ecosystem condition and ecosystem services and integrated assessment (see also EEA, 2016). A first version of the common assessment framework is published in the second MAES report. An updated version of this framework is published as a journal article (Burkhard et al., 2018). The common assessment framework provides an operational basis for this EU wide ecosystem assessment.

- **Typologies** for ecosystems (first MAES report), for pressures (fifth MAES report), for ecosystem condition (fifth MAES report) and for ecosystem services (first MAES report).

- A selection of **indicators** per ecosystem type to assess the pressures, condition (fifth MAES report) and ecosystem services (second MAES report). These indicators are available per ecosystem type and across ecosystem types.

2.5 Practical implementation

2.5.1 Coordination and working approach

The ecosystem assessment was coordinated by a coordination team consisting of representatives from DG Environment, the Joint Research Centre (JRC) and the European Environment Agency (EEA). They steered the work done by different assessments (see Figure 2.1). A coordinated approach was ensured through monthly technical meetings to discuss progress and to propose solutions for specific problems and issues. The coordinating team drafted methodological guidelines and templates ensuring consistency in the methodology and the reporting. All information was shared on a wiki used by the European Commission.

Every thematic ecosystem assessment and every cross-cutting ecosystem assessment was led by a coordinating lead author. These were staff members of the Joint Research Centre or of the European Topic Centres (ETCs) of the European Environment Agency. Starting from the fifth MAES report on ecosystem condition, the thematic ecosystem assessments selected indicators and collected the underpinning datasets. Information on trends was crucial so indicators were only retained if data for at least two points in time was available.

For every indicator an indicator fact sheet was completed containing general information about the indicator such as name and classification in the pressures or condition typology (fifth MAES report), information about the data sources, an assessment of the indicator including maps (if spatially explicit) and the key trends at EU level. Indicator fact sheets and the data are hosted on a common website of the EEA and will be made publicly available once the assessment is reviewed and finalised.

A similar approach was followed for crosscutting assessments and for the ecosystem services assessment: quantification of indicators, reporting of metadata in indicator fact sheets and a common way of reporting the conclusions of the assessment.

2.5.2 Involvement of policymakers, Member States, research and stakeholders

Throughout the assessment, different parties were consulted or kept informed through dedicated workshops: policy units of DG Environment responsible for specific policies such as water, urban, nature, forest, agriculture, soil, biodiversity; Member States (through their involvement in the working group MAES); stakeholders on biodiversity (agriculture, wetlands, conservation NGOs); and research.

Policy services of the Commission have been involved in a reality check meeting in December 2018. A special two-day stakeholder workshop organised by DG Research and Innovation in June 2019 allowed an in-depth discussion on the assessments across all ecosystem types and for the crosscutting assessments on soil and ecosystem services. In between, several thematic ecosystem assessment leaders organised bilateral meetings between the assessment team and the responsible policy officers at DG Environment to keep them up to date about the progress and to ask for reactions and comments on the approach and the results. The progress of the EU wide assessment was presented and discussed with the Member States in March and September 2019 on the working group MAES meetings in Brussels. The first draft of this assessment was presented at the High Level Celebration Conference of the first EU wide ecosystem assessment in Helsinki, Finland, on 13 December 2019. This event was organised by the European Commission and the Finnish Presidency of the Council of the EU.

Following this first presentation, the draft assessment has been extensively peer-reviewed by scientists, experts of the European Environment Agency and the Joint Research Centre who did not directly contribute to the assessment, and policy officers from the following services of the European Commission: DG Environment, DG Research and Innovation, DG Climate Action, DG Agriculture and Rural Development, and Eurostat

The final assessment will be summarized in a summary for policymakers that will be jointly written by the assessment team and policymakers of DG Environment.

2.6 Geographical scope and ecosystem types

The geographical coverage is the territory of EU-28 which comprises the following countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and

Sweden. On 31 January 2020, the United Kingdom left the EU. However, the UK is also considered in this assessment since the data cover the period during which the UK was still a member of the EU. The assessment also includes the following regional sea areas: the north-east Atlantic Ocean, the Baltic Sea, the Mediterranean Sea, and the Black Sea.

The EU's outermost regions (Guadeloupe, French Guiana, Réunion, Martinique, Mayotte and Saint-Martin (France), the Azores and Madeira (Portugal), and the Canary Islands (Spain)) are not included in this report with the exception of some datasets that cover the Portuguese and Spanish regions situated in the Atlantic Ocean. The MOVE[2] and MOVE ON projects carry out MAES type assessments in these regions.

The trends in pressures and condition following MAES ecosystem types are reported. There are seven terrestrial ecosystem types: urban ecosystems, cropland, grassland, forests, wetlands, heathland and shrubs, sparsely vegetated land; one freshwater ecosystem type: rivers and lakes, and four marine ecosystem types: marine inlets and transitional waters, coastal, shelf and open ocean. For data related and organisation reasons, the assessments of cropland and grassland have been combined and are reported as agroecosystems; coastal wetlands are reported in the chapter of wetlands; and there are no separate assessments for the marine ecosystem types, they have all been combined into a single assessment per marine region.

The calculation of the extent of terrestrial ecosystem types is based on the CORINE land cover data (see section 2.7).

2.7 The use of CORINE land cover data in the ecosystem assessment

The CORINE Land Cover data (CLC) constitute a reference dataset for this assessment. The CLC dataset has been used (1) to delineate the extent of ecosystems in the EU, (2) to analyse the trends in the extent of ecosystems, and (3) as an input layer for the calculation of trends of specific ecosystem condition indicators.

The CLC data set is regularly updated by the EEA to correct mistakes and integrate the data of the most recent reference year into the change detection system. New updates receive a new version number. These updates and in particular the production of the CLC2018 data coincided with the scientific work of the different thematic assessments. Some calculations, particularly of ecosystem services, require substantial resources and computing time so that it was not always possible to use the latest available version of CLC. This result in the usage of different versions of CLC data in this ecosystem assessment but it is a fact we have to accept.

In first instance, the CLC dataset has been used to delineate the different MAES terrestrial and freshwater ecosystem types. The delineation is based on Annex 2 of the first MAES report (Table 2.1) which provides a correspondence between the CLC level 3 classes and the MAES ecosystem types.

The European Environment Agency also produced an ecosystem map[3] to refine the MAES ecosystem types using EUNIS habitat information. The current version (01 July 2020) is version 3.1. The ecosystem map was not used in this assessment because it is available for one point in time only as opposed to the CLC data. Once updates for the ecosystem types map are available, follow up work on ecosystems in the EU should be based on this spatial delineation. See also chapter 6 for a discussion on ecosystem extent.

[2] https://moveproject.eu/

[3] https://www.eea.europa.eu/data-and-maps/data/ecosystem-types-of-europe-1

Table 2.1. Correspondence between CORINE land cover (CLC) classes and MAES ecosystem types.

CLC level 1	CLC level 2	CLC level 3	MAES Level 1	MAES Level 2
Artificial surfaces	Urban fabric	Continuous urban fabric	Terrestrial	Urban ecosystems
		Discontinuous urban fabric		
	Industrial, commercial and transport units	Industrial or commercial units		
		Road and rail networks and associated land		
		Port areas		
		Airports		
	Mine, dump and construction sites	Mineral extraction sites		
		Dump sites		
		Construction sites		
	Artificial, non-agricultural vegetated areas	Green urban areas		
		Sport and leisure facilities		
Agricultural areas	Arable land	Non-irrigated arable land		Cropland
		Permanently irrigated land		
		Rice fields		
	Permanent crops	Vineyards		
		Fruit trees and berry plantations		
		Olive groves		
	Pastures	Pastures		Grassland
	Heterogeneous agricultural areas	Annual crops associated with permanent crops		Cropland
		Complex cultivation patterns		
		Land principally occupied by agriculture, with significant areas of natural vegetation		
		Agro-forestry areas		
Forest and semi natural areas	Forests	Broad-leaved forest		Forest
		Coniferous forest		
		Mixed forest		
	Scrub and/or herbaceous vegetation associations	Natural grasslands		Grassland
		Moors and heathland		Heathland and shrub
		Sclerophyllous vegetation		
		Transitional woodland-shrub		Forest
	Open spaces with little or no vegetation	Beaches, dunes, sands		Sparsely vegetated land
		Bare rocks		
		Sparsely vegetated areas		
		Burnt areas		
		Glaciers and perpetual snow		
Wetlands	Inland wetlands	Inland marshes		Inland wetlands
		Peat bogs		
	Maritime wetlands	Salt marshes	Marine	Marine inlets and transitional water
		Salines		
		Intertidal flats		
Water bodies	Inland waters	Water courses	Freshwater	Rivers and lakes
		Water bodies		
	Marine waters	Coastal lagoons	Marine	Marine inlets and transitional water
		Estuaries		
		Sea and ocean		Coastal, shelf and open ocean

A second use of the CLC data layers is the analysis of how the total area or extent of ecosystems changed over time. This analysis is based on the crosswalk between CLC level 3 types and the MAES level 2 ecosystem types (Table 2.1). To this end, the CLC accounting layers have been used[4]. The method is documented in EEA (2018). The data is based on the CLC maps (status layers) covering the years 2000, 2006, 2012 and 2018 and the respective change layers 2000-2006, 2006-2012 and 2012-2018.

Every terrestrial thematic ecosystem assessment reports the extent of its respective ecosystem type and changes in coverage as documented using the CLC data sets and the change detection. The advantage is a harmonized approach across the different assessments that delivers a reference value for ecosystem extent over time which avoids double counting of land ecosystems.

However, two important remarks should be made: (1) CLC is not the only source of data to assess the extent of ecosystems, and (2) the delineations of ecosystems do not always reflect the complex reality on the field as the classes are very aggregated to be compatible with the individual classifications of the Member States and the assessments in their territories. See also chapter 6 for a discussion on different delineations and overlaps between ecosystem types. To put CLC based ecosystem extent information in a context, some thematic ecosystem assessments including the assessments on forests, agroecosystems and freshwater therefore also report using additional data sources that estimate the total size or extent of the ecosystems in the EU-28. Mostly, differences occur because of the use of different definitions of ecosystems by different stakeholders. Forest areas for example can vary due to different definition of forests in terms of minimum area and tree heights in Member States compared to the mapping of overall tree coverage in CLC data.

Secondly, delineating ecosystems incurs making choices on what to include or exclude. Therefore, the different assessments had also the freedom to enlarge the area under assessment so as to capture relevant structures or functions that are an inherent part of the ecosystem under study. This was particularly evident for urban areas and wetlands. Urban ecosystems go beyond the narrow delineation based on the occurrence of artificial areas. The chapter on urban ecosystems thus reports also on other ecosystem types that fall within the boundary of cities. The same can be said for wetlands. The MAES definition limits wetlands to inland marshes and peatbogs (Table 2.1). The RAMSAR definition for wetlands goes much broader including also forests and grasslands with wetland water regimes as it is the case in floodplains and other areas with near surface groundwater levels. Also here, separate mapping and assessment was necessary to better reflect the reality on the ground. Consequently this ecosystem assessment accepts some overlaps between the thematic assessments. The indicator fact sheets also report indicators on ecosystem extent along with the data used to calculate the extent of ecosystem types based on different definitions.

Besides ecosystem delineation and analysis of trends in total ecosystem area, CLC data have also been used as input layers in several assessments to quantify indicators such as land take, ecosystem gain and loss, landscape mosaic, and ecosystem services. The following set of rules was adopted to harmonize the use of CLC data in the various assessments and chapters:

- The calculation of pressure and condition indicators based on CLC will use the various CLC status layers to assess the trend of the indicator. Version 18.5 of CLC 2000-2012 and version v20b2 for 2018 have been recommended for usage to all the thematic and crosscutting assessments that still needed to calculate indicators. Some indicators use the latest v20 for all assessment years consistently. In any case, the metadata on the indicator fact sheets clearly mentions the version that has been used for indicator quantification so that deviations in reported areas and changed can be tracked..
- The calculation of the extent of ecosystems and changes over time is based on the CLC accounting layers.
- The quantification of ecosystem services is based on the CLC accounting layers, in essence to be aligned with the rules on ecosystem accounting (Vallecillo et al. 2019).

[4] https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

2.8 The use of Article 17 data on the conservation status of habitats

The Article 17 habitat conservation status data, reported by the Member States under the Habitats Directive (EC, 1992), are an essential source of information on ecosystem condition and biodiversity for this assessment.

Conservation status is assessed by the Member States every six years. There are currently three assessment cycles reported: 2000-2006, 2007-2012, and 2013-2018. The third cycle is reported in 2019. The EU wide assessments are published as State of Nature reports (EEA, 2015a, 2020).

The conservation status of habitats listed under Annex I of the Habitats Directive is determined using 4 parameters: range, area, structure and function and future prospects. Each of these parameters is assessed using four possible outcomes: good or favourable conservation status, poor or unfavourable inadequate conservation status, bad or unfavourable bad conservation status, or an unknown conservation status. The Member Status assess every Annex 1 habitat on their territory and per biogeographical region. The outcomes of these four parameters are aggregated into a single assessment conclusion for a given habitat per Member State and per biogeographical region. Aggregation is based on the one out all out principle: good status is reached if all parameters are qualified as good. In a final step, assessments per Member State are aggregated into an assessment at the level of the EU based on an area-weighed aggregation (EEA, State of Nature report, forthcoming).

Following the review of the report and the chapters on ecosystem condition, and based on discussions with the Nature Unit of DG Environment, European Environment Agency (EEA) and its European Topic Centre for Biological Diversity (ETC/BD), it was decided to use the data of the EU level assessment conclusions of the conservation status of habitats in such a way that the statistics reported in this ecosystem assessment are the same as the data reported in the forthcoming State of Nature report.

There are two important differences between the Article 17 assessments of habitat conservation status as documented in the State of Nature report and this ecosystem assessment: First the classification of MAES ecosystem types and Annex 1 habitats, and second the total area covered by each assessment. A good understanding of these differences is essential for the interpretation and comparison of the results of both assessments.

The Annex 1 habitat types are grouped into the following broad habitat categories: coastal habitats, bogs, mires and fens, dunes habitats, forests, grasslands, heath and scrub, freshwater habitats, sclerophyllous scrubs, and rocky habitats.

There is no simple, one to one relationships between the Annex 1 broad habitats types and the MAES ecosystem types. Table 2.2 breaks down the number of Annex 1 habitats in a matrix with the Annex 1 broad habitats types as rows and the MAES ecosystem types as columns. Firstly, the MAES types urban ecosystems and cropland are not covered by Annex 1 habitat types. Secondly, for freshwater habitats and rivers and lakes there is a one to one relation. Thirdly, there are many to many relations for all other ecosystem types and broad habitat groups. Consider for instance the broad habitat type forests which contains 81 different forest habitats of which 79 correspond to the MAES ecosystem type forest, 1 to agroecosystems and 1 to heathlands and shrub.

One option to report data on conservation status was to take the different Art. 17 habitat assessments, and reanalyse them per MAES ecosystem type. This option, however, results in summary statistics that would deviate from the State of Nature report, in particular for MAES types heathlands and shrubs and for sparsely vegetated ecosystems which are more aggregated than the corresponding Annex 1 broad habitat groups.

To avoid any confusion and to ensure consistent reporting in both this ecosystem assessment and in the forthcoming State of Nature report, it was decided to report conservation status per broad habitat group (instead of aggregating habitat types per MAES ecosystem type). Where appropriate (see table 2.2), the thematic ecosystem assessments report the following two indicators (1) the percent of habitats in a good status (per broad habitat group) and (2) the trends of unfavourable conservation status of habitats (also per broad habitat group) (see table). The drawback of this approach is that the Art. 17 information is underutilised. For instance the conservation status data of dunes habitats is not considered in this assessment as different dunes habitats are assigned to different MAES ecosystem types with important shares to both grasslands and heathlands and shrubs and lower shares to forests, wetlands and sparsely vegetated land.

Table 2.2. The number of Annex 1 habitats per MAES ecosystem type and per Annex 1 broad habitat group. Cells with numbers printed in bold indicate how the status and trends in habitat conservation status are reported per MAES ecosystem type and the respective chapters of this report.

Chapter number	3.1	3.2		3.3	3.4	3.5		3.6	3.7
MAES ecosystem types → ↓ Annex 1 broad habitat group (number of habitats)	Urban ecosystems	Cropland	Grasslands	Forests	Wetlands	Heathlands and shrubs	Sparsely vegetated land	Rivers and lakes	Marine Ecosystems
Coastal habitats (28)	0	0	6	0	0	3	8	0	**11**
Dunes habitats (21)	0	0	7	2	2	9	3	0	
Freshwater habitats (20)	0	0	0	0	0	0	0	**20**	
Heath & scrub (12)	0	0	0	0	0	**12**	0	0	
Sclerophyllous scrubs (13)	0	0	0	0	0	**13**	0	0	
Grasslands (32)	0	0	**32**	0	0	0	0	0	
Bogs, mires & fens (12)	0	0	0	0	**12**	0	0	0	
Rocky habitats (14)	0	0	0	0	0	0	**13**	0	1
Forests (81)	0	0	1	**79**	0	1	0	0	

A second important difference between this EU wide ecosystem assessment and the Art. 17 assessment of habitat conservation status is the geographical scope. This assessment covers the entire territory of the EU-28 whereas the habitat assessments under Art. 17 of the Habitats Directive is limited to the area of Annex 1 habitats. Table 2.3 calculates for every MAES ecosystem type the total area of Annex 1 habitat. The total area of Annex 1 habitat amounts to 1.65 million km^2 including also coastal habitats that overlap with marine ecosystems. Urban ecosystems and cropland are not covered by Annex 1 habitat. In chapter 6, these statistics are compared with the total surface area of the different MAES ecosystem types in order to better understand the current gaps in legal designation.

Table 2.3. Area (km²) of Annex 1 habitat per MAES ecosystem type and per broad habitat group.

Chapter number	3.1	3.2		3.3	3.4	3.5		3.6	3.7	
MAES ecosystem types → ↓ Annex 1 broad habitat group (number of habitats)	Urban ecosystems	Cropland	Grasslands	Forests	Wetlands	Heathlands and shrubs	Sparsely vegetated land	Rivers and lakes	Marine Ecosystems	**Total**
Coastal habitats (28)	0	0	9,104	0	0	3,069	6,078	0	387,701	405,952
Dunes habitats (21)	0	0	3,105	2,477	699	2,357	567	0	0	9,205
Freshwater habitats (20)	0	0	0	0	0	0	0	127,754	0	127,754
Heath & scrub (12)	0	0	0	0	0	88,335		0	0	883,35
Sclerophyllous scrubs (13)	0	0	0	0	0	35,132		0	0	35,132
Grasslands (32)	0	0	234,300	0	0	0	0	0	0	234,300
Bogs, mires & fens (12)	0	0	0	0	137,738	0	0	0	0	137,738
Rocky habitats (14)	0	0	0	0	0	0	121,807	0	0	121,807
Forests (81)	0	0	819	491,915	0	1		0	0	492,735
Total	0	0	247,328	494,392	138,437	128,894	128,452	127,754	387,701	1,652,959

The data collected under the Birds Directive is not available for this assessment as deadlines for the reporting are in 2020. Also the species data collected under the Habitats Directive have not been used in this assessment as there is currently no common set of rules to assign species to different ecosystem types.

2.9 Common approach to map and assess changes in ecosystem condition and services

A common approach was used to enable consistent final conclusions about the trends in pressures and condition of ecosystems across Europe. The different thematic ecosystem assessments used a single typology to classify pressure and condition indicators and a single methodology to assess trends relative to the baseline value for 2010. For the purpose of this study, the same definitions for pressure and ecosystem condition are used as in the fifth MAES report: Ecosystem condition refers to the physical, chemical and biological condition or quality of an ecosystem at a particular point in time. Pressure refers to a human induced process that alters the condition of ecosystems

2.9.1 Typology for pressure and ecosystem condition indicators

The different thematic ecosystem assessments use the classification in Table 2.4 to organise the presentation of the data and the results of the trend analyses. The classification of pressure indicators follows an internationally used typology (MA, 2005) that recognised five broad classes of pressures on biodiversity. The classification of ecosystem condition indicators is based on the definition of ecosystem condition and thus distinguishes between indicators for environmental quality (which express the physical and chemical quality of ecosystems) and ecosystem attributes (which express the biological quality of ecosystems) (Table 2.4). Note that the difference between pressure indicators and indicators of environmental quality can be inferred from the units. Pressure indicators are measured in units per unit time, for instance the amount of nitrogen deposited on a forest over the course on one year (kg N/ha/year). Indicators of environmental quality are based on point in time measurements, for instance the concentration of nitrogen in a litre of lake water (mg N/l). Ecosystem attributes refer to both structural and functional indicators. Structural indicators say something about the composition of the ecosystems as well as the architecture in terms of biomass and vegetation. Functional indicators describe ecosystem processes. Some indicators receive special attention because of their role in policy or because of their relevance for ecosystem condition. This is the case for structural ecosystem attributes based on species diversity and abundance, for indicators derived from the assessment of conservation status of habitats and species under Art.17 of the Habitats Directive and for soil indicators (Table 2.4).

Table 2.4. Hierarchical structure and classification of pressure and condition indicators

Pressures	Habitat conversion and degradation (land conversion)
	Introductions of invasive alien species
	Pollution and nutrient enrichment
	Over-exploitation
	Climate change
	Other pressures

Ecosystem Condition	Environmental quality (physical and chemical quality)		
	Ecosystem attributes (biological quality)	Structural ecosystem attributes	Structural ecosystem attributes (general)
			Structural ecosystem attributes based on species diversity and abundance
			Structural ecosystem attributes monitored under the EU nature directives
			Structural soil attributes
		Functional ecosystem attributes	Functional ecosystem attributes (general)
			Functional soil attributes

2.9.2 Defining the baseline, short-term and long-term trends

Each of the different thematic and cross-cutting ecosystem assessments collected a set of indicators underpinned by EU wide datasets which describe the condition (or services) of ecosystems or the pressures acting on them. For each ecosystem type, a core set of policy relevant indicators has been identified (Chapter 5 of the fifth MAES report). These indicators are used in this ecosystem assessment to evaluate whether or not the condition and services of ecosystems have changed over the short or long term. Short term trends analyse changes relative to 2010, the baseline year for this assessment. Long term trends analyse changes relative to a year preceding 2010, usually 2000 or 1990 but others years are possible as well depending on data availability and dynamic of the respective ecosystem type.

The baseline year 2010 corresponds to the starting point of the EU Biodiversity Strategy to 2020 of which its targets are under evaluation (see also EEA, 2015b).

The basic methodology that every thematic and crosscutting assessment follows is:

- Establish a baseline value for each indicator (an indicator value for 2010);
- Assess the short-term trend (2010 to 2018) as the percentage change per decade (10 years) of each indicator; and
- If data are available assess the long-term trend (e.g., since 1990 or 2000 to 2018) as the percentage change per decade (10 years) of each indicator.

For ecosystem services the assessment reports a maximum of three time steps related to the reference years of the CORINE Land Cover data sets (2000, 2006 and 2012). The trend at EU level was calculated between 2000 and 2012 as the percentage change per decade of each indicator. However, a more detailed analysis also describes the changes for both periods included: first period (between 2000 and 2006) and second period (between 2006 and 2012). When data were not available for all three years, changes were estimated considering the years assessed (e.g. 2006 and 2012 for flood control).

For both the short-term and long-term trends, four outcomes are possible (Figure 2.3). The condition of ecosystems as measured by one indicator at the end of the assessment period did not change relative to 2010 (or an earlier baseline year) means the condition is stable, which is labelled as “no change”, the condition improved (improvement); the condition declined (degradation), or the indicator does not allow any conclusion (unresolved):

- **No change** (the change is not significantly different from 0% per decade): the condition of the ecosystem remained the same.
- A significant **improvement** (significantly downward trend of pressure indicator or upward trend of condition indicator): change to a higher state or level of ecosystem condition caused by natural regeneration or restoration.
- A significant **degradation** (significantly upward trend of pressure indicator or downward trend of condition indicator): change to a lower state or level of ecosystem condition caused by pressures (in the MAES glossary, a degradation is defined as persistent decline in the condition of an ecosystem).
- **Unresolved** (the direction of the trend could not be defined): the assessment of change was inconclusive. This also includes essential indicators for which only one point in time data was available (i.e. unknown trends) or indicators for which no data was available.

Note that for the ecosystem services assessment a same neutral terminology is used: no changes, increase, decrease. The category unresolved does not apply.

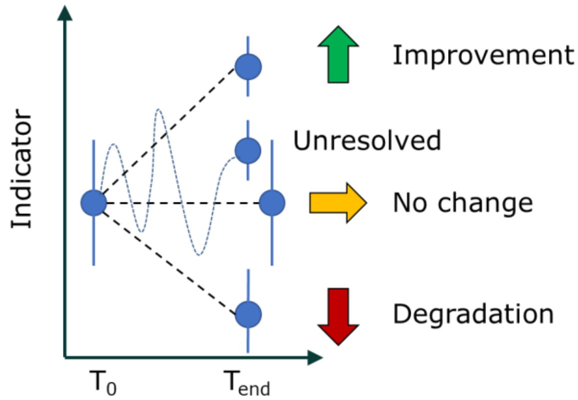

Figure 2.3. Four possible outcomes for with respect to changes in the condition of ecosystems relative between T_0 and T_{end} based on a convergence of evidence approach: Improvement, Degradation, No change, Unresolved.

2.9.3 Methodology for calculating the baseline

The baseline year for this ecosystem assessment is 2010. Indicators which have data for 2010 used this value as baseline value. If data for 2010 was not available, linear interpolation was used to calculate a baseline value by taking the indicator values of the two surrounding years that comprise 2010 (e.g., 2008 and 2011).

The formula for finding the baseline value of an indicator based on interpolation between two years T1 and T2 with indicator values Y1 and Y2, respectively, is

$$Indicator\ value\ at\ baseline\ year\ 2010 = \frac{(Y2-Y1)}{T2-T1} \times (2010 - T1) + Y1 \quad \text{(Equation 2.1)}$$

For indicators based on CORINE Land Cover the datasets CLC2006 and CLC2012 were used to calculate the baseline value for the year 2010.

2.9.4 Methodology for calculating trends and their significance

This assessment presents trends as the percentage change per decade. This percentage is found either by calculating the change based on the first and last year of the observation (equations 2.2 and 2.3) or, in case of multiple indicator values, on linear regression using intercept and slope (equation 2.4).

$$percent\ change\ per\ decade = \left(\frac{X_{last\ year} - X_{first\ year}}{X_{first\ year}} \times 100\right) \times \left(\frac{10}{last\ year - first\ year}\right) \quad \text{(Equation 2.2)}$$

where X are the values of the indicator. The right factor converts the percentage per year to a percentage per decade. E.g. if the first year of the time series is 2000 and the last year is 2016, then the right factor becomes 10/16 and modulates the percentage to a per decade value.

Equation 2.2 can, in principle, not be applied in case of indicators measured on an interval scale (i.e. with values < 0, e.g. temperature or sea level, see Stevens 1947). In such cases, a different approach has been used.

In case of indicators measured on an absolute scale (i.e. ones that refer to a percentage or a proportion), Equation 2.2 does not apply and the change is simply the difference between the last year and the first year, but corrected for number of years between according to the following formula:

$$percent\ change\ per\ decade = \left(X_{last\ year}(\%) - X_{first\ year}(\%)\right) \times \left(\frac{10}{last\ year - first\ year}\right) \quad \text{(Equation 2.3)}$$

where X are the values of the indicator.

In case linear regression is used, the percentage change per decade is calculated using the two regression coefficients (slope and intercept) according to:

$$percent\ change\ per\ decade = \frac{\text{Slope} \times 10}{\text{Intercept} + \text{Slope} \times 2010} \times 100 \quad \text{(Equation 2.4)}$$

Note that for indicators based on CLC data, the short term trend (expressed as % change per decade) was based on the CLC2012 and CLC2018 datasets. The long term trend was based on the CLC2000 and CLC2018 datasets.

In a next step, the percentage change was assigned to one of the four possible assessment outcomes (improvement, degradation, no change, unresolved) using a procedure that combines policy relevance with statistical significance.

The following procedure applies to all indicators:

- Change is always considered as significant in case the percentage change per decade is higher than or equal to +5% or lower than or equal to -5%. This is valid for both short and long-term trends and regardless statistical testing. A change outside this interval is thus always considered as policy-relevant to report. This change is assigned as an **improvement** or a **degradation** (depending on the sign and the interpretation of the indicator, e.g. degradation if pressures increase, improvement if condition increases).
- In case the change level falls within the interval of -5% and +5% per decade, **no change** is assumed. In these cases, it is advised to perform a statistical test to detect statistical significance. In case of statistical significance, the trend may be reclassified from no change to either improvement or degradation depending on the sign and the interpretation of the indicator. The indicator fact sheets contain information about the statistical test used for detecting change[5].
- Indicators that after visual inspection show a stochastic behaviour over time or for which there are concerns that justify a different assignment can be classified as **unresolved**. This class also includes policy-relevant indicators (see fifth MAES report) for which there are no data available.

The **5% per decade rule** is based on the precautionary principle. Even in absence of statistical significance, we consider it important to notify policymakers of a level of change in ecosystem condition that reaches or exceeds 5% over ten years. There can be many reasons for a lack of statistical significance including an insufficient number of data points available. By highlighting considerable changes as significant (irrespective of the outcome of the statistical tests) we would like to avoid exclusion of relevant processes from the policy evaluation just because there is not enough data for a powerful statistical test. The selected threshold in the level of change corresponds to +0.49% per year (or -0.51% per year for declining trends) and to +63% per 100 years (or -40% per 100 years for declining trends). It is useful to refer to the IPBES global assessment to contextualise losses in biodiversity and ecosystem condition. The IPBES assessment reports that global indicators of ecosystem extent and condition have shown a decrease by an average of 47% of their estimated natural baselines, with many continuing to decline by at least 4% per decade (IPBES, 2019). IPBES further reports: area of wetlands (0.8% per year from 1970 to 2008); area of forests and natural mosaics (7% between 2000 and 2013); extent of seagrass meadows (over 10% per decade from 1970 to 2000). More details on specific rates of declines for species, habitats and ecosystems are also available in this report (IPBES, 2019). Given these declines, we opted to set a threshold on 5% per decade to report a significant loss of ecosystem condition.

Note that Eurostat uses a much higher value i.e. 1% per year as cut off level to identify significant change in the Sustainable Development Goals (SDG) indicators (Eurostat, 2019). This would correspond to 10% per decade. This level of change may be relevant for pressures. Applying this cut off level, however, risks overlooking ecologically relevant changes in ecosystem condition as the response of ecosystems to pressures may be much slower than the actual change in pressures.

[5] The general recommendation to the thematic and crosscutting assessments was (1) in case of a small number of observations (N<4) to use the classic t-test for dependent samples or its non-parametric variants (Wilcoxon test for 2 years and Friedman ANOVA for more than two years). In case of mapped data these test were combined with bootstrapping or random sampling of 1% of the data, (2) in case of a higher number of observations to use ordinary least squares regression. Non parametric alternatives to estimate regression slopes are then Theil-Sen estimator and the Mann-Kendall test.

2.9.5 Assessment of the confidence

The confidence of every indicator as measure of how certain we are that the observed trend is effectively reflecting changes in the condition of ecosystems is assessed using a procedure that delivers a qualitative confidence score with three classes: low confidence, medium confidence and high confidence.

To this end every pressure, condition or service indicator used in this assessment has been classified according to its expected annual dynamic of change. A way to assess the annual dynamics of change of a particular indicator is to question how predictable the value of a particular year is based on the value of the preceding year. Some variables such as the abundance of species can show a highly variable pattern over time with strong year to year variations whereas processes such a land use change may be more stable or predictable. Annual recruitment to fish stocks for instance would be very hard to predict based on the recruitment recorded for the previous year since we know that fish recruitment is a very dynamic process with high natural inter-annual variability. In contrast, the total share of land covered by artificial area might be more predictable. It is probably a "little bit more than last year".

Table 2.5 presents a typology for the annual dynamics of changes in ecosystems (day to day and seasonal dynamics are not considered here).This gradient in dynamics is important to understand the confidence of the estimated value for change per decade. This information should be considered when assigning levels of confidence on the indicators used in the thematic and cross cutting ecosystem assessments. Table 2.5 does not contain quantitative thresholds, for instance, based on the coefficient of variance but it is a proposal based on expert judgement.

Table 2.5. Annual dynamics of change in pressure and ecosystem variables

Annual dynamic of change	Description	Examples of indicator types
Highly variable	Strong year to year variations with long term and short term time trends superimposed on each other due to a fast response of the variable to changed environmental conditions.	Abundance of species Recruitment processes Ecosystem productivity Ecosystem functions Climate variables
Moderately variable	Moderate year to year variations with a clear long term and deviations due to short term time trends	Species diversity (number of species) Physical-chemical variables of water quality and air quality Soil indicators Invasive alien species
Moderately stable	Low year to year variations with a clear, monotonous upward, stable or downward trend	Emissions of pollutants Deposition
Highly stable	Hardly any year to year variations; Slow processes which take years to manifest	Land cover and land use change Fragmentation Landscape mosaic Land take Natura 2000 coverage Conservation status of habitats

Every indicator used in this assessment is scored for its confidence using Table 2.6. The table uses the typology for pressure and condition indicators proposed in Table 2.4 and assigns the different categories to the four levels of change (varying from highly variable to highly stable) as defined in Table 2.5.

Next three criteria are used to score the level of confidence using three classes: high confidence, medium confidence, and low confidence. The criteria used are

- The total number of observations: depending on the dynamics of change more observations are related to an increasing level of confidence.
- The latest observation: depending on the dynamics of change an observation closer to 2020 is related to an increasing level of confidence
- The method used to calculate the indicator: independent of the dynamics of change an established indicator or methodology based on direct observations is more reliant than indicators derived from models.

Note that statistical significance is already used in the labelling of indicators (no change, improvement, degradation, unresolved) so this is not used again in Table 2.6.

Note also that for structural ecosystem attributes (general), a difference is made between indicators based on the use of land cover data and other structural ecosystem attributes (general).

Trends in ecosystem service potential, use and demand were analysed assuming highly stable dynamics, mainly because potential and demand are to a substantial extent based on the use of CLC data.

Applying Table 2.6 implies that the short-term trends always have a lower confidence than the long-term trends.

2.10 Mapping change: spatially explicit aggregation of trends

About half of the indicators used in this ecosystem assessment are based on spatially explicit data and can thus be mapped. Two maps with data for different points in time can be used to make a new map of change by essentially applying Equation 2.2 but then at the level of the spatial mapping unit. Possible mapping units include both raster and vector-based geometries such as grids at various resolutions (in this assessment usually between 100 m and 25 km), catchments, river basins, functional urban areas, or administrative regions (e.g., NUTS regions). The maps merge both the pressure and condition indicators in order to map the change in ecosystems. This is different from the assessment based on aggregated values at EU level, where pressures and condition are kept separated in the assessment conclusion. The reason is that the number of spatially-explicit condition indicators is rather low, in particular for the assessment of agroecosystems. Most spatial indicators relate to pressures only.

The mapping approach delivers three maps that show per spatial unit (1) the number of indicators that deliver an improvement outcome, (2) the number of indicators that show a degradation outcome, or (3) the number of indicators that show no change. The decision on the assessment outcome per spatial unit is based using a similar procedure as for the EU wide trend assessment (the combination of the 5% per decade rule or based on statistical testing).

At this stage of the assessment, the maps are presented as such. A more elaborated assessment approach is under development including a prioritisation of pressure and condition indicators, which is necessary to make a more informed decision on whether ecosystems are improving, stable or degrading[6]. The change maps in combination with data on extent are used to assess the total area of ecosystems under a specific outcome.

[6] A more elaborated assessment approach needs to address the following question: Assume that ecosystem condition is assessed based on 10 indicators of which 5 suggest improvement, 1 suggest no change and 4 suggest degradation. The approach used in this ecosystem assessment is to simply report this outcome (corrected for confidence of the indicators) rather than to conclude on a final conclusion (improvement, no change, degradation). Deciding on a final conclusion requires a better (causal) understanding of the relative impact of various pressures on the condition of ecosystems. An additional predicament is that these impacts may manifest themselves in a dynamic way (e.g., years later) or only once a threshold is exceeded. This analysis goes beyond the scope of this assessment (although the datasets collected could help address this issue). It will be part of the integrated assessment and narratives chapter which will be prepared during the first semester of 2020.

Table 2.6. Look up table for scoring the confidence in trends based on indicators (High confidence, HC, Medium Confidence MC, Low confidence LC).

	Pressure class	Condition class	1. Number of observations (years)			2. Latest observation (year)			3. Indicator calculation method		
Confidence level			**HC**	**MC**	**LC**	**HC**	**MC**	**LC**	**HC**	**MC**	**LC**
Highly variable	Climate change	Functional ecosystem attributes Structural ecosystem attributes based on species diversity and abundance	> 30	15 - 30	< 15	2018	2016 - 2017	< 2016	Data based on direct observations (field observations, remote sensing, land cover data); Officially reported statistics with high confidence	Data as output from a validated model; Officially reported statistics with medium confidence	Data as output from a new method or from an unvalidated model; Officially reported statistics with low confidence
Moderately variable	Invasive alien species Soil erosion	Environmental quality Structural soil attributes	> 20	10 - 20	< 10	2018	2015 - 2017	< 2015			
Moderately stable	Pollution and nutrient enrichment Over-exploitation	Structural ecosystem attributes (general)	> 10	5 - 10	< 5	2018	2015 - 2017	< 2015			
Highly stable	Habitat conversion and degradation	Structural ecosystem attributes (general) which are based on CLC Structural ecosystem attributes monitored under the Nature directives and national legislation	> 5	3 - 5	2	2018	2012 - 2017	< 2012			

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3 Thematic ecosystem assessments

This chapter consists of seven sections which describe the trends in pressures and ecosystem condition of urban areas (section 3.1), agroecosystems (section 3.2), forests (section 3.3), wetlands (section 3.4), heathlands and shrubs, and sparsely vegetated lands (section 3.5), rivers and lakes (section 3.6), and marine ecosystems (section 3.7).

Every section or thematic assessment in this chapter is structured in a similar way. Each time, the ecosystem and its governance is briefly introduced. Next we report the total area of the ecosystem type. The largest part of each section is devoted to an analysis of the trends of pressure and condition indicators on the short term (using 2010 as baseline) and on the long term (based on time series that start before 2010). All chapters use a similar methodology to assess trends. These methods are described in chapter 2 of this report. Every section ends with a table summarizing the trends in pressures and condition, a discussion on what these results mean for policy and a brief analysis of the knowledge gaps.

The analysis of trends in pressure and condition is presented first with a table summarizing all available statistics at EU-28 level. This table is then followed by an in-depth assessment where for selected indicators more spatial and temporal detail is provided.

The different thematic ecosystem assessments have been carried out by different research teams. So each section mentions the coordinating and contributing authors. The first coordinating author is the main point of contact for questions regarding the ecosystem assessment under his or her supervision. The section also lists the reviewers that have commented on an earlier draft (insofar reviewers agreed that their names can be disclosed).

Chapter 4.4 on pressures and condition of soil could only be drafted in the period after the review of Chapter 3. Therefore, most soil indicators that are referred to in Chapter 3 have not been quantified and trends are reported as unresolved. Please use chapter 4.4 for soil related information.

Figure and table numbers always start with the number of the section followed by a number expressing their order of use in the section.

The different thematic assessments come with a series of indicator fact sheets which provide additional details on the data used in this assessment (metadata, maps, and data) and where appropriate the statistical details of the trend analysis. The fact sheets are encoded with 5 digits of which the first two refer to the section number, the third to pressures (1) or condition (2) and the two last digits refer to the order of appearance in the section. All the fact sheets of this report are bundled in a separate supplement of this report.

This supplement can be downloaded here: https://publications.jrc.ec.europa.eu/repository/handle/JRC120383

3.1 Urban ecosystems

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Summary: The policy context for urban ecosystems is very complex and includes all sectoral policies which are, directly and indirectly, connected with quality of life and well-being in cities. Urban environmental policies are having a renewal in agenda and importance. They are gaining importance especially in the EU and international agendas: e.g. in Goal 11 of the Sustainable Development goals, the priority objectives of the 7th environmental action program (EAP) on "Sustainable cities: "Working together for common solutions, "Building a climate-neutral, green, fair and social Europe" is one of the four priorities of the 8th Environment Action Programme, where the need to "…*to improve the environment in our cities and our countryside*…" is made explicit. Greening urban and peri-urban areas is also an objective of the recently adopted EU Biodiversity Strategy for 2030.

Urban ecosystems are cities and the surrounding, socio-ecological systems where most people live. They are very peculiar ecosystem types: they are almost completely artificial but they include, in different proportions, all other ecosystem types (forests, lakes and rivers and agricultural areas can all be part of urban fringe) and they are strongly influenced by human activities.

As pressure indicators, emission of air pollutants, soil sealing and municipal waste were included. At EU level, a relative reduction of the most important air pollutants was observed in the long and short term. The result is consistent with other assessments carried out on at a national scale. However, there is still the need to decrease air pollutants emissions and limit population exposure. Besides that, a relative increase in municipal waste and sealed soil, especially within densely built areas in core cities was recorded.

In the last twenty years urbanization has increased in Europe. All structural condition indicators confirm the trend, despite regional patterns linked to spatial configuration, demographic transition stage and economic development of European cities. At EU level, areas dominated by the presence of artificial land increased with 3.2% between 2000 and 2018. When considering the share of dominant land types (the proportion of areas dominated by artificial, agricultural or natural land), 69% of Functional Urban Area remained relatively stable, with no clear direction of change. When a change has occurred, it has been characterized by a loss of agricultural or natural land and an increase in areas with no clear characterization, which is a proxy of urban sprawl.

Functional Urban Areas are characterized by a progressive densification of settlements. The vegetation cover of urban green infrastructure has been relatively stable in the long term, with a slight upward trend in areas of the cities that are not densely built in both core cities and commuting zones. However, when focusing on the balance between abrupt greening (defined as a relatively sharp upward trend in urban vegetation) and browning (defined as a relatively fast loss in urban vegetation), cities are not able to compensate for land taken. This means that when a loss of vegetation is observed (usually due to land use change, i.e. housing or infrastructure policies) there is no corresponding compensation strategy in place to recover the vegetation within the green infrastructure. This can result in progressive increase in fragmentation of semi-natural patches and consequential loss of city resilience.

Cities and their surroundings can be part of the solution. They can host biodiversity spots and Urban Green Infrastructure (UGI) can deliver important benefits and be part of a regional eco-networks. However, defining a clear role of urban ecosystems within sectoral EU legislation and policies is required. Clear rules need to be set to compensate for land taken and vegetation loss. Moreover, there is a need for setting targets to specifically monitor urban condition, urban biodiversity and urban their ecosystem services.

3.1.1 Introduction and description of urban ecosystems

Urban ecosystems are cities and the surrounding, socio-ecological systems where most people live (Maes, et. al. 2016). They are very peculiar ecosystem types: they are almost completely artificial but they include, in different proportions, all other ecosystem types (forests, lakes and rivers and agricultural areas can all be part of urban fringe) and they are strongly influenced by human activities.

Urban ecology can be defined as the ecology of all organisms (including humans), in urban ecosystems (Parris, 2016). It investigates the overall urban biophysical environment and how it affects human health and other ecosystems condition. Moreover, human consumption and behaviour in one area can affect the health and wellbeing of people or ecosystems in another. This can be considered a “form of transboundary environmental trade that transfers adverse impacts and their related costs from one jurisdiction, whether municipal or national, to another” (Douglas, 2012).

Urban ecology includes people because “…the presence, population dynamics and behaviour of people and the environmental changes that occur when they construct towns and cities, are central to our understanding of how urban systems function”.

Urban ecosystems can be described at many scales (e.g. districts, city, urban centre and its surroundings). How we define urban depends essentially on the research question (see reporting units of this chapter).

Urban ecology and the study of urban ecosystems are important for the following reasons: urban environments are extensive and growing; the nature of urban environments affects the health and wellbeing of their human inhabitants; they are important for conserving biological diversity; they have an impact on their close surroundings; and they have an impact across boundaries on other cities or other ecosystem types.

“A better understanding of urban environments will help us to create more liveable cities that provide high-quality habitat for humans and non-humans alike” (Parris, 2016).

In line with the overall objective of this report, the aim of this chapter is to determine and report the trends in the pressures and condition of urban ecosystems relative to the baseline year 2010. This chapter can thus be used to evaluate the targets of the EU Biodiversity Strategy to 2020. It is important to stress that this assessment is primarily based on indicators for which European wide, harmonized datasets have been collected. Where needed more context is provided by citing to relevant literature. However, this chapter did not make a systematic review of the literature on pressures on urban biodiversity and ecosystems.

This chapter delivers the baseline data to establish a (legally binding) methodology for mapping and assessment of ecosystems and their capacity to deliver services and to determine the minimum criteria for good ecosystem condition of urban ecosystem as required by the new EU Biodiversity Strategy to 2030. Determining these criteria of urban ecosystems requires also agreeing on an agreed reference or target condition against which the past or present condition can be evaluated, which is far from evident in an urban context. More work will be needed to determine the target and reference levels of pressure and condition indicators in agreement with stakeholders, scientists and policymakers.

3.1.2 Specific ecosystem related policies that govern urban ecosystems

European cities are very diverse in terms of land composition, policymaking, and territorial development. They are at different stages of urbanization and demographic transition, however, urbanized areas share common problems. These problems are related to poor air quality, high levels of noise pollution, limited capacity to tolerate flooding events (and increased risk of flooding due to the high share of impermeable surfaces) and to cope with urban heat island effect, as well as modest contact with “natural” environments and green spaces.

Urban environmental policies are about to have renewal in agenda and importance. “Sustainable cities and communities” is Goal 11 of the UN Sustainable Development goals. “Sustainable cities: "Working together for common solutions" is one of the nine priority objectives of the 7th environmental action program (EAP)[7]. “Building a climate-neutral, green, fair and social Europe” is one of the four priorities of the 8th Environment Action Programme[8], where the need to *“…to improve the environment in our cities and our countryside…”* is made explicit. “Greening urban and peri-urban areas” is section 2.2.8 of the new Biodiversity strategy to 2030[9].

The transition to more resilient cities is a multi-scale process, which implies:

1) Actions at local scale for the implementation of specific policies for sustainable urban planning and design;

2) Actions at regional and national scale for the implementation of transboundary policies, such as policies related to air, water, noise quality, mobility, or the deployment of an integrated Green Infrastructure (GI).

Urban ecosystems played a crucial role also in the Biodiversity Strategy to 2020 and GI Strategy (EC 2013; EC 2019a) and potentially represent a source of environmental pressures leading to negative environmental

[7] https://ec.europa.eu/environment/action-programme/

[8] https://www.consilium.europa.eu/en/press/press-releases/2019/10/04/8th-environmental-action-programme-council-adopts-conclusions/

[9] https://ec.europa.eu/info/sites/info/files/communication-annex-eu-biodiversity-strategy-2030_en.pdf

impact. However, they also represent an opportunity of implementing actions where most people live, thus potentially reaching a high number of beneficiaries. They can host biodiversity and they could be an effective component of an integrated, multi-level green infrastructure network. Functional Urban Areas contain 15.2% of Natura 2000 sites and the complex system of urban blue green infrastructure is fundamental for providing ecological functions and ecosystem services. The review of GI strategy (EC 2019b; EC 2019c) provides an exhaustive list of sectoral GI related policies which are directly or indirectly connected with urban ecosystems.

Greening urban and peri-urban areas is also an objective of the recently adopted EU Biodiversity Strategy for 2030. As part of a wider nature restoration plan, more focus will go to cities. To bring nature back to cities and reward community action, the Commission calls on European cities of at least 20,000 inhabitants to develop ambitious urban greening plans by the end of 2021. These should include measures to create biodiverse and accessible urban forests, parks and gardens; urban farms; green roofs and walls; tree-lined streets; urban meadows; and urban hedges. They should also help improve connections between green spaces.

3.1.3 Ecosystem extent and change

Europe experienced an increase of urban ecosystem type over the last 20 years by 3.4% per decade on the long term (Table 3.1.1). According to the MAES framework (Maes, et. al. 2014), “Urban” consists of all artificial land cover types included in Corine land Cover Map (Level 1).

Table 3.1.1. Surface area of urban ecosystem type, based on Corine Land Cover accounting layers for 2000, 2006, 2012 and 2018.

Area (km^2)	2000	2006	2012	2018	Change (% per decade)	
					Short term	Long term
Urban ecosystems	209,409	214,939	219,549	222,188	3.4	2.0

3.1.4 Data and reporting units

This chapter presents the main results of the assessment of conditions characterizing urban ecosystems in the EU-28. To this aim, the state, short-term, and long term-trend of different indicators have been analyzed. Concerning the scale of the assessment, following Douglas (2012), urban ecosystems were analyzed considering the core city and its surrounding (that Douglas defines as “*Urban region*”). This choice allows to:

- Analyze “…..The immediate urban life-support system of the urban areas and its surroundings (the peri-urban area) providing such ecosystem services as water supplies, sand and gravel, landfill sites, recreation areas, water shed protection, greenhouse gas uptake and biodiversity…..” (Douglas, 2012, p. 386).
- Use (when possible) the system of Functional Urban Areas promoted by EUROSTAT, which includes more than 700 urban environments.
- Consider the transboundary effect with consistency.

The reporting unit chosen to express each indicator varies according to the data available, the type of indicator, and the policy targeted. Not all data were spatially explicit and available at the same aggregation level. When possible, we used the spatial system for city statistics, version 2018, as recommended by Eurostat (Dijkstra and Poelman 2012; EuroStat 2016; Eurostat 2017, Fact sheet 3.1.100, Supplement). We always used the extent published in 2018, with the aim of exploring the evolution of urban environments through the decades. The system is structured as follows:

Functional Urban Areas are defined as the core city (with at least 50,000 inhabitants) and the commuting zone and are based on commuters; employed persons living in one city who work in another city. It represents an ‘operational urban spatial extent’ that allows mapping and evaluating the city and its surroundings. The commuting area is an area of transition, from agricultural or semi-natural land uses to urban land use and is very important when considering ecosystem services. There are cities that have never had a commuting zone or lost their commuting zone.

Core cities are cities with at least 50,000 inhabitants. One FUA includes one or more core cities. As reporting unit for core cities, we aggregated all core cities within the same FUA. Core cities normally correspond to the Lower Administrative Units (LAU).

Commuting zones (or sub-city districts), represents the commuting zone around the core city; occasionally FUAs do not include a commuting zone (15% of the cases). In this case the FUA correspond to the core city. The commuting zone includes the cluster of Low Administrative Units (LAU) that surround around the core city.

'Greater city' are urbanized areas that stretch far beyond their administrative boundaries. The greater city can completely overlap the FUA and includes one or more urban centres (Eurostat 2017). For reasons of consistency, Greater cities have been considered the core cities for the respective FUAs (e.g. Naples, Paris, London, Athens, see Eurostat, 2017). Figure 1 and Figure 2 show the distribution of FUAs and core cities in Europe. Commuting zones can be vast compared to core cities. In total, FUAs cover 20% of European territory. Core cities cover only the 3.5%.

The entity of **Agglomeration** is not part of the FUA system; it represents urban areas with more than 100000 inhabitants (EIONET Report – ETC/ACM 2018/14).

Additional technical details can be found in the fact sheet 3.1.100.

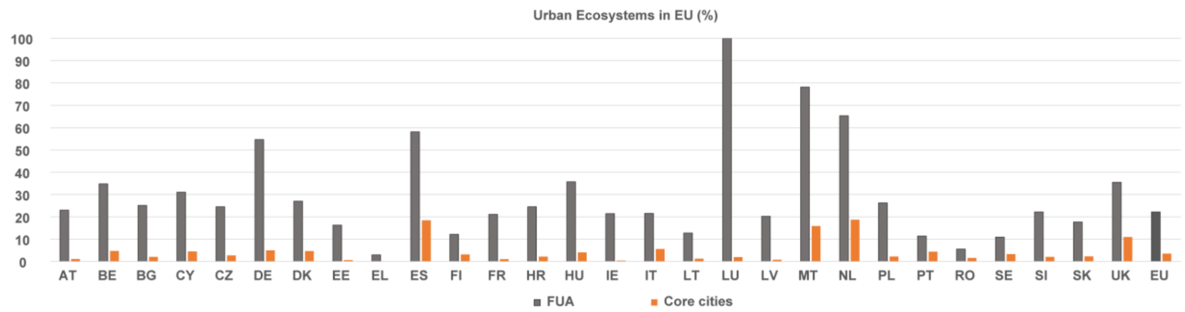


Figure 3.1.1. Proportion of surface area of FUA and core cities in EU countries territory (%).

The assessment was implemented following the 5th MAES report (Maes et. al 2018) and the recent discussion paper prepared for the SEEA (Czúcz et al. 2019). The framework proposes a set of indicators to evaluate the ecosystems describing pressures, environmental quality, structural attributes and ancillary aspects.

Pressures are often considered as an indirect approach for measuring ecosystem condition, when we need to consider variables as environmental 'stock' that determine a degradation of ecosystems, e.g. air pollutants emissions or amount of waste generated. **Environmental quality** and **structural attributes** of ecosystems represent characteristics of the environment which measure the condition of ecosystems. Environmental quality indicators are based on point in time measurement (for instance concentration of air pollutants). Structural attributes of ecosystems evaluate ecosystem type specific landscape characteristics and includes metrics of land types mosaics, landscape connectivity or vegetation biomass. **Ancillary indicators** represent policy-relevant metrics that cannot be included in the other classes but are important in order to provide a context (for example population density in urban areas).

Table 3.1.2 synthetizes the reporting units used in the assessment. Air pollutants (emissions and concentrations), the share of dominant land types, the urban structure, population and bathing water quality were reported at the FUA level. Data on municipal waste generated were available at national scale and could be expressed only at national and EU level. The population exposed to harmful levels of noise was reported at the agglomeration level. Indicators related to urban vegetation for which high-resolution data were available, were reported using four reporting units: core city and commuting zone, respectively densely built and not-densely built. Most cities are "*mosaics of built infrastructures and open spaces*" Parris (2016), p. xi; the proportion of built-up areas is an important aspects when we describe urban environments and when we define policies or management strategies.

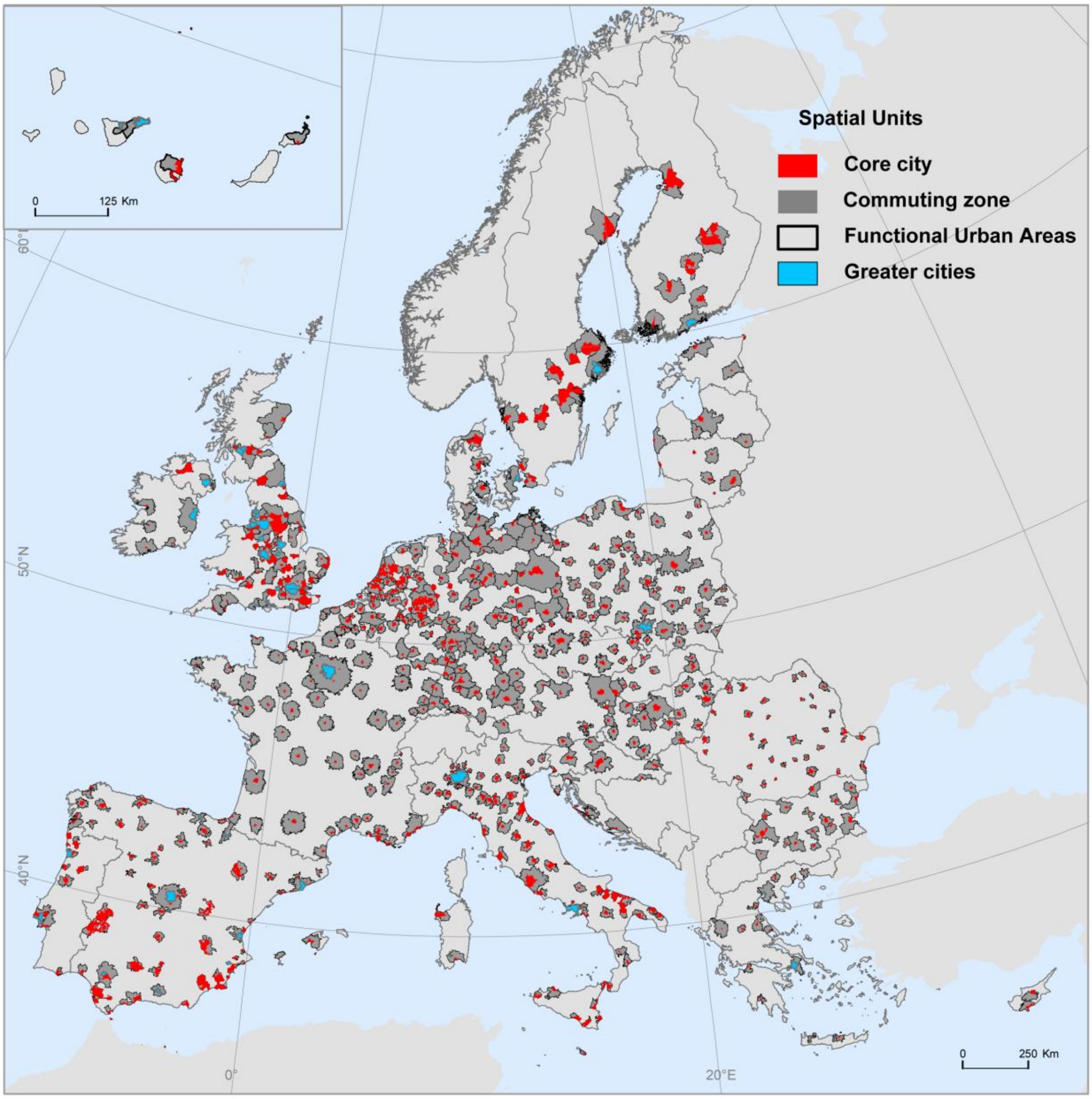


Figure 3.1.2. Distribution of Functional Urban Areas, Core cities and Greater cities in Europe (EU-28).

Table 3.1.2. Indicators for urban ecosystems and reporting unit used in the assessment. All fact sheets are available as a supplement to this report.

Class	Indicator	Reporting unit		Data	Time-series range	Fact sheet
Pressure	Air pollutants emissions	Functional Urban Area		EMEP/CEIP 2019	1990-2018	3.1.101
	Imperviousness	Core city	Densely built	EEA –Imperviousness https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness	2009-2015	3.1.103
			Not-densely built			
	Municipal waste generated	Aggregated municipalities per MS		EUROSTAT dissemination database https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190123-1	1990-2018	3.1.102
Condition-Environmental quality	Air pollutant concentrations	Functional Urban Area		EMEP/CEIP 2019	1990-2018	3.1.101
	Bathing water quality			Bathing Water Directive - Status of bathing water https://www.eea.europa.eu/data-and-maps/data/bathing-water-directive-status-of-bathing-water-11	1990-2018	3.1.205
	Population exposed to road noise pollution	Agglomerations		EEA, data on noise exposure https://www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-7	2012-2017	3.1.104
Condition-Structural ecosystem attributes	Share of dominant land types	Functional Urban Area		Corine Land Cover https://land.copernicus.eu/pan-european/corine-land-cover	2000-2018	3.1.207
	Urban structure	Functional Urban Area		GHS built-up grid https://data.jrc.ec.europa.eu/dataset/jrc-ghsl-10007	1975-2014	3.1.208
	Trends in vegetation cover within Urban Green Infrastructure (UGI)	Core city	Densely built	LANDSAT https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LE07_C01_T1_ANNUAL_GREENEST_TOA	1996-2018	3.1.209
			Not-densely built			
		Commuting Zone	Densely built			
			Not-densely built			
	Balance between abrupt changes within UGI	Core city	Densely built			
			Not-densely built			
		Commuting Zone	Densely built			
			Not-densely built			

Class	Indicator	Reporting unit	Data	Time-series range	Fact sheet
Condition - Structural ecosystem attributes monitored under the EU Nature directives and national legislation	Percentage of urban ecosystems covered by Natura 2000	Functional Urban Areas	NA	NA	NA
Condition - Structural soil attributes	Soil organic carbon (SOC)	Functional Urban Areas	NA	NA	NA
Ancillary indicators	Population	Functional Urban Area Core city	EUROSTAT-URBAN AUDIT https://ec.europa.eu/eurostat/web/cities/data/database	2010-2017	3.1.106

NA: Data are not available or data are available but still need to be adapted to the ecosystem typology used in this assessment. Data on soil are reported in chapter 4.4.

This is particularly true if the open spaces and remnant areas are involved. For this reason, using a model derived from the landscape ecology (the Landscape Mosaic Vogt and Riitters, 2017) two specific zones of interest were defined: "*Densely built*" where the relative proportion of artificial land cover types is dominant (> 60% artificial in a neighbourhood surrounding that location) ; "Not-densely-built" where the relative proportion of artificial land cover types is not prevalent in a neighbourhood surrounding that location and there is still a proportion of other ecosystem types (forest, wetlands or agriculture). More details on the methodology applied can be found in Chapter 4.3 and fact sheet 3.1.107.

Table 3.1.3. Nature-based solutions (NBS) classified according to share of built-up areas and the typology of NBS. The table was compiled following Somarakis et al. (2020), chapter 2 and Annex 1.

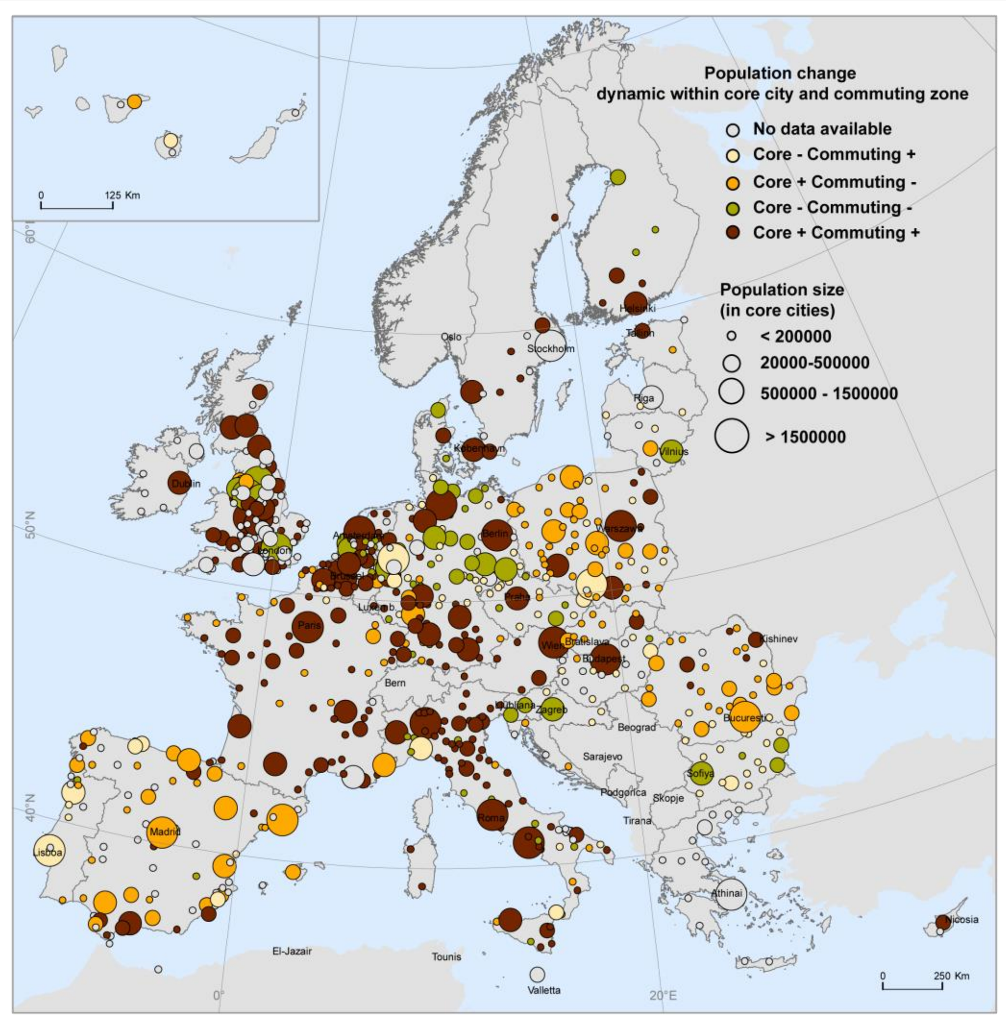
NBS Type	**NBS-sub-type**	**Examples**
Core city or Commuting zone -Densely built		
Type 3 – Design and management of new ecosystems.	Intensive urban green space management	Integrated and ecological management - spatial aspects Choices of plants Structure of urban parks system (Large urban park; Pocket garden/park; Community gardens) Flower field Street trees Green roof Green wall system
	Urban water management	Sustainable urban drainage systems
	Ecological restoration of degraded terrestrial ecosystems	Soil and slope revegetation Plant trees/ hedges/perennial grass strips to intercept surface run-off
	Restoration and creation of semi-natural water bodies and hydrographic networks	Re-vegetation of riverbanks Constructed wetlands and built structures for water management
Core city or Commuting zone - Not-densely built		
Type 1 – Better use of protected/natural ecosystems	Protection and conservation strategies in terrestrial and marine Protected Areas (e.g. Natura2000 or MPA	Limit or prevent specific uses and practices Ensure continuity with ecological network Protect forests from clearing and degradation from logging, fire, and unsustainable levels of non-timber resource extraction
Type 2 – NBS for sustainability and multi functionality of managed ecosystems	Agricultural and Forest landscape management	Agro-ecological practices Agro-ecological network structure Forest patches Hedge and planted fence Flower strips
	Extensive urban green space management	Ensure continuity with ecological network Planning tools to control urban expansion Historical urban green network structure Choices of plants Heritage park Urban natural protected areas Introduced vs. local plants Vegetation diversification Green corridors and belts Planning tools for biodiversity, green infrastructure, and ecosystem services

In many cities, the interface zone between the core city and the surroundings is vulnerable: this is the place where space is still available for further development. Rural-urban fringe (or the outskirts or urban hinterland) is the interface between town and country. It is a transition zone where often urban and rural uses mix. This is an important concept in settlement geography as it represent a boundary zone where urban development may (or may not) happen. Examples of urban development are, decentralization of offices or business parks (which may cause an increase of commuting activities), transport infrastructure or housing development. The type of impact that urban development(s) has on ecosystems is strongly related to land policies and to the solutions implemented.

There are several nature-based solutions (NBS) available to increase resilience of cities (or their ability to cope with a wide range of stresses (Ilgen et al., 2019) in case of urban development. The choice of the solution depends on the several aspects; in this assessment we considered land configuration and the share of built up areas (which represent the amount of open space still available) and zone location, in core city or commuting zone (which we use to represent the city and the outskirts). Table 3.1.3 presents a synthesis of possible NBS, classified according to the share of built-up areas within core cities and commuting zones.

Box 3.1.1. Population dynamics and condition of urban ecosystems

Population dynamic (e.g., population size, growth, density, age and sex composition, migration, distribution) are seen as one of the main drivers of environmental impact of urbanized areas (Newman, 2006), which we consider as ancillary data in the context of this assessment (Czúcz et al., 2019). The impact intensity of population density is strongly related to the type of resource management and to lifestyle (de Sherbinin et al., 2007). On the other hand, people are an essential component of urban ecosystems. They may have a strong impact on urban nature, linked to management choices and they are strongly impacted by urban nature. A relative slight increase in urban population at EU scale has been registered during the last ten years (by about 6% at both core city and FUA level). In some cases, the phenomenon presents discrepancies between the core city and its commuting zone. In most of the FUA (57%), population within the core city and its commuting zone change in the same direction (brown dots and green dots in the Figure). In 44.3% population is increasing; in 12.7% population is decreasing. Conversely, in 26.8% of FUA population tend to move to be within the core city (with a decrease of population in the commuting zone). This dynamic affects part of urban areas in the Iberian Peninsula, Poland and Romania. In 16% of the FUA, it is the core city that loses population with an increase of inhabitants in the surroundings.



Population change (2010-2017). Brown dots represent FUA where population increased in both core cities and commuting zones. Green dots represent FUA where population decreased in both core cities and commuting zones. Orange dotes represent FUA where population increased only in core cities. Yellow dots represent FUA where the population increased only in Commuting zones

3.1.5 Drivers and pressures: spatial heterogeneity and change over time

Trends in pressure indicators are presented and discussed in this section. The reference table on urban ecosystems in the 5th MAES report (Table 4.1, Maes et al., 2018) lists 9 pressure indicators of which 2 are considered of policy relevance (air pollutants emissions and land take). Important pressures on urban ecosystems are related to habitat conversion and land degradation, pollution (air, water and noise pollution) and unwanted introduction of invasive alien species. Unfortunately no consistent and fully representative datasets were available to analyse all these pressures at a local, urban level. With reference to the MAES framework, availability of data allowed calculating trends for five air pollutant emissions, soil sealing and municipal waste. Invasive alien species, on the other hand, have been analysed in chapter 4.2.

3.1.5.1 Assessment at the level of EU-28

Table 3.1.4 presents the trend results at EU-28 level. At first glance Table 3.1.4 shows that:

The total air pollutants emissions (within Functional Urban Areas) registered a reduction in the long and short term (see fact sheet 3.1.101). The result is consistent with other assessments at national level (EEA 2019a; EEA 2019b; EEA 2020).

Proxies of land degradation were soil sealing and municipal waste. In both cases a degradation was registered. The share of sealed soil is significantly increasing in core cities, both in densely built areas and even more so in not-densely built areas where there are still opportunities for alternative solutions for dealing with territorial development. Municipal waste, which depends on urbanization, population density and lifestyle, is also increasing slightly in the long term. Nevertheless, the trend varies a lot among Member States, not only in terms of total amount generated but also concerning management and treatment strategies (see fact sheet 3.1.102).

The analysis confirms an overall reduction in total air pollutants emissions within FUA. A more detailed analysis could consider the different sources of emissions to verify which sector is responsible for the trends. Indicators connected with urbanization present upward trends with potentially negative consequences. An example is that, the persistent increase of impervious surfaces reduces resilience of urban ecosystems and exposes them to risks presented by climatic events (flooding or heat waves).

Data on invasive alien species (IAS) were not available for estimating trends. However, urban areas are particularly affected by them. Chapter 4.2 of this report estimates the impact of invasive alien species and the MAES urban ecosystem type is the most impacted ecosystem, with 70% of the extent under impact of IAS. Moreover, considering that agricultural land, forest, wetlands and inland water are also affected by IAS, we might expected that their area under the FUA be also affected.

Table 3.1.4. EU-28 aggregated pressure data in relation to urban ecosystems. The table contains per indicator the baseline value as well as statistics for the short and long-term trend (for methodological details see chapter 2).

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation (land conversion)	Imperviousness in densely built areas	%	50.84	0.97	↓	6		unresolved	
	Imperviousness in not-densely built areas	%	35.28	1.46	↓	6		unresolved	
	Land annually taken for built-up areas per person	(m2/person /year)			unresolved			unresolved	
Pollution and nutrient enrichment	Nitrous oxides (NOx)	Million tonne/ year	7.01	-31.92	↑	5	-22.69	↑	5
	Particular Matter (PM10)	Million tonne/ year	1.42	-19.25	↑	5	-16.72	↑	5
	Particular Matter (PM2.5)	Million tonne/ year	0.94	-23.43	↑	5	-18.0	↑	5
	Non-methane volatile organic compound (NMVOC)	Million tonne/ year	5.7	-18.5	↑	5	-23.9	↑	5
	Sulphur oxides (SOx)	Million tonne/ year	2.95	-65.0	↑	5	-33.9	↑	5
	Municipal waste	Thousand tonne	253950	-0.53	→	7	1.395	→	7

↑: Significant improvement (significant downward trend of pressure indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

3.1.5.2 *In-depth assessment*

A detailed interpretation of the indicators is provided in the following sub-sections.

Air **pollutants emissions** at EU scale are decreasing. The trend is in line with other official assessments at national scale (EEA 2019a, EEA 2019b, EEA 2020), which confirms the compliance of all Member States concerning reductions on Nitrogen oxides (NOx) and Sulphur dioxide (SO2) emissions. Nevertheless, especially when considering the short-term trend, regional patterns are revealed. Additional technical details can be found in the fact sheet 3.1.101.

Specifically within FUAs:

NOx (Figure 3.1.3)

- in the long term, the downward trend is confirmed in 97% of European urbanized areas. Poland is the only region with slightly increased emissions within FUAs (or a slower downward trend);
- in the short term, 90% of urbanized areas are characterized by a downward trend. In some cities, the downward trend is becoming a slightly upward one (north east Spain, Romania, Poland, UK)

NMVOCs (Figure 3.1.4)

- in the long term, the downward trend is confirmed in 90% of European urbanized areas. Poland is the only Member State where emissions increase within urban areas.
- in the short term, the downward trend remains constant at 73% in urbanized areas. However, in Poland, Spain and some cities in UK we register an upward trend

PM10 (Figure 3.1.5)

- in the long term, the downward trend persists in 82% of European urbanized areas. However, we register an upward trend in some cities in Romania, Italy, Spain (north east), Poland, Bulgaria, Latvia and Lithuania.
- in the short term, 88% of urbanized areas present a downward trend. However, in some cities the downward trend is turning into an upward one (north east Spain, South UK, few German cities)

PM 2.5 (Figure 3.1.6)

- in the long term, the downward trend persists in 85.5% of European urbanized areas. However, we register an upward trend in some cities in Romania, Italy, Spain (north east), Poland, Bulgaria, Latvia and Lithuania.
- in the short term, the downward trend remains constant in 89% of urbanized areas. However, in some cities the downward trend is turning into an upward one (northeast Spain, South UK, few German cities); in other areas (Romania, Italy, some Spanish and Polish cities) the emissions decrease.

SOx (Figure 3.1.7)

- in the long term, the downward trend persists in all European urbanized areas.
- in the short term, the downward trend remains constant in 82% of urbanized areas. Nevertheless, in some urbanized regions we register an inverse tendency (Bulgaria, Spain, Germany)

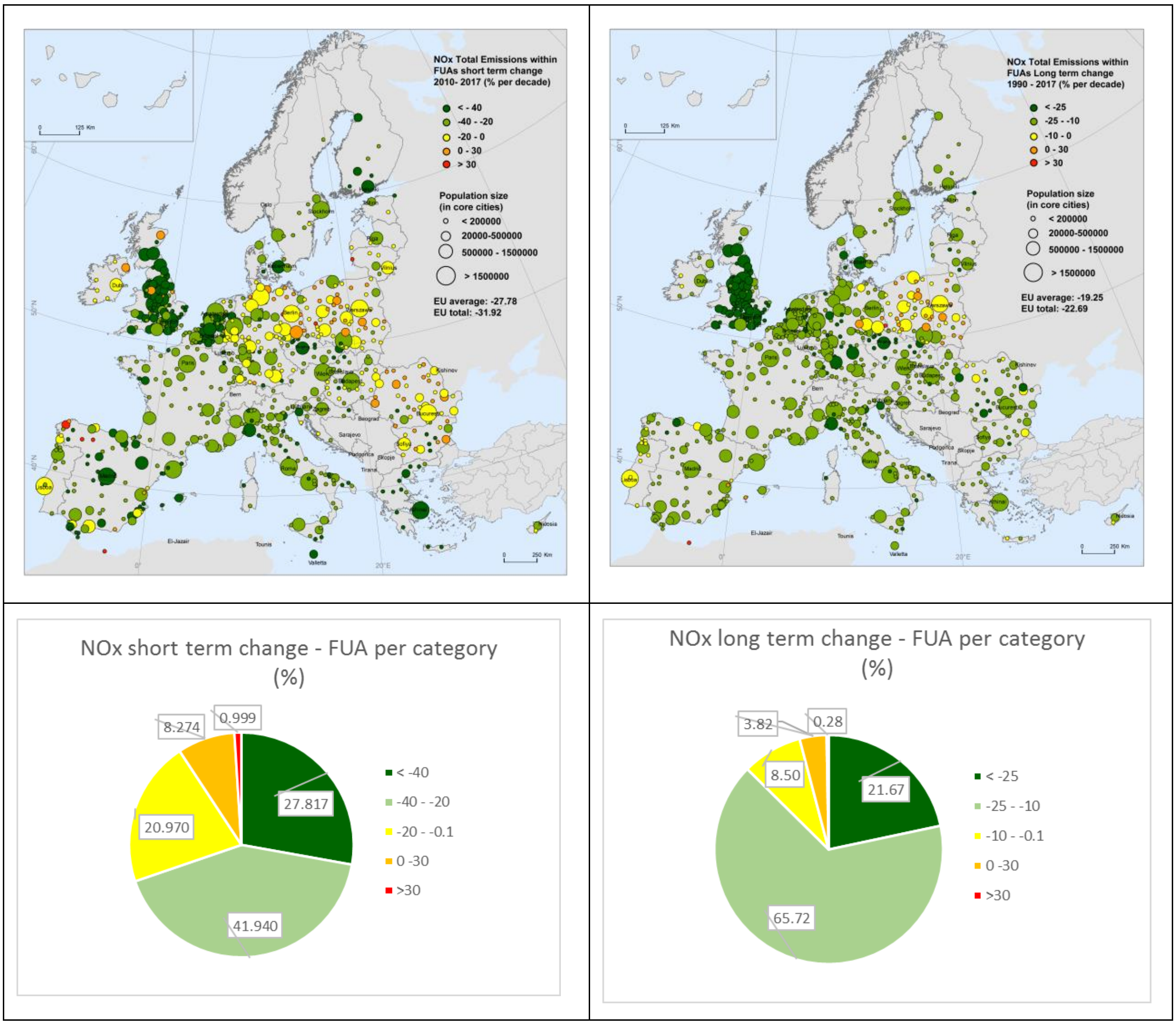


Figure 3.1.3. Total NOx emissions within FUAs in the Short and Long Term (source: EMEP/CEIP 2019, officially reported emission data.

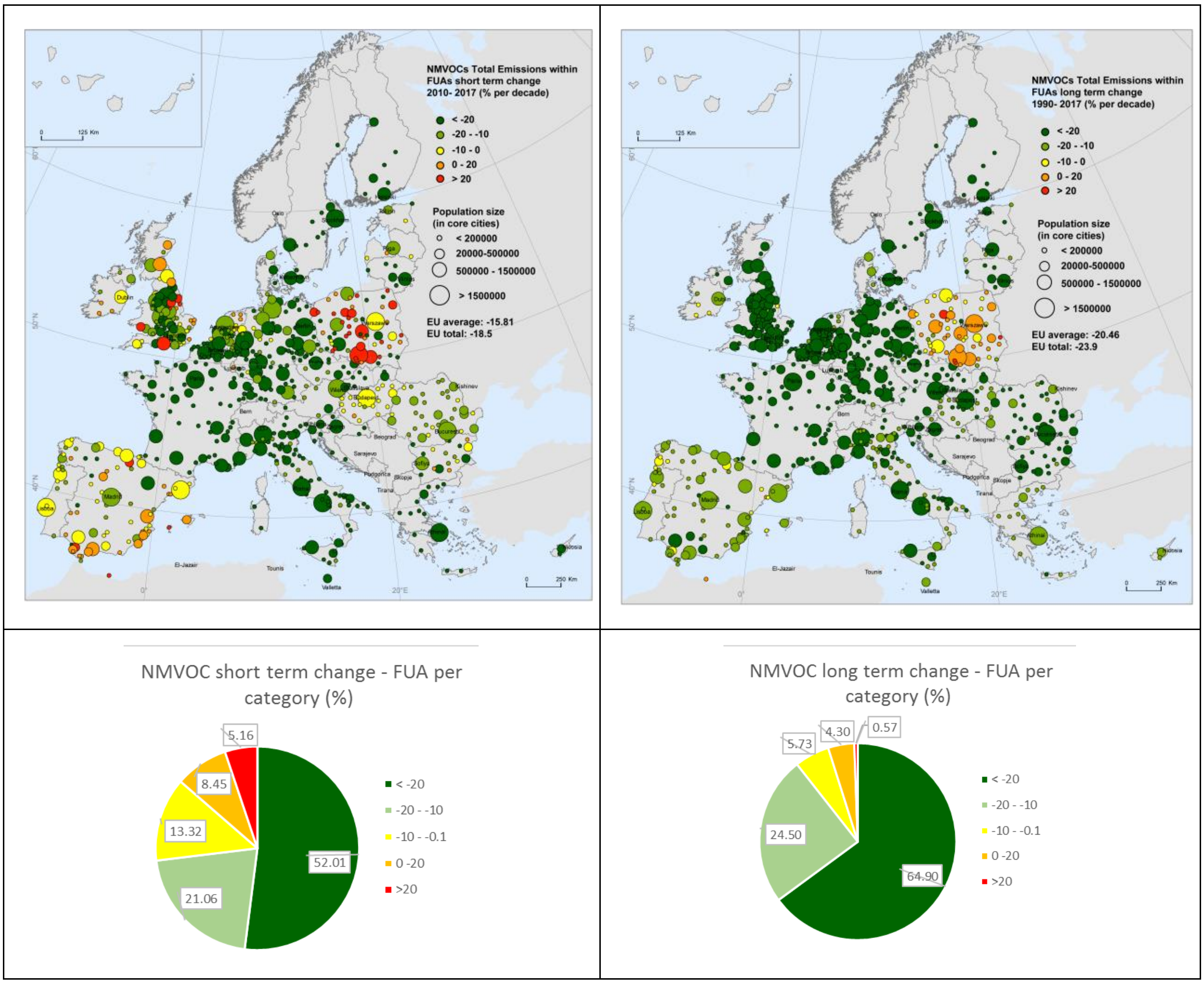


Figure 3.1.4. Total NMVOC emissions within FUAs in the Short and Long Term (source: EMEP/CEIP 2019, Officially reported emission data.

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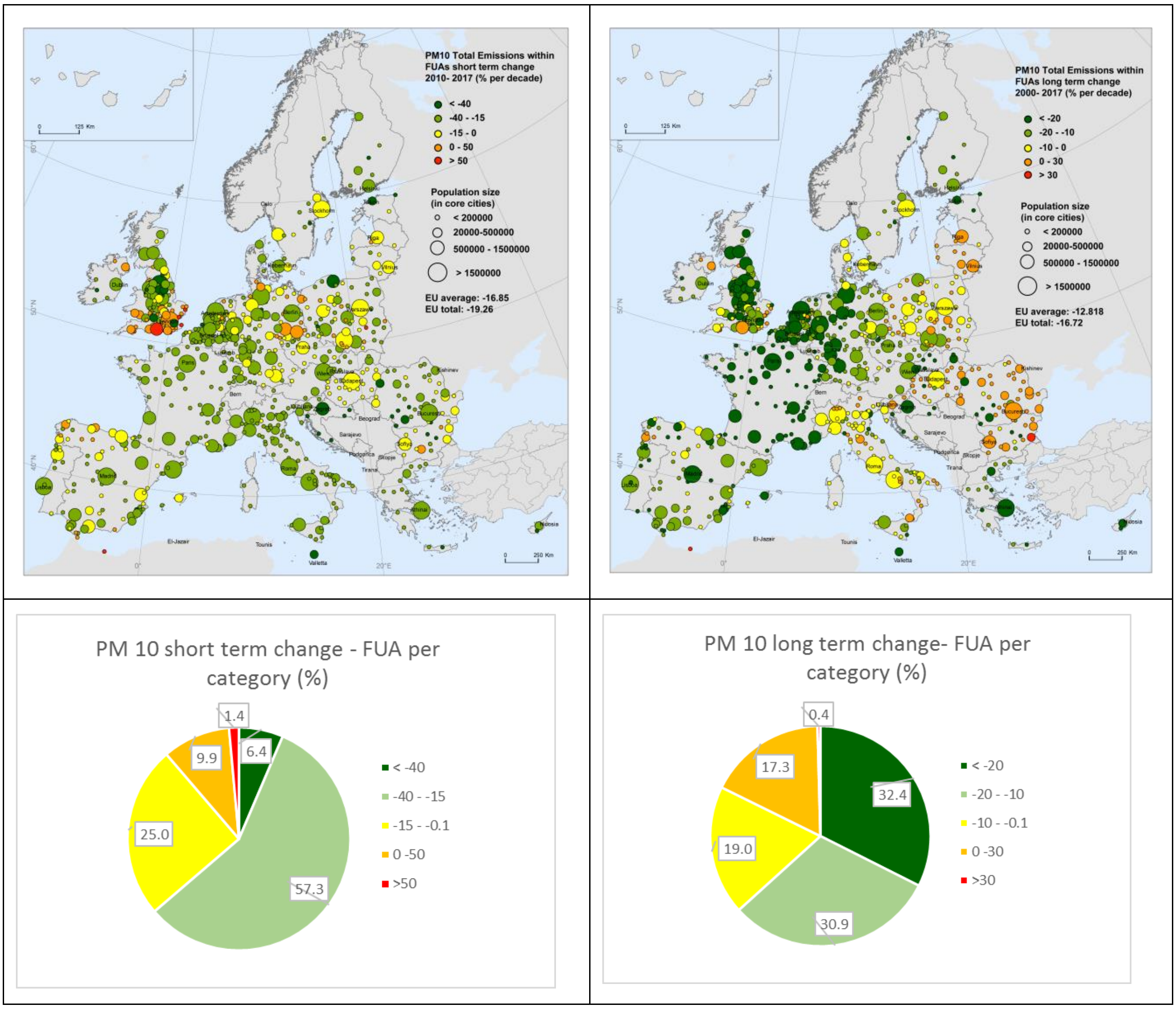

Figure 3.1.5. Total PM_{10} emissions within FUAs in the Short and Long Term (source: EMEP/CEIP 2019, officially reported emission data.

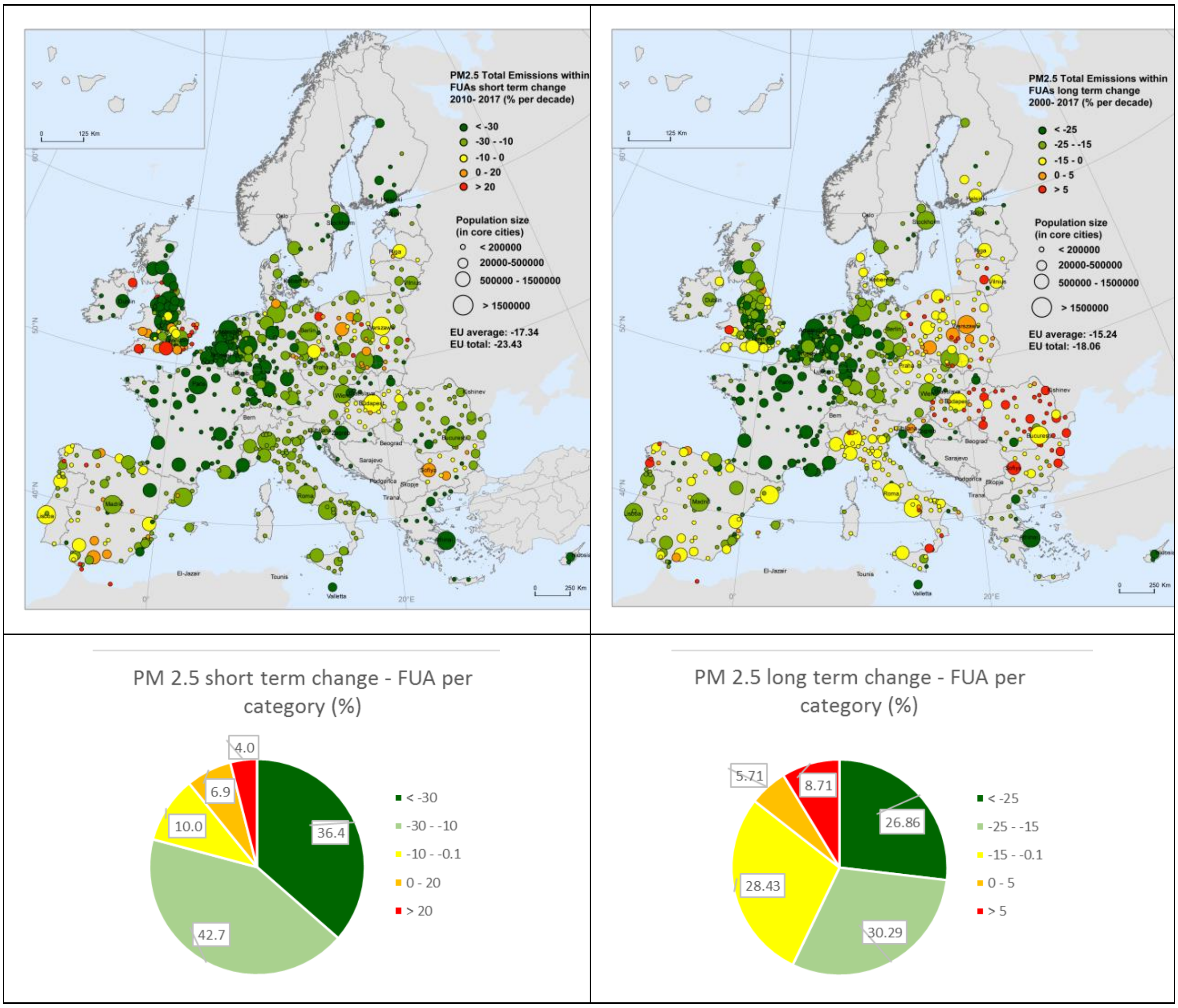

Figure 3.1.6. Total $PM_{2.5}$ emissions within FUAs in the Short and Long Term (source: EMEP/CEIP 2019, officially reported emission data

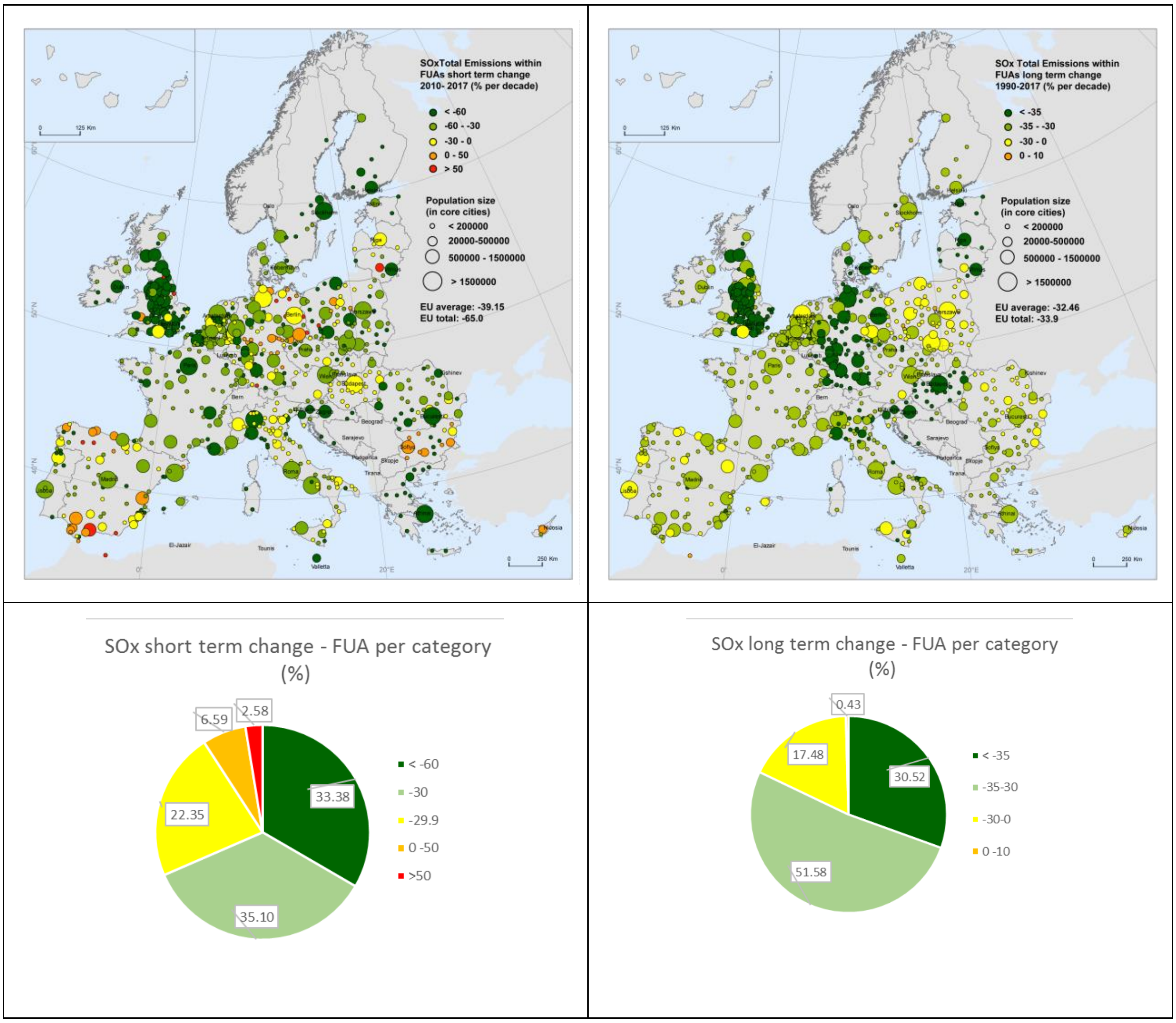

Figure 3.1.7. Total SO_x emissions within FUAs in the Short and Long Term (source: EMEP/CEIP 2019, officially reported emission data.

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Municipal waste is defined as waste collected and treated by or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, as well as yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste if managed as household waste. The amount of municipal waste generated in each country is related to the rate of urbanization, the population density, the type and pattern of consumption, household revenue and lifestyle (OECD, 2019). Over the past 30 years, efforts at European policy level resulted in actions aiming to reduce the negative environmental and health impact of waste. Waste disposal, in fact, may cause loss of materials or produce impact on the environment (Taelman et al. 2018).

In the long term, there has been a slight increase of municipal waste generated at EU scale (1.39%), nevertheless the value cannot be considered statistically different from 0, and has been recorded as stable in the EU level assessment. Figure 3.1.8 shows the graph of municipal waste generated.

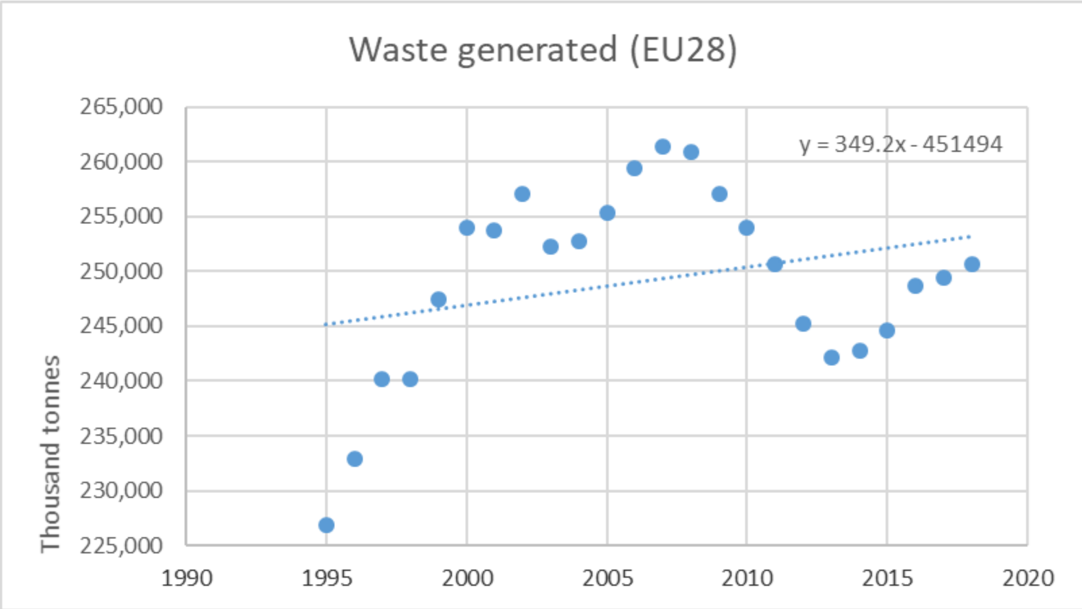


Figure 3.1.8. Municipal waste generated at EU level (source: EUROSTAT).

The picture varies a lot at the national level. In ten Member States, we denote a decrease in the amount of municipal waste produced. In Spain, Germany, United Kingdom and The Netherlands however the direction of change cannot be considered statistically significant. On the contrary eighteen Member states show a clear upward trend, and only in Poland and Belgium the change is not considered statistically significant.

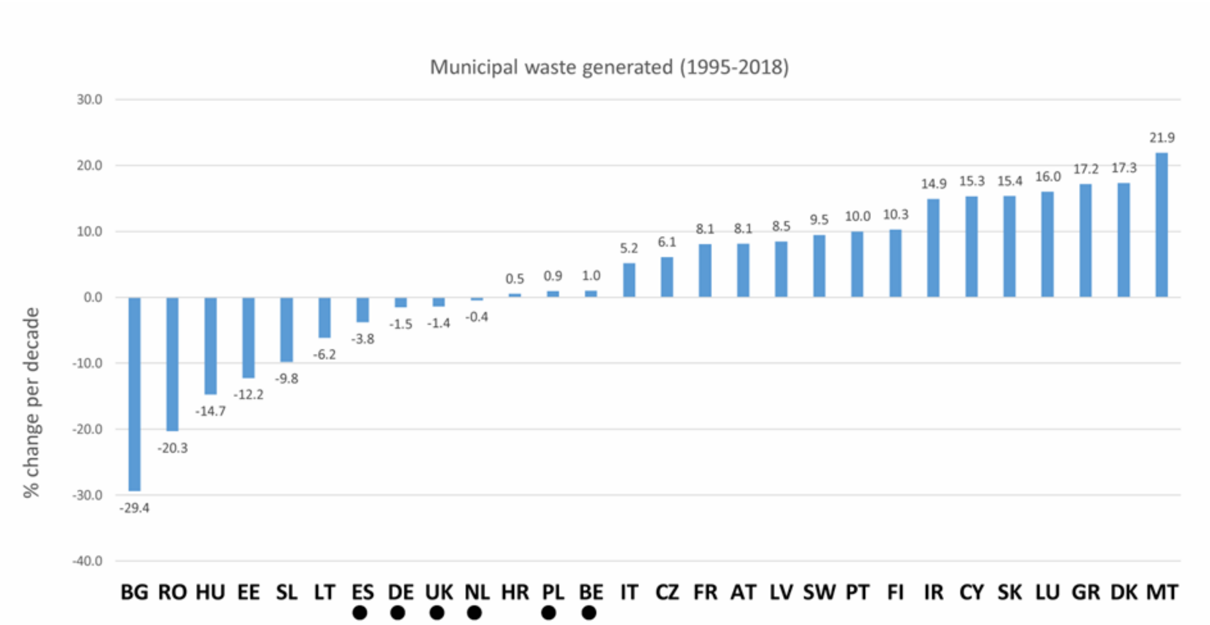


Figure 3.1.9. Municipal waste generated per MS (1995-2018), change per decade (%). Black dots represent the MS for which the change cannot be considered statistically significant. (source: EUROSTAT).

As reported by EUROSTAT the variations among Member States, which are confirmed by the values expressed in kg per capita, "...reflect differences in consumption patterns and economic wealth, but also depend on how municipal waste is collected and managed. There are differences between countries regarding the degree to which waste from commerce, trade and administration is collected and managed together with waste from households[10]. Additional technical details can be found in the fact sheet 3.1.102.

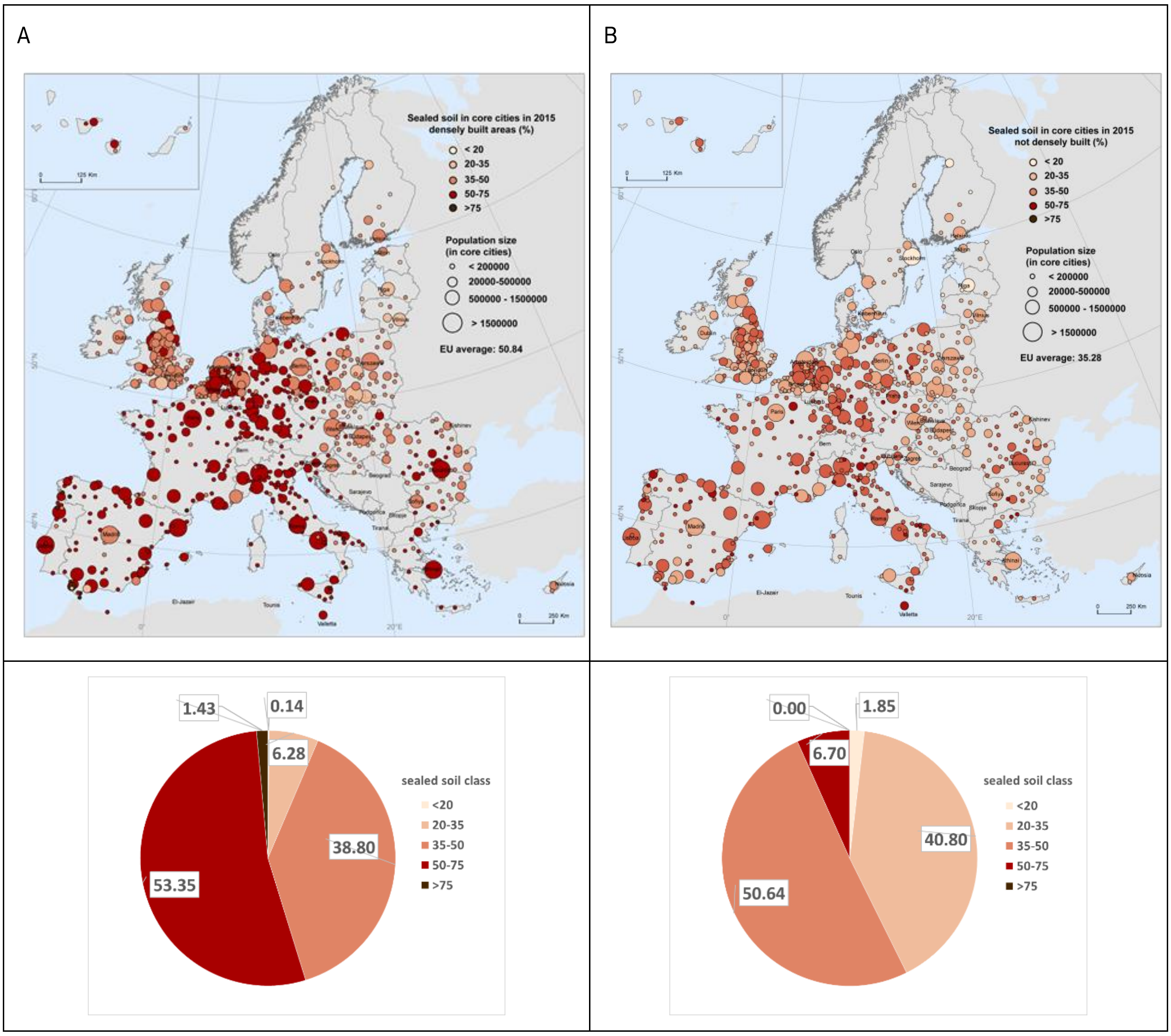


Figure 3.1.10. Percentage of sealed soil in core cities in 2015 within densely and not-densely built areas. Pie charts show the proportion of core cities per sealed soil class (%) (source: EEA -Imperviousness (https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness).

Figure 3.1.10 shows the percentage of sealed soil in core cities. Additional technical details can be found in the fact sheet 3.1.103. Within densely built areas (Map A, Figure 3.1.10), more than 50% of the land is sealed in 55% of the core cities. This condition exposes urban areas to several risks connected with local climate regulation, flood protection and water regulation. With regards to flood protection and water regulation, for example, an impervious cover greater than 50% implies a decrease of deep and shallow infiltration and conversely an increase of surface run-off in case of rain (Chithra et al., 2015). The increase of surface run-off requires more infrastructure to minimize flooding and exposes people and buildings to risks.

The trend is relatively steady in the short term (Figure 3.1.11, Map A and B). Within core cities-densely built areas, the percentage of sealed soil remains almost stable, showing a very light upward trend. In 85% of the cities, there is an increase of sealed soil ranging by 0.05 and 2.5%. This pattern is consistent in almost all European core cities, with few exceptions where a more intense increase is registered.

[10] https://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics#Municipal_waste_generation

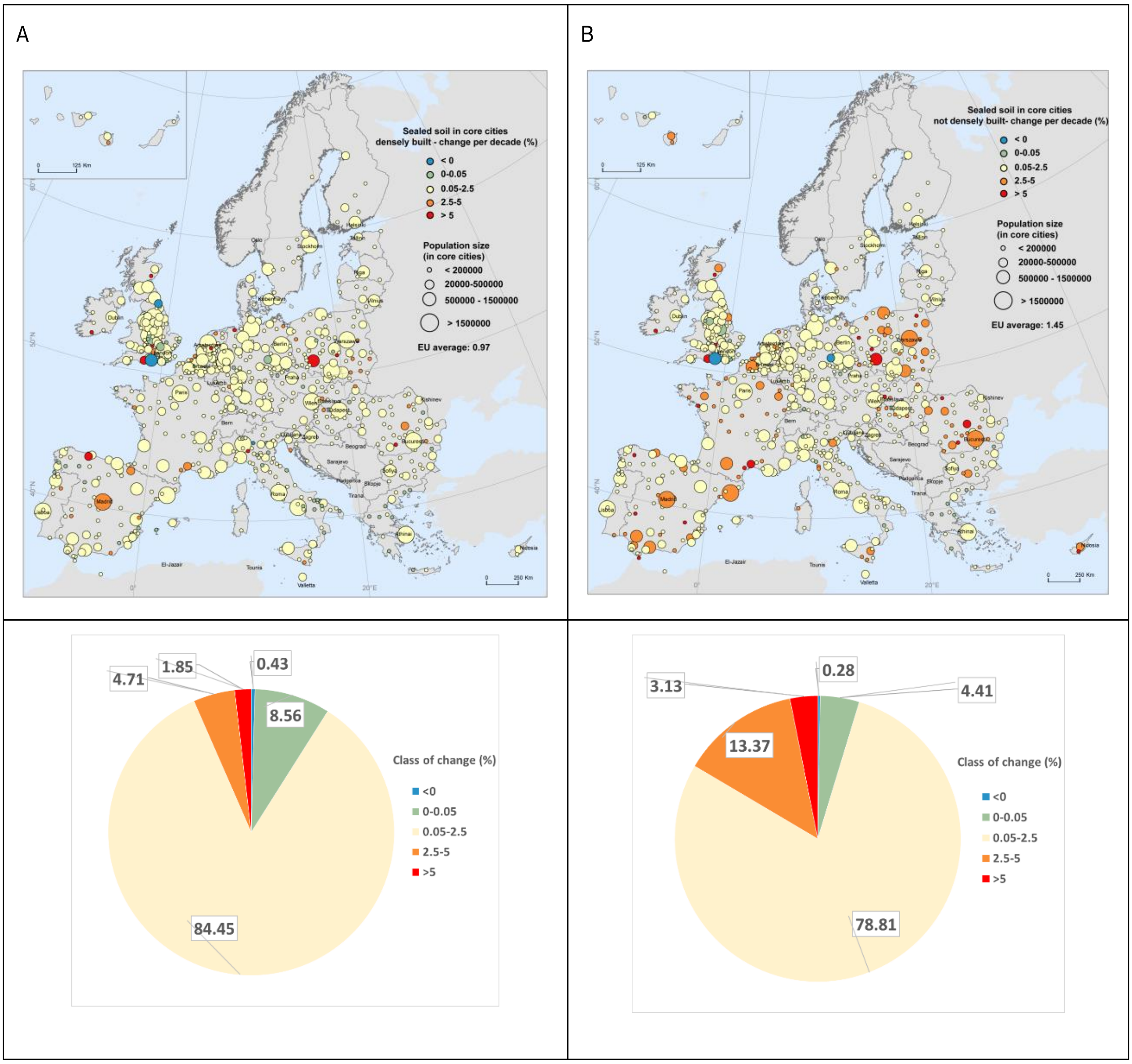


Figure 3.1.11. Percentage of sealed soil in core cities, changes in the short term per decade. Pie charts show the proportion of core cities per class of change (%) (source: EEA -Imperviousness (https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness).

The increase in sealed soil within not-densely built areas is slightly different; in 78.8% of cities we report a slight increase in sealed soil [between 0.05 and 2.5%]; in 15.5% of cities the increase of soil sealing is more evident (> 2.5%) and this pattern characterizes the Iberian peninsula, eastern Europe, as well as some cities in central Europe. This dynamic is also confirmed using indicators which represent structural ecosystem attributes (for example urban structure, share of dominant land types, trends in vegetation cover within urban green infrastructure).

3.1.6 Ecosystem condition: spatial heterogeneity and change over time

The reference table on urban ecosystems in the 5th MAES report (Table 4.1, Maes et al., 2018) lists 29 condition indicators, of which 10 are considered as policy relevant. Environmental quality indicators cover air and water quality, noise levels, soil contamination and metrics that connect population density and built areas. On the other hand, structural ecosystem attributes describe the spatial elements that characterize an urban area, i.e. share of ecosystem types (urban green, natural areas, built-up areas, and abandoned areas); hectares of canopy coverage; fragmentation of urban green spaces. Other elements should be reported to fully describe ecosystem condition, such as structural ecosystem attributes based on species diversity and monitored under the EU nature directives. However, there is a lack of consistent, up-to date and comparable data to fully report on changes of condition of urban ecosystems at European level and this is the reason why only a selection of indicators could be reported.

3.1.6.1 Assessment at the level of EU-28

The assessment of condition of agroecosystems is based on 14 indicators for which, except for one, short and long term trends are available.

Table 3.1.5 presents trends at EU level providing values for the short and long terms. At a first glance Table 3.1.5 shows that:

Indicators that represent environmental quality are improving at an aggregated EU level. With regards to air pollutants concentrations, on the long term, and using aggregated average data, the situation seems to improve for the pollutants considered and the trend is consistent with other assessments which report specifically on air quality in Europe (EEA 2019b). Nevertheless, it must be pointed out that aggregated average data are not precise enough to assess air pollution at urban level. *Moreover, °… the contributions from the different emission source sectors to ambient air pollutant concentrations and air pollution impacts depend not only on the amount of pollutant emitted but also on the proximity to the source, emission/dispersion conditions and other factors, such as topography. Emission sectors with low emission heights, such as traffic and household emissions, generally make larger contributions to surface concentrations and health impacts in urban areas than emissions from high stacks*° (EEA, 2020, p. 25).

There has been an increase in bathing locations with good water quality. The exposure to harmful levels of noise pollution derived from roads is stable for the cities where data were available and comparable.

Structural ecosystem attributes, which represent the configuration of urban ecosystems, offer a slightly different picture and demonstrate a clear and intense process of urbanization in Europe. The extension of artificial areas in the long term (by 3.2%) and short term is increasing (by 2%). There is an increase in the proportion of areas dominated by artificial land type and of land with no dominant land type (zones where there is a mix of land uses). In parallel, we register a loss of areas with dominance of agricultural land or natural land. The process is confirmed by other indicators, which can be reported in more detail and for which results are statistically significant. There is a loss of areas without settlements and a relatively rapid densification of settlements within FUA. Trends in vegetation cover within UGI are stable within the densely built areas, in core cities and commuting zones. The trend is increasing slightly in areas that are not-densely built (and this is quite expected, as vegetation tends to grow). However, when we measure the difference between the share of urban green infrastructure where there is a relevant increase and loss of vegetation, we note a negative balance.

Table 3.1.5. EU-28 aggregated urban condition indicators. Urban ecosystem condition: Baseline value, trends and confidence scores in indicators (for methodological details see chapter 2).

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score (3-9)	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score (3-9)
Environ-mental quality (physical and chemical quality)	Background nitrous oxide (NO2)	µg/m3	9.77	-30.1	↑	5	-20.52	↑	5
	Fine particulate matter (PM 2.5)	µg/m3	10.40	-25.05	↑	5	-23.80	↑	5
	Particulate matter (PM 10)	µg/m3	13.00	-18.35	↑	5	-21.48	↑	5
	Sum of ozone means >35 ppb	ppb	2082.73	-0.90	↑	5	-5.21	↑	5
	Population exposed to road noise (>55dB)	%	37.01	3.82	→	6		unresolved	
	Bathing water quality in poor condition	%	1.97	-31.82	↑	8	-27.39	↑	8
	Bathing water quality in good or excellent condition	%	74.13	19.69	↑	8	13.25	↑	8
	Population connected to urban water waste collection and treatment plants	%			unresolved			unresolved	
	Concentration of nutrients and biological oxygen demand in surface water	mg/l			unresolved			unresolved	
	Population exposed to air pollution above the standards	%			unresolved			unresolved	
Structural ecosystem attributes (general)	Share of dominant land types within FUA Dominant artificial	%	5.84	0.3	→	4	0.49	→	4
	Share of dominant land types within FUA Dominant agriculture	%	51.68	-0.87	→	4	-1.57	→	4
	Share of dominant land types within FUA Dominant natural and semi-natural	%	27.0	-0.15	→	4	-0.23	→	4
	Share of dominant land types within FUA No dominant land type	%	15.4	0.55	→	4	0.75	→	4
	Urban Structure - Degree of settlement dispersion	Dimension less [0-140]	33.29	-13.63	↓	6	-11.30	↓	6
	Urban Structure - Share of FUA grid classified as highly compact	%	3.60	0.28	↓	6	0.37	↓	6

	Urban Structure - Share of FUA grid classified as continuous	%	6.99	0.46	↓	6	0.60	↓	6
	Urban Structure - Share of FUA grid classified as dense	%	30.08	2.1	↓	6	2.44	↓	6
	Urban Structure - Share of FUA grid classified as not-built	%	17.66	-4.24	↓	6	-2.81	↓	6
	Vegetation cover in core city densely built areas.	[0-1]	0.43		unresolved		0.098	→	8
	Vegetation cover in core city not-densely built areas	[0-1]	0.58		unresolved		0.227	↑	8
	Vegetation cover in commuting zone densely built areas.	[0-1]	0.45		unresolved		0.013	→	8
	Vegetation cover in commuting zone not- densely built areas	[0-1]	0.59		unresolved		0.24	↑	8
	Balance between abrupt changes within UGI in core city densely built areas	Difference between share of greening and browning			unresolved		-4.36	↓	8
	Balance between abrupt changes within UGI in core city not-densely built areas				unresolved		-0.48	↓	8
	Balance between abrupt changes within UGI in in commuting zone densely built areas.				unresolved		-6.36	↓	8
	Balance between abrupt changes within UGI in Commuting zone not- densely built areas				unresolved		-0.07	→	8
Structural ecosystem attributes monitored under the EU Nature directives and national legislation (Percentage of urban ecosystems covered by Natura 2000)		%			unresolved			unresolved	
Structural soil attributes	Soil organic carbon	g/kg			unresolved			unresolved	

↑: Significant improvement (significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

3.1.6.2 In-depth assessment

3.1.6.2.1 Environmental quality

Environmental quality was measured using indicators on air and noise pollution, bathing water quality and population density.

The Environmental Noise Directive (END, 2002/49/EC) is the main EU instrument to identify noise pollution levels and to trigger the necessary action both at Member State and at EU level. Environmental noise is defined as: “unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport (road traffic, rail traffic, air traffic) and from sites of industrial activity, which have negative effects on human health”. The Directive applies to “…environmental noise which humans are exposed to, in particular in built-up areas, in public parks or other quiet areas in an agglomeration, in quiet areas in open country, near schools, hospitals and other noise sensitive buildings and areas” (END, 2002/49/EC). Environmental noise exposure can lead to annoyance, stress reactions, sleep disturbance, poor mental health and well-being, impaired cognitive function in children, and negative effects on the cardiovascular and metabolic systems[11] .

In this assessment, for comparative purposes, we used data on percentage of people exposed to harmful noise levels derived from roads, which is considered the most widespread source of environmental noise. Unfortunately, the assessment is not completely representative of European cities but it represents the best data available. Data for only 284 cities were considered comparable, even with a certain level of uncertainty due to differences in data collection and mapping. In 2012, 431 cities were represented (82.5% of the agglomerations for which data were requested), and in 2017 there were data for 303 cities (57.2% of the agglomerations for which data were requested).

In 2017, 78 million people were exposed to harmful levels of noise in EU-28 agglomeration with available data. The percentage of citizens exposed to road noise remains stable, with a total change (not considered significant) per decade estimated at + 3.8%. In around half of the cities (43%), the share of population exposed remains stable, and in 33% we register an increase of population exposed to road noise pollution. In 23% of the agglomeration, there is an improvement. Additional technical details can be found in the fact sheet 3.1.104.

With regards to **air pollutant concentrations**, on the long term and using average data, the situation is improving for the pollutants considered and the trend is consistent with other assessments which report specifically on air quality in Europe (EEA, 2019b), however, detailed spatial data were not available. Whether the air can flow freely can be a huge factor in ambient pollution. For example, a dual carriageway in open countryside may have lower concentrations than a single carriageway road lined by tall buildings. This is known as the “street canyon effect”. Similarly, wind speed and direction can also have a big impact on pollution. These factors help to explain why levels of pollution vary so much in different parts of the city and they could not be captured by the indicators selected for this report. **This is the reason why at this scale the indicators are only partially able to reflect the magnitude of problems connected with air pollutants.**

3.1.6.2.2 Structural ecosystem attributes

In the fourth MAES report (2016), the concept of urban ecosystems (the socio-ecological system within an urbanised area) was introduced to the MAES community and considered more suitable for the assessment of condition of urban areas.

Concepts derived from landscape ecology: land configuration and composition (Zurlini et al. 2006; Zurlini et al. 2007), provide the background for the analysis of structural ecosystem attributes. Land configuration: “the spatial arrangement of elements” was used to report on the presence and combination of dominant land types and on urban structure. Land composition: “what and how much is there” was used to analyse annual trends in vegetation cover within urban green infrastructure at a very detailed level (within the core city and commuting zone in areas densely built and not-densely built). This approach could only be implemented where consistent and detailed spatially explicit data were available.

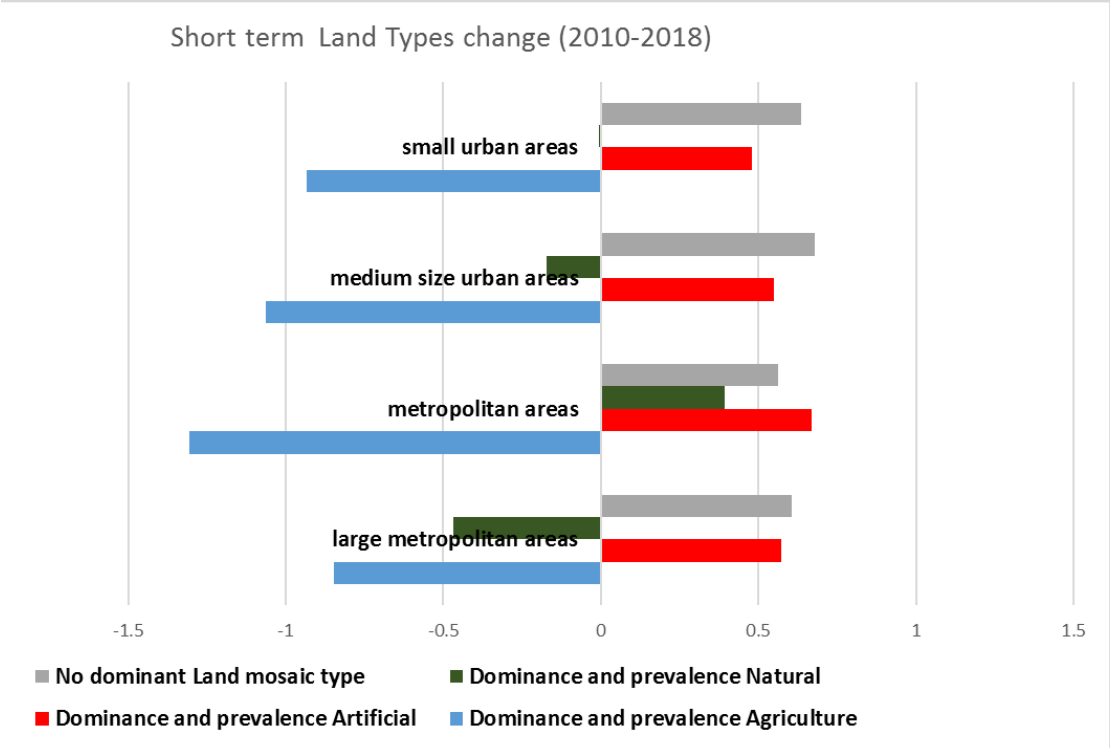
[11] https://www.eea.europa.eu/airs/2018/environment-and-health/environmental-noise

The share of dominant land types

Urban ecosystems are composed of biological and physical components which interact with one another in a specific area. European urbanized areas are very diverse in regards to their size and the distribution of other ecosystem types within the city and its surroundings. These structural characteristics are directly linked to level of pressures, condition of ecosystems and provision of ecosystem services. Previous studies have demonstrated that 10% of European FUA are dominated by forest, 53% by agricultural land, 27% by artificial land, and 10% by land with no dominant land type (Maes et al. 2019). In this assessment, we measured the share of dominant land types and, in case of change, magnitude and direction of the transition. The share of dominant land types is a measure of spatial distribution of landscape elements. We used the Landscape Mosaic (LM) model available in GuidosToolbox (Vogt and Riitters 2017). The model measures the relative contributions of land types within a given neighbourhood (or observation area). It was implemented using Corine Land Cover (2000 and 2018). In this case we were not interested in specific categories of artificial land types and CLC allows the boundary effect to be included in the analysis in case of adjacent FUA. Additional technical details on the urban application can be found in the fact sheet 3.1.107; chapter 4.3 of this report focuses on the Land Mosaic applied at European scale. The model classifies a given location according to the relative proportions of the three land cover types Agriculture, Natural, and Developed in a neighbourhood surrounding (2.25 km^2) that location (Riitters et al. 2000, 2009; Vogt 2019).

Despite the fact that the indicators were not statistically significant, we note an increase in the total share of areas dominated by the presence of artificial land types and of land characterized by no specific land type. This last category represents all interface zones; areas which, in different degrees, overlap with a sprawled urbanization and tend to fragment the remaining, relatively natural or rural ecosystems. In parallel, there has been a generalized decrease in areas with a dominance of agriculture and areas with a dominance of natural and semi-natural vegetation.

Direction and magnitude of changes vary according to the size, location and characteristics of cities. However, at EU level FUA present a decrease in agricultural land and an increase in artificial areas and land with no dominant land type. Figure 3.1.12 shows the short and long term changes per decade, presented considering the FUA population size.



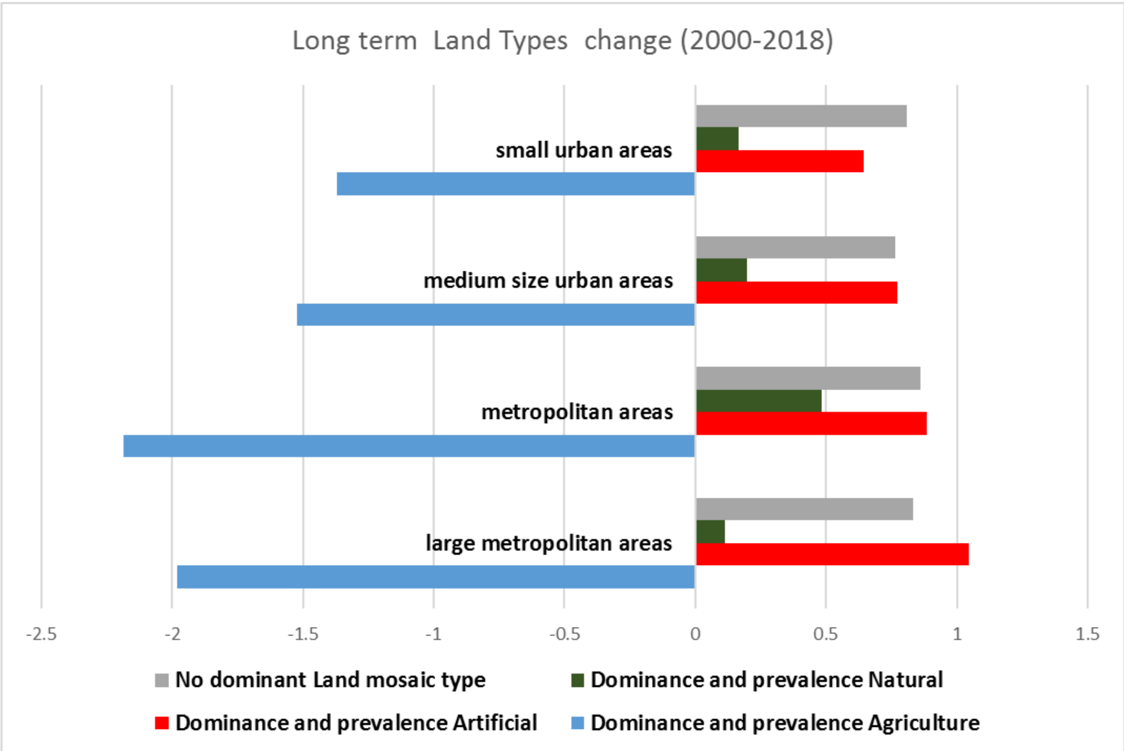


Figure 3.1.12. Change (% decade) in the short and long term of dominant land types per FUA population size. (small urban areas [50,000 and 200,000 inhabitants]; medium-size urban areas [200,000 and 500,000 inhabitants]; metropolitan areas [500,000 and 1.5 million inhabitants]; large metropolitan areas [> 1.5 million inhabitants] OECD, 2013).

Changes in share of dominant land types are relatively stable. Figure 3.1.13 presents FUA classified according to magnitude of change and direction of change (the main direction of transition in case of change of land type). In 70.4% of FUA land type changes were negligible (meaning that it was not detectable using CLC). A medium magnitude of change characterized 24.8% of FUA. The main direction of change in this case has been versus toward “Land with do no dominant land use types”, which represents an areas with mixed uses. In 4.8% of the FUA there was a major change, with a slightly inverse tendency, signaling an increase in areas primarily occupied by agricultural or natural land types.

The urban structure

The analysis of urban structure is based on a spatially explicit approach implemented to estimate the degree of dispersion of built-up areas. Assuming the circular form as the most “compact” possible, the index is based on the calculation of distances between different built-up areas on a 2 km buffer around each 1 km grid cell within each FUA. The index measures the degree of dispersion of urban settlements through a purely geometric point of view (Romano et al. 2017; Saganeiti et al. 2018). The distance buffer of 2 km around each sub-reporting unit (1 km cell) was chosen following previous works on urban sprawl developed at European scale (Aurambout et al. 2018). The value 0 represents a fully (100%) built-up environment surrounding that location (2 km^2). A negative value represents a progressive densification. At European scale such process is quantified in order of 11.30% per decade in the long term and 13.63% in the short term.

Changes in settlement patterns are related to morphological changes of urbanized areas and to the diffusion of artificial elements in the urban fringe. Peri-urban rural landscape and peri-urban forests suffer most from this dynamic (Colsaet 2017). The phenomenon involves the transformation of large patches of natural habitats into smaller ones (fragments) which tend to be isolated from the original natural habitat (Saganeiti et al. 2018), and, in many cases having an impact on the structure and connectivity of them.

As input data of the mode, the Global Human Settlements Layers (GHSL) was used (Corbane et al. 2019). The data set is available at 30 m, from 1975 to 2014. Additional technical details can be found in the fact sheet 3.1.108.

To make interpretation easier, the indicator was classified into six classes which represent categories of urban structure having an impact on city performance in terms of mobility, urban resilience, ecosystem services and biodiversity (Cortinovis et al. 2019).

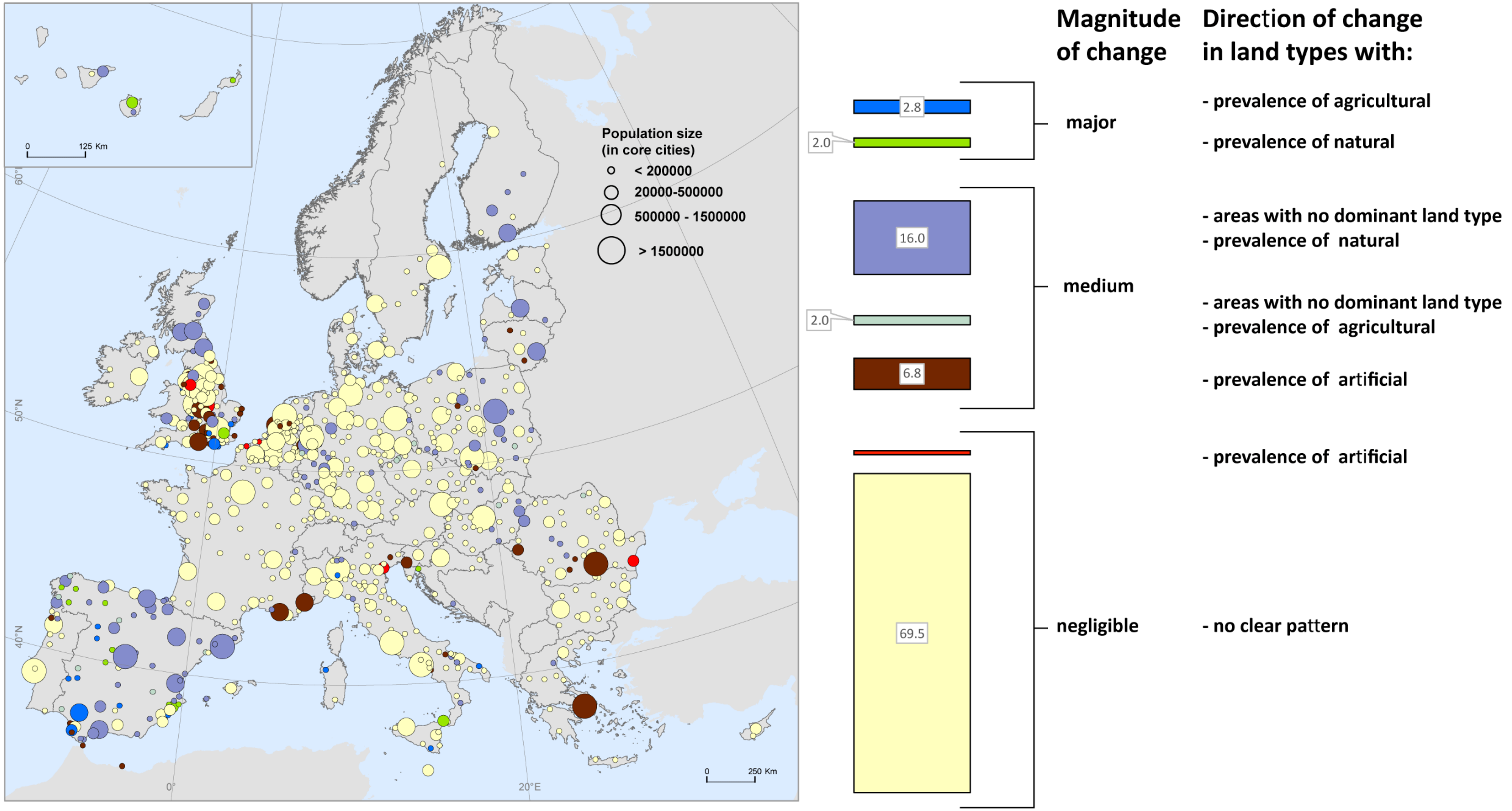


Figure 3.1.13. Functional urban areas classified in terms of land types magnitude and direction of change between 2000 and 2018.

Box 3.1.2. Urban structure in Padua (Italy)

The figure presents an example of urban structure in Padua (Italy). We register a progressive increase of compact structure within the core city and a progressive densification within the commuting zone in this case at the expense of agricultural areas (south-east) and of a Natura 2000 site (the Colli Euganei Regional Park).

Figure: Analysis of urban structure applied to the FUA of Padua (Italy). The maps show the 1 km grids reclassified in six key categories. The charts show the average degree of settlement dispersion value from 1975 to 2014 and the share of each category in 1975 and 2014. In Padua compact grids increased relatively and mainly within the core city, on the contrary the grids characterized by continuous settlements slowly replaced areas occupied by sparse and sprinkled settlements. 1km grid data are available for all 700 European cities.

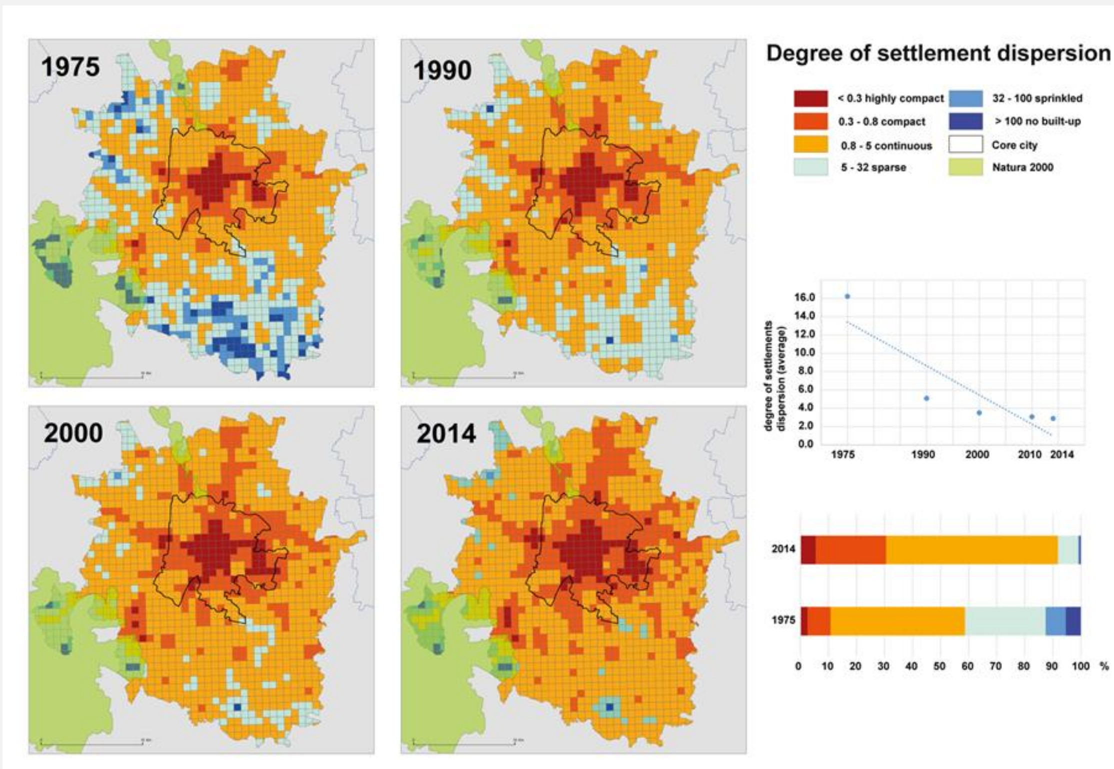


Figure 3.1.14 and Figure 3.1.15, respectively, show the share of urban structure categories in each observation period and the long term change, expressed in percentage per decade, in a sample of European FUA. Helsinki (FI), Stockholm (SE) and Sofia (BG) have a very similar trend with a low share of FUA occupied by compact and continuous settlements and an increase of sparse settlements. However "no built areas" in Helsinki and Stockholm are covered by peri-urban forest and inland water whereas in Sofia no built areas are mainly occupied by agricultural land (Maes et al. 2019). On the contrary, the FUA of Naples, Padua and Milan (IT) are almost totally built and no built space areas essentially no longer exist.

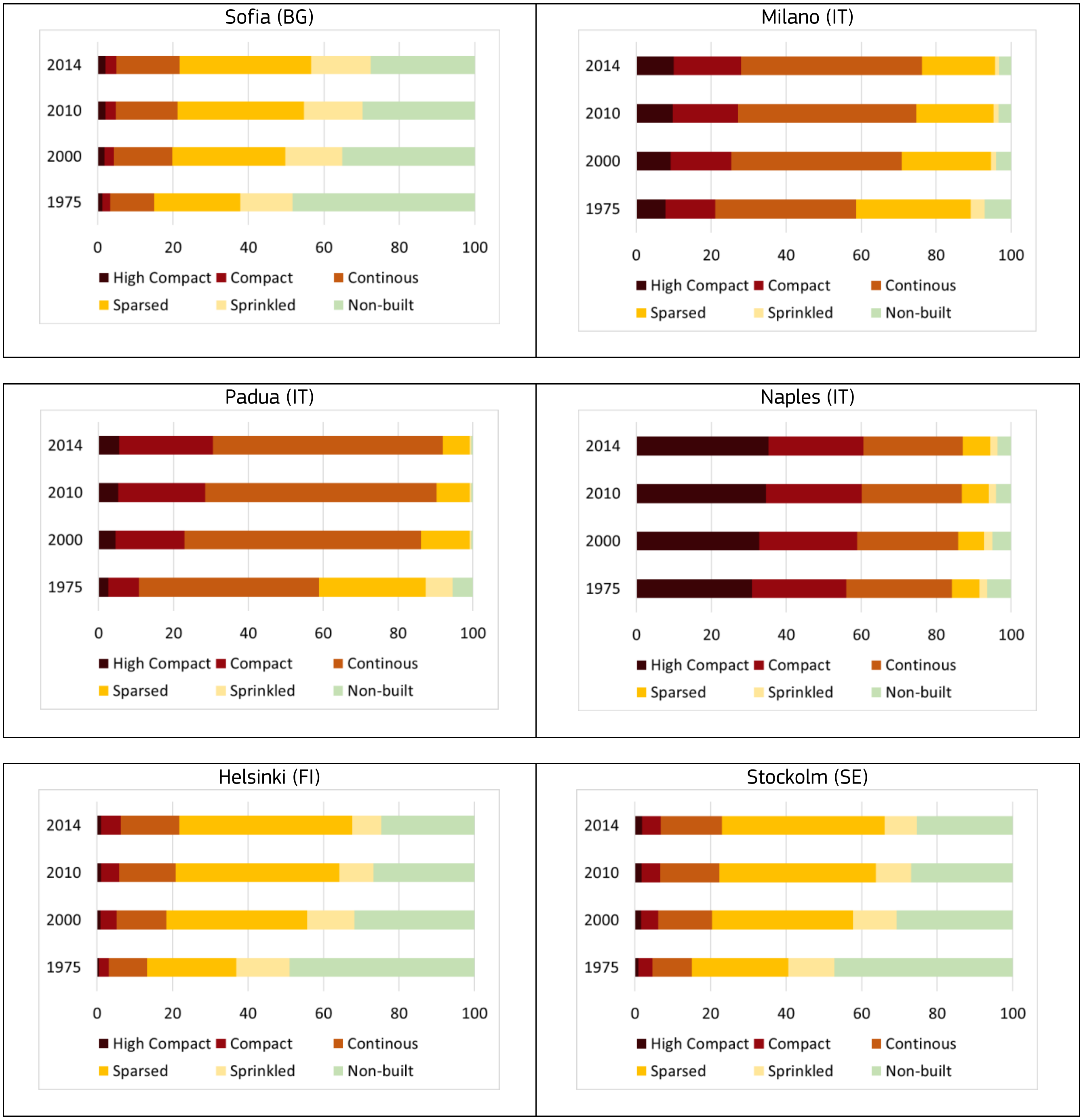


Figure 3.1.14. Share of urban structure categories in a sample of European FUA.

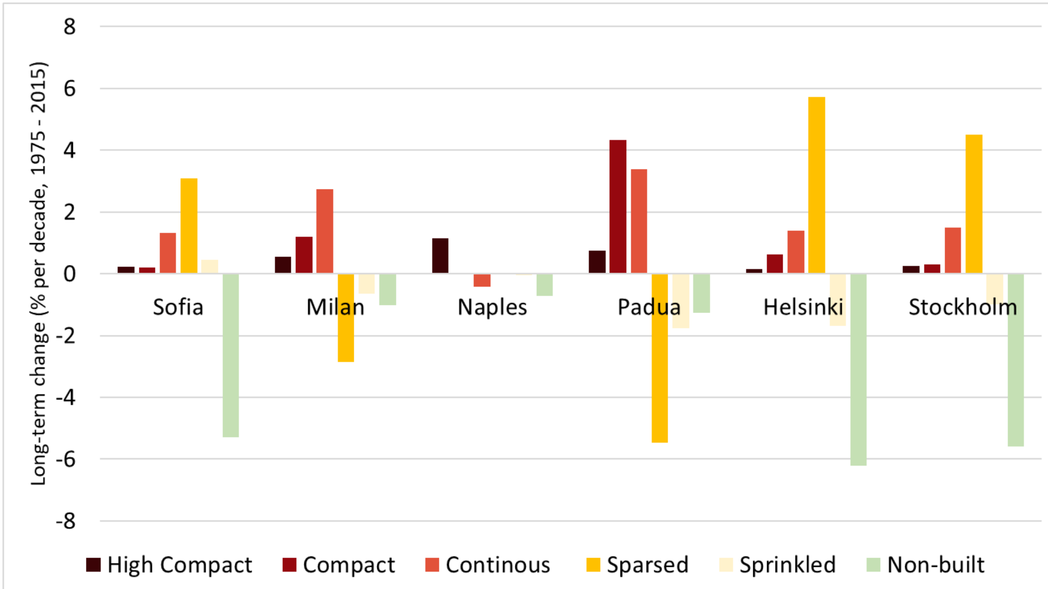


Figure 3.1.15. Long term change expressed in percentage per decade (1975-2014) in six European cities.

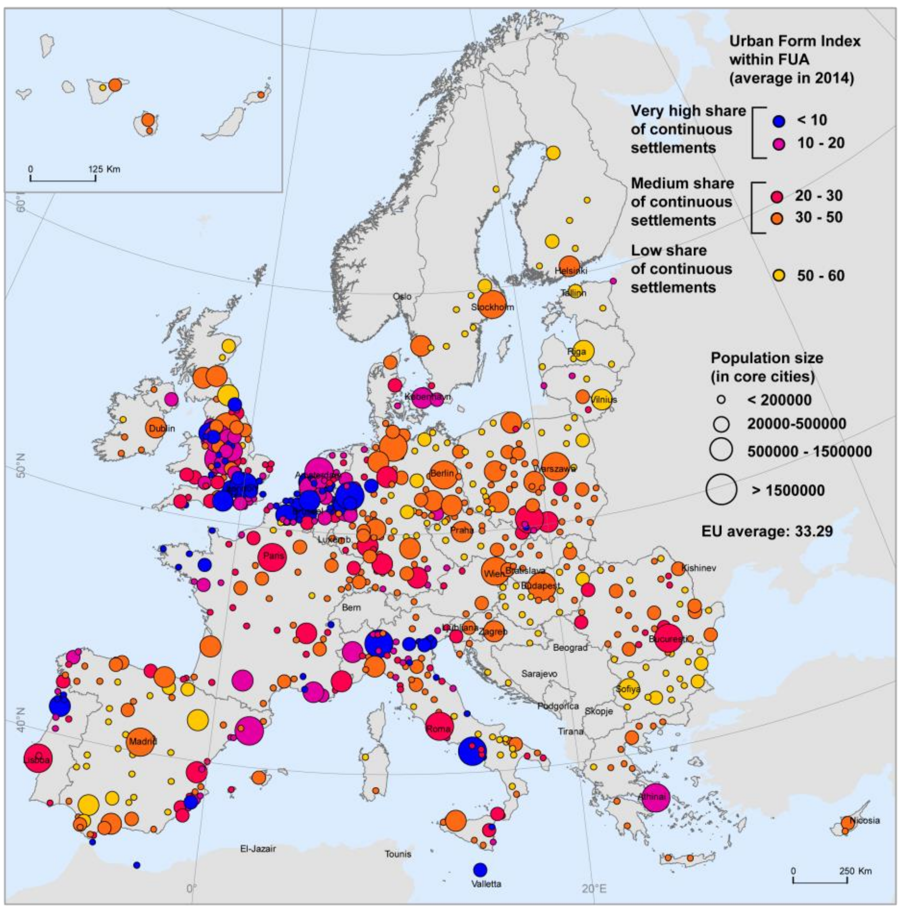


Figure 3.1.16. Status maps of degree of settlement dispersion, average value per FUA (2014). The urban structure indicator is a dimensionless measure, where 0 = to very dense settlement structure in a horizon of 2 km^2.

Figure 3.1.16 shows the different degree of settlement dispersion in FUA in 2014. A very high share of dense settlements, i.e. in Naples or Milan, evidence a situation where the commuting zone (or the cluster of municipalities around the core city) is assuming the characteristics of a conurbation (or of an extended urban area).

In the long term, a progressive densification process is reported (Figure 3.1.17 Map B) at EU level. An intense transition versus a very dense structure (red and orange dots) characterizes FUAs in England, Belgium and The Netherlands. In the short term, (Figure 3.1.17 Map A) the process demonstrates a relatively rapid urbanization in eastern, Nordic and Mediterranean cities, probably connected with the stage of economic development of European cities. However, additional socio-economic data are needed to fully understand the trend.

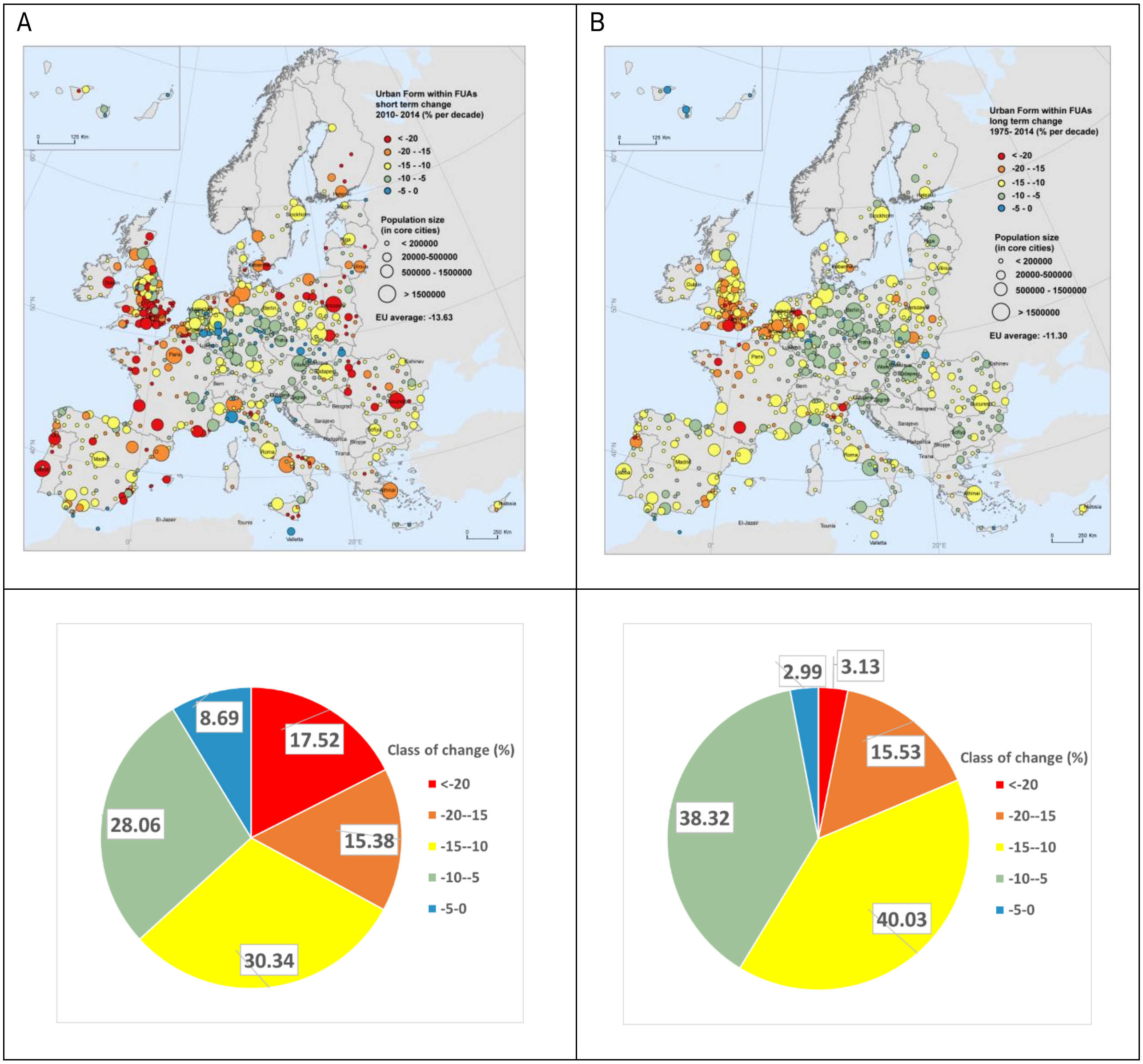


Figure 3.1.17. Degree of settlement dispersion, short and long-term trends. The indicator measures settlements densification, which by definition can only increase. Pie charts show the proportion of FUA per class of change (%).

Structural ecosystem attributes – Trends in vegetation within Urban Green Infrastructure

Urban green infrastructure (UGI) is considered a key element of urban resilience. UGI is a collection of blue /green spaces with different characteristics in term of size, type of vegetation cover, property and land use destination (IV MAES Report 2016).

At EU level, there is a gap in the availability of detailed and consistent data related to UGI and its vegetation cover that allow monitoring of trends in the UGI structure and distribution. Corine Land Cover does not capture UGI and Urban Atlas is available for only 300 cities between 2006 and 2012.

The presence of vegetation within the UGI, measured using the Normalized Difference Vegetation Index (NDVI), was used as a proxy to estimate the structural ecosystem attributes related to urban green. Trend detection in Normalized Difference Vegetation Index (NDVI) time series can help to identify and quantify relatively recent changes in ecosystem properties (Teferi et al. 2015; Guan et al. 2018; Jin et al. 2019b).

In order to measure how vegetation within UGI has changed over time we used a collection of Landsat composite images over a 22 years period (1996-2018). Additional technical details can be found in the fact sheet 3.1.109.

Vegetation trends tend to be highly stable and changes are gradual. In human dominated ecosystems, however, they are not always monotonic (or gradual) but can reveal what is called an “abrupt” character (Forkel et al. 2013; Yu et al. 2017). Gradual and abrupt changes have different meanings and origins (Zhu et al. 2016; Novillo et al. 2019):

— Gradual changes:
    - generally caused by vegetation growth, climate change, land degradation, extended drought, pests as well as other factors;
    - develop over a relatively long time periods (5+ years);
— Abrupt changes:
    - generally induced by land cover change (e.g. housing development) or intensive urban green space management (e.g. tree plantations within a new park);
    - can have an impact on greenness within a short time period (1~2 years);

Abrupt changes are classified according to the trend direction (Jin et al. 2019a):

— Abrupt greening are defined as relatively fast upward trends in urban vegetation

— Abrupt browning are defined as relatively fast losses in urban vegetation

Figure 3.1.18 shows a spatially explicit example of upward major trend detected in Padua (Italy). The abrupt greening change is due to intensive urban green space management. In 1996, the “Parco degli Alpini” was opened and new trees were planted.

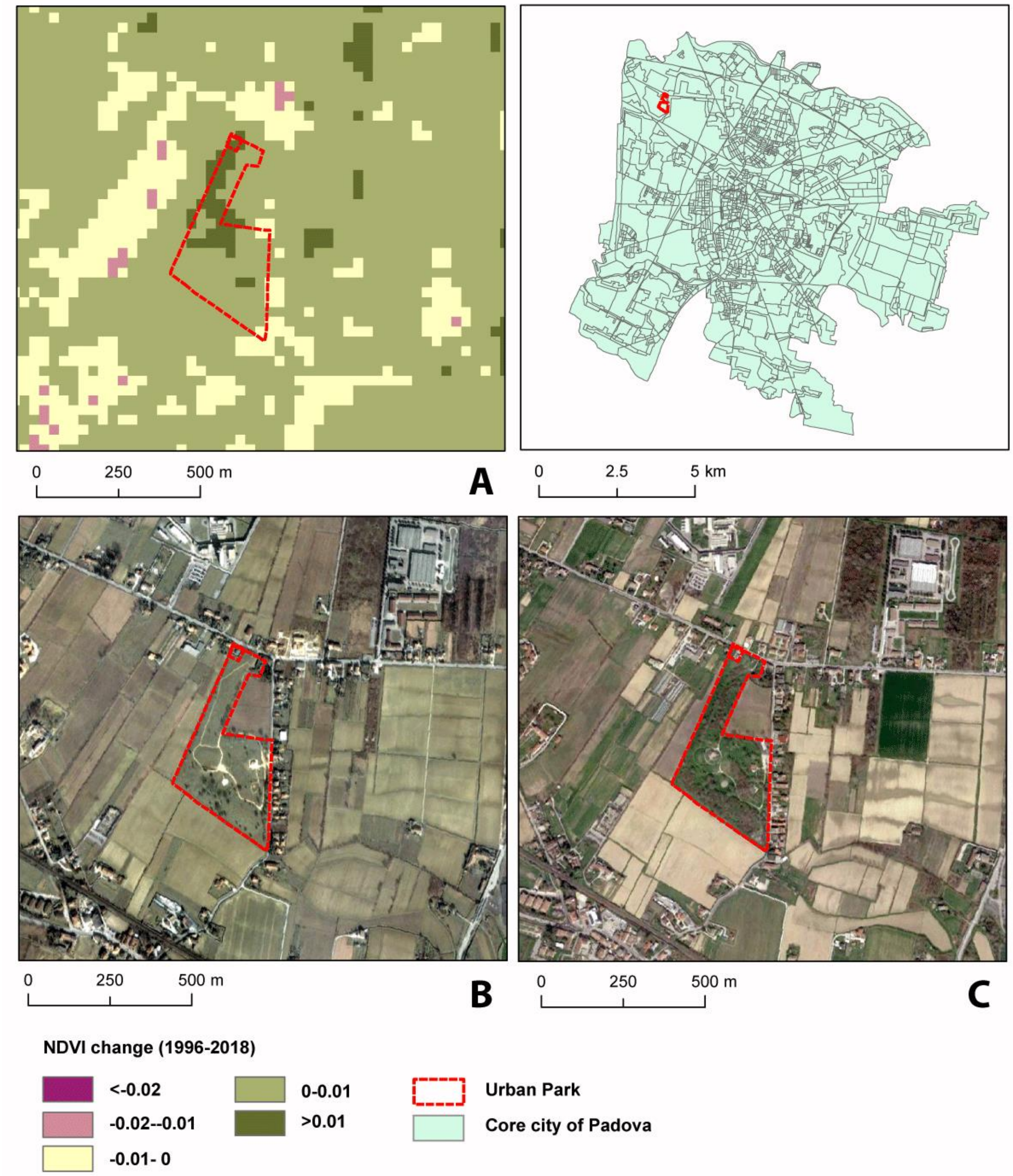


Figure 3.1.18. Example of abrupt greening (upward trend) due to due to green infrastructure management in Padua core city - not densely built zone (Italy). A. represents the NDVI change between 1996 and 2018; B represents the park in 2001 and C represents the park in 2018.

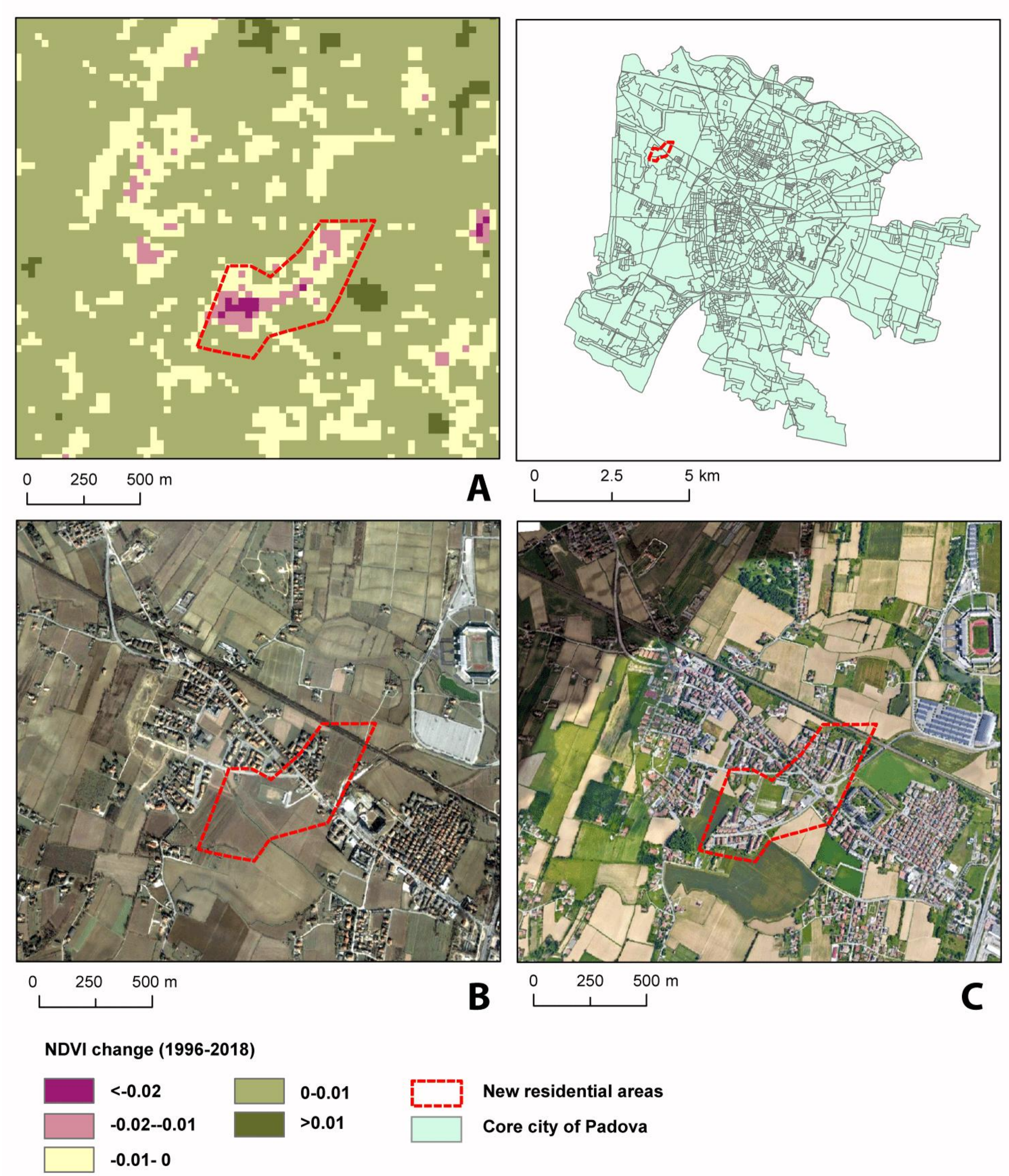


Figure 3.1.19. Example of abrupt browning (downward trend) due to housing policies in Padua core city - not densely built zone (Italy). A. represents the NDVI change between 1996 and 2018; B represents the area in 2001 and C represents the area with a new residential zone in 2018.

Figure 3.1.19 shows an example of downward major trend detected in Padua (Italy). The abrupt browning change is due the recent residential and commercial development of the city. The vegetation trends within UGI were measured in two steps: (1) Estimating the % change per decade (using only significant pixels); (2) Calculating the difference in share of areas characterized by abrupt greening and browning. A negative balance indicates the absence of an efficient compensation policy to offset what consumes UG.

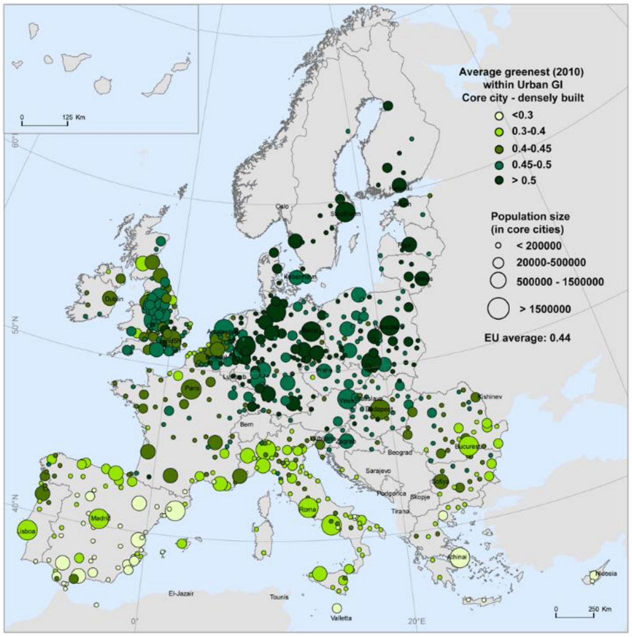
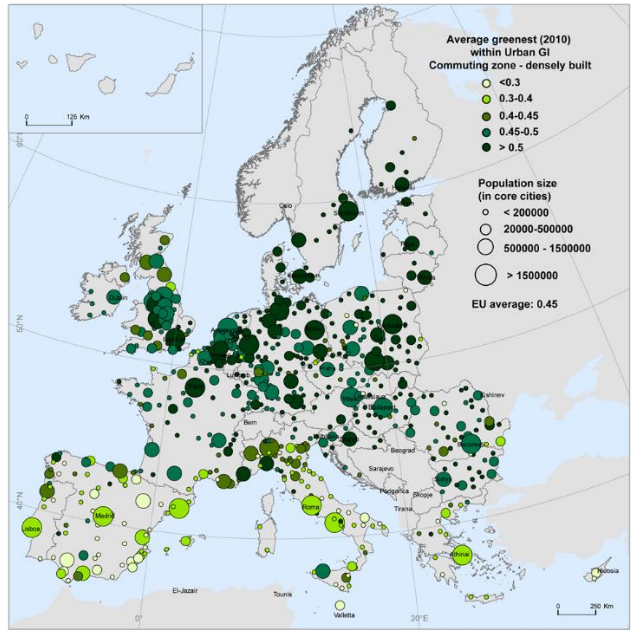
A-Core Cities	B-Commuting zone
	

Figure 3.1.20. Average greenness NDVI within UGI in densely built areas (A- core cities; B commuting zone) in 2010.

Figure 3.1.20 shows the average value of greenness NDVI within UGI in densely built areas. The pattern confirms previous studies with European cities characterized by an evident north –south pattern (Maes et al. 2019).

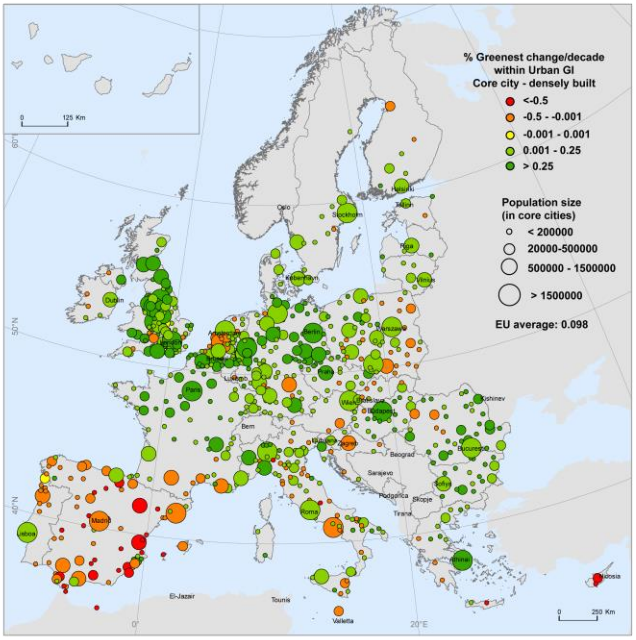
Over the last 22 years, a general slight upward trend characterizes the presence of vegetation within UGI in European cities. The upward trend is extremely gradual over time. This is probably due to climatic conditions and rapid urbanization (see Table 8). Within core cities and commuting zone-densely built, the trend is classified as stable; in not-densely built areas, a relative upward trend is recorded (average value for EU cities is reported in Table 8).

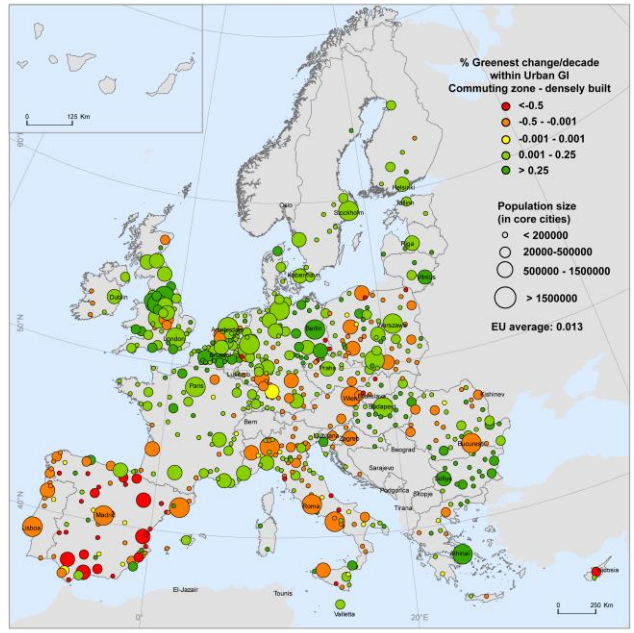
The spatial pattern that characterizes European cities is clearer when we analyse the maps. Figure 3.1.21 shows the trend in vegetation cover of UGI in densely built areas (within core cities and commuting zones). A downward trend characterizes 26.3% of core cities-densely built. The proportion of urbanized areas in which there is a loss of vegetation in UGI increases in the commuting zone, where 32% of the cities presents a downward trend.

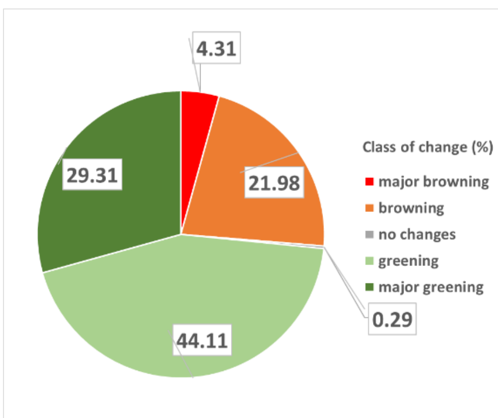
A negative balance between abrupt changes (greening and browning) has been recorded at EU level (average value for EU cities is reported in Table 8). This indicator depends on abrupt changes generally attributed to intensive urban green management and land use change. A negative pattern is a sign that, in general, European cities did not undertake the indispensable initiatives needed to maintain an efficient urban green infrastructure and no clear compensation policies have been implemented.

Figure 3.1.22 shows that, with different order of magnitude, the negative balance affects most parts of European cities (75% of core cities and 77% of commuting zones in densely built areas). Even considering the relatively stable trends (due to the nature of the processes) there have probably not been consistent actions to compensate the loss of vegetation within UGI. Compensating for land take is fundamental. Clear actions should be implemented in the form of not only large (such as motorways or business areas), but also small-sized projects.

A-Core Cities	B-Commuting zone







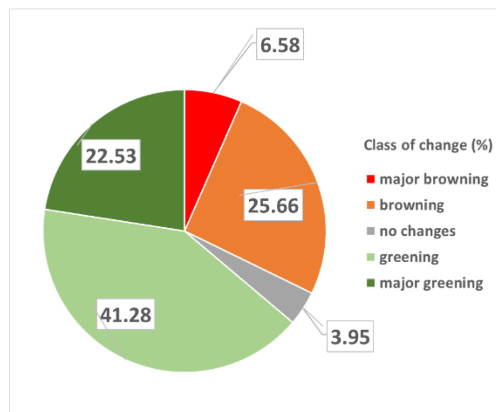


Figure 3.1.21. Trends in vegetation cover (% change/decade), within densely built areas in core cities and commuting zones. Pie charts show the proportion of reporting units per class of change (%).

3.1.7 Convergence of evidence: Summary of the trends in pressure and condition

Table 3.1.6 shows the summary of trends in pressures and condition in urban ecosystems. All air pollutants emissions marked an improvement in the short and long term (5 pollutants); municipal waste generated remained stable in the short and long term (1 indicator) and imperviousness registered a change resulting in degradation in the short term (2 indicators). No indicators, consistent with the rest of the assessment, were available for land take.In terms of condition, the concentration of all air pollutants marked an improvement in the short and long term (4 pollutants). Noise pollution from roads remained stable in the short term (1 indicator) and bathing water quality improved in the short and long term (2 indicators).

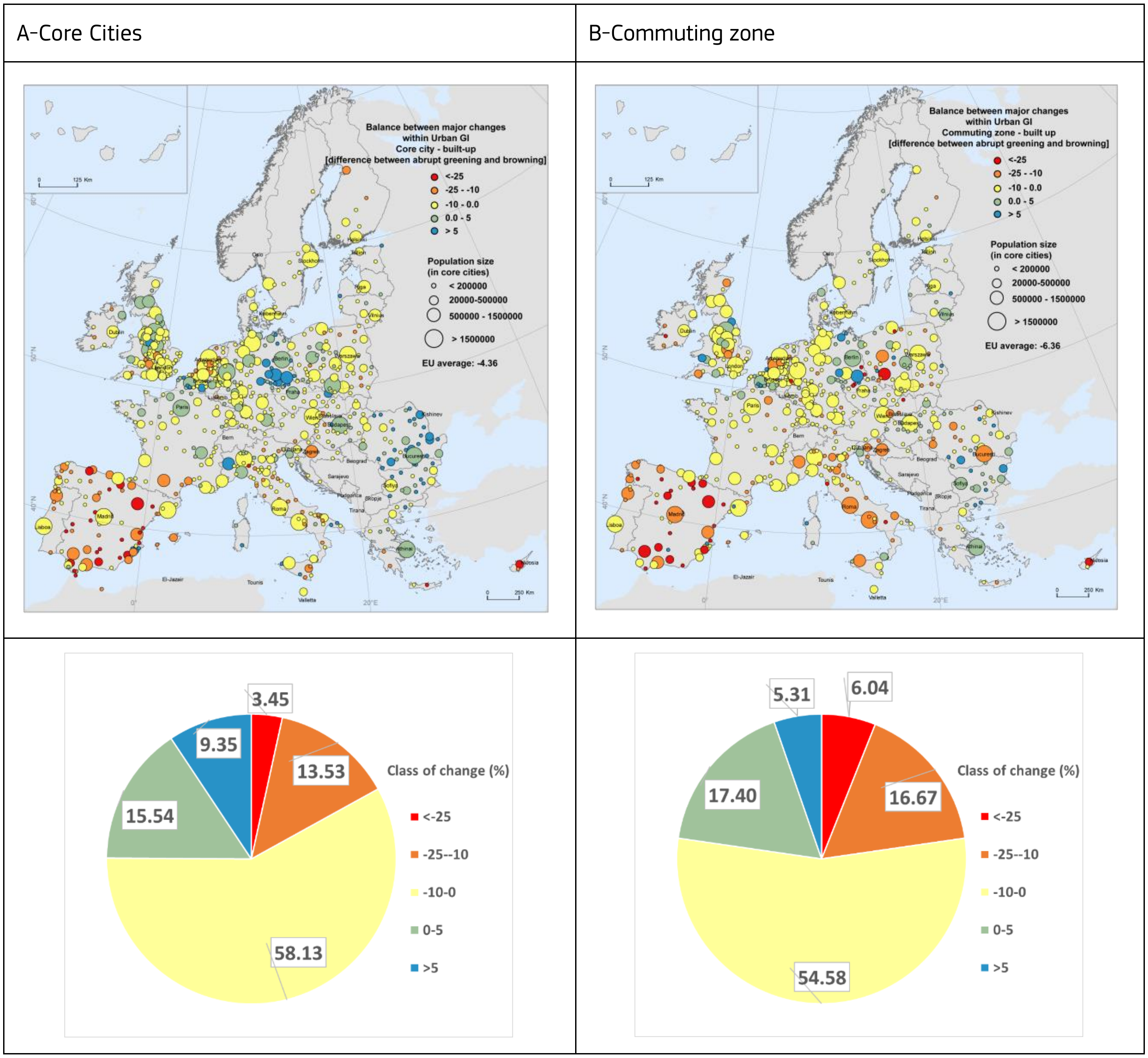


Figure 3.1.22. Balance between abrupt greening and browning changes within densely built areas in core cities and commuting zones. Pie charts show the proportion of reporting units per class of change (%).

All indicators representing the share of dominant land type within FUA are marked as stable in the short and long term (4 indicators). The typology of urban structure shows a significantly negative change resulting in degradation (5 indicators) in both short and long terms. In the long term, the vegetation cover in urban green infrastructure remained stable within densely built up areas in both core cities and commuting zone (2 indicators) and improved within the not-densely built areas in both core cities and commuting zone (2 indicators). The balance between abrupt changes within Urban GI resulted in a degradation in 4 reporting units (core cities and commuting zone densely built) and remained stable in 1 case: commuting zone not-densely.

No indicators, consistent with the rest of the assessment, were available for Population connected to urban water waste collection and treatment plants; Concentration of nutrients and biological oxygen demand in surface water; Percentage of population exposed to air pollution above the standards; Percentage of urban ecosystems covered by Natura 2000; Soil organic carbon (SOC).

Table 3.1.6. Summary of trends in pressure and condition of urban ecosystems in the EU-28.

	Indicator	Short-term trend Since 2010	Long-term trend Since 1990 or 2000
Pressures	Emissions of nitrous oxides (NOx)	↑	↑
	Emissions of particular matter PM10	↑	↑
	Emissions of particular matter PM2.5	↑	↑
	Emissions of non-methane volatile organic compound (NMVOC)	↑	↑
	Emissions of sulphur oxides (SOx)	↑	↑
	Municipal waste generated	→	→
	Imperviousness in core city - densely built areas	↓	unresolved
	Imperviousness in core city – Not-densely built areas	↓	unresolved
	Land annually taken for built-up areas per person	unresolved	unresolved
Condition	Background NO2 concentration	↑	↑
	PM10 concentration	↑	↑
	PM2.5 concentration	↑	↑
	Sum of ozone means over 35 ppb*	↑	↑
	Noise pollution from roads	→	unresolved
	Bathing water quality within FUA in poor condition	↑	↑
	Bathing water quality within FUA in good or excellent condition	↑	↑
	Population connected to urban water waste collection and treatment plants	unresolved	unresolved
	Concentration of nutrients and biological oxygen demand in surface water	unresolved	unresolved
	Percentage of population exposed to air pollution above the standards	unresolved	unresolved
	Share of dominant artificial land type	→	→
	Share of dominant agriculture type	→	→
	Share of dominant natural and semi-natural type	→	→
	No dominant land type	→	→
	Degree of dispersion of built-up area (in a neighbourhood surrounding that location).	↓	↓
	Share of FUA grid classified as highly compact	↓	↓
	Share of FUA grid classified as compact	↓	↓
	Share of FUA grid classified as dense	↓	↓
	Share of FUA grid classified as no-built	↓	↓
	Vegetation cover in core city densely built areas	unresolved	→
	Vegetation cover in core city not-densely built areas	unresolved	↑
	Vegetation cover in commuting zone densely built areas.	unresolved	→
	Vegetation cover in commuting zone not-densely built areas	unresolved	↑
	Balance between abrupt changes within UGI in core city densely built areas	unresolved	↓
	Balance between abrupt changes within UGI in core city not densely built areas	unresolved	↓
	Balance between abrupt changes within UGI in commuting zone densely built areas	unresolved	↓
	Balance between abrupt changes within UGI in commuting zone not-densely built areas	unresolved	→
	Percentage of urban ecosystems covered by Natura 2000	unresolved	unresolved
	Soil organic carbon	unresolved	unresolved

↑: Significant improvement (significant downward trend of pressure indicator; significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator; significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

3.1.8 Options for policy

Challenges for policies on urban ecosystems fall under different categories:

Compensation policies and biodiversity-friendly areas

To limit the degradation of Urban Green Infrastructure more focus should be placed on:

- Land take compensation policies. In practice, compensating for land take affects a multitude of projects (even small size ones) that "consume" agricultural and natural land
- Management practices within Urban Green Infrastructure should carefully consider the importance of biodiversity-friendly areas

The role of citizens

Lifestyle and citizen engagement play a key role in the impact that population density and population dynamic (growth, structure, mobility) have on ecosystems. This is true for most topics covered in this assessment. Air pollutants emissions, concentrations and population exposure, for instance, depend (at least in part) on lifestyle choices, connected to mobility and transportation or energy use (Ballesta et al. 2006; Priddle 2018). Sustainable consumption, recycle and lifestyle affect municipal waste management and land take (Colsaet 2017; Gaudillat et al. 2018). Proper, responsible conduct is very important for biodiversity and nature conservation when enjoying nature-based recreation activities and when managing domestic gardens (Goddard et al. 2010; Nilon 2010; Beumer and Martens 2015).

Mainstreaming of urban ecosystem services and NBS into urban policy making

A well-managed Urban Green Infrastructure is essential to support Urban Ecosystem Services such as microclimate regulation, noise reduction, flood protection, air quality regulation and nature-based recreation. The mainstreaming of Urban Ecosystem Services into urban policy making has started (many cities already have in place specific strategies on Urban Green Infrastructure) and has been promoted at EU level (EC 2019d).

Nonetheless, there is a need for setting targets to specifically monitor urban condition, biodiversity and ecosystem services. The issue was discussed in October 2019, during the EU week on regions and cities , where one of the takeaway messages was that as researchers we can set up assessment frameworks but targets for monitoring urban biodiversity and ecosystem services should be set up at a local level, taking into account specific territorial context.

In order to be financed and adequately implemented at a local level, NBS should be officially recognized and included in policy regulations. One of the final objectives of the Action Plan of the Partnership on Sustainable Land Use was to promote NBS as a tool to build sustainable, resilient and livable urban areas, with specific requests for a better regulation to boost NBS at European, national and local levels; and better financing for NBS.

Territorial level[12] and policy level

Policies related to urban ecosystems should be structured on three levels which are complementary and not mutually exclusive:

1) Municipal level; district level
    a. All policies directly and indirectly linked to management and planning of green spaces and green infrastructure, mobility, waste management, water quality
2) FUA level

[12] https://ec.europa.eu/eurostat/web/regions-and-cities

    a. The connection between urban ecosystems and the other ecosystems types should be taken into account, especially with regards to:
        i. croplands and the role of local agricultural production in the local market,
        ii. forest and its role within the Urban Green Infrastructure.

3) Regional level and National level
    a. The regional network of cities should be considered with a view that can reflect the overall impact of urbanized areas on the ecosystems

3.1.9 Knowledge gaps and future research challenges

What emerged in this assessment is the lack of consistent data available for a complete analysis of the condition of urban ecosystems at European scale. Policy-relevant data gaps are shown in Table 7 and Table 8. These fall under different categories:

- lack of consistency at EU level regarding data collection and reporting units
- lack of consistent and verified spatially explicit data needed to analyze pressures and urban ecosystems condition

Specifically there is a lack of:

- Accurate and detailed data on **air pollutants concentration** to evaluate:
    - the effective condition of air quality within the cities, considering very local dynamics (such as the canyon effect)
    - the capacity of vegetation to remove air pollutants
- Consistent, spatially explicit data to monitor **Natura 2000 sites** within Functional Urban Areas
- Accurate and detailed data on urban biodiversity
- Accurate and detailed data on public pocket parks, public gardens and public parks to properly monitor trends in accessibility of public green

3.1.10 Conclusions

Cities are not "*single entities*" and they do not only include artificial areas. They are part of a complex larger-scale, socio-ecological system. This assessment demonstrates that is very difficult and scientifically challenging to synthetize the complex dynamics of cities into a set of simple key messages or aggregated trends. However, what seems to be very important is to set up and test monitoring frameworks that help cities to identify whether their change is normal or unusual in the EU and regional context, or to provide evidence that some mayors are concerned with maintaining natural habitat in living environment of people.

Functional Urban Areas, the core cities and their commuting zones, where most European citizens live and work cover 20% of the EU territory. Urban population is increasing with regional patterns that are connected to different stages of economic development.

Urbanization is increasing and this is confirmed by pressure indicators (increase impact of municipal waste or sealed soil); environmental quality indicators (population density) and structural ecosystem attributes, such as the degree of densification of settlements within FUA; a decline of number of areas occupied by croplands or natural areas and the increase of areas with a mix of uses. The commuting zones are assuming characteristics similar to the core cities. When evaluating the trends in vegetation cover of Urban Green Infrastructure, we recorded a more intense loss of vegetation within commuting zones than within core cities. Pressures and environmental quality indicators that have a clear EU regulation (noise pollution, air pollutants emissions and concentrations, bathing water) are all stable or improving at EU level.

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3.2 Agroecosystems

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Summary: This report assesses pressure and condition trends for agroecosystems in the EU. The assessment describes quantitatively the current condition of agroecosystems, the key drivers of degradation and improvement aspects.

Agroecosystems, defined in the frame of MAES as communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fibre, fuel and other products for human consumption and processing (Maes, 2018), are composed by cropland and grassland, and cover about 47% of the EU's land area. To a very large degree these are managed ecosystems, only some grassland habitats exist in fact under a natural state. The history of agriculture spans for several millennia, a sufficient time to have specific species and habitats coevolving together with human management. The latter is key to maintain agroecosystems in good condition. But what is a good condition for a managed ecosystem, therefore in an ecosystem that exists to a great extent for the benefit of humans? The approach taken in this report is that a good condition requires balance: in the use of natural resources while maintaining biodiversity, in the supply of a set of ecosystems services, in the necessity to fulfil the needs of current as well as of future generations.

Of the five pressure categories addressed in this report: habitat conversion, pollution and nutrient enrichment, climate change, overexploitation of resources, and invasive alien species, the first three are analysed in the frame of agroecosystems. The reference timeframes of the analysis are: the long term trend, corresponding to the whole series of available data; the short term trend, which is the 2010-2020 decade with 2010 as base year. On the long term, while habitat conversion, pollution and nutrient enrichment show mostly stable or even improving trends, out of 15 analysed climatic indicators, eight show statistically significant increasing pressures over the long term. This is summarized by agro-climatic zones shifting North, with higher migration velocities of up to 100 km per 10 years in Eastern and North-eastern Europe, and the Atlantic zone moving east. Birds and butterflies have already shown a reaction to such changes, with northward shifts and changes in community composition already recorded. Except for some improvement in exceedances of critical loads, pesticides and mineral nitrogen show either stable or degrading trends within the analysed periods.

Surveyed biodiversity (birds, butterflies, protected habitats) shows declining trends, while structural parameters characterizing farmland (crop diversity, high nature value farmland, share of fallow land) are stable. Lastly, the area under organic farming has increased and yearly gross primary (biomass) production as well. Care should be taken in interpreting the latter, since the causes for such an increase can depend upon e.g. change in fertilization rate and irrigation as well as the introduction of soil conservation practices such as cover crops.

The EU level assessment of the conservation status of 32 grassland habitats concluded that 14.3% are in good (or favourable) conservation status. The remaining habitats are in poor status (32.5%), a bad status (49.2%) or unknown (4.0%). In addition, habitats dependent on adequate agricultural management are assessed as bad (45 %) and poor (38 %)."

In the past decades, environmental concern has been directly addressed and more and more integrated into policies regulating or impacting (agricultural) land management (Nitrates directive, Water Framework Directive, Common Agricultural Policy and related reforms, EU Biodiversity Strategy). While this has probably avoided further major losses, it has neither bent nor halted the ongoing degradation of agroecosystems condition and biodiversity loss. Analysed indicators show that no major changes are recorded at the macro scale in pressures deriving from the use of chemical inputs, and in some structural parameters. This, coupled to the unprecedented

challenge of climate change, calls for a courageous rethinking of the options farming can provide to halt biodiversity loss, in line with the transformational changes advocated by the European Green Deal.

3.2.1 Introduction and description of agroecosystems

In the context of MAES, agroecosystems are defined as communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, feed, fibre, energy and other products for human consumption and processing (Maes, 2018). The MAES process has classified agroecosystems into cropland and grassland ecosystems (Maes et al., 2013), which together account for almost half of EU terrestrial ecosystems. Cropland includes land area under temporary and permanent crops cultivation, land temporarily fallow, horticultural and domestic habitats. Grasslands are areas covered by grass-dominated vegetation (including tall forbs, mosses and lichens), which include pastures, meadows and natural grasslands. In both cases semi-natural features (e.g. field margins, hedges, grass strips, lines of trees, ponds, terraces, patches of uncultivated land) are considered an integral and important part of agroecosystems, as from a pragmatic definition they are managed within the same context (and land managers) and affected by agricultural activities, and from an ecological perspective they are nesting and breeding sites, food sources, migratory corridors to fauna, supporting ecosystem services such as pollination, pest control and other regulating and cultural ecosystems services.

Agroecosystems host some of the most species-rich habitats in the EU (Wilson et al, 2012) and it is estimated that ca. 50% of all species in Europe rely on agricultural habitats at least to some extent (Halada et al., 2011; Lomba et al., 2015). Moreover, agrobiodiversity and in particular genetic resources for food and agriculture (wild crop relatives, plant varieties, landraces etc.) represent an insurance for the future, guaranteeing the capacity to respond to crises (climatic, economic etc.) contributing thus to food security.

Due to the prolonged interaction between natural and human systems, it is necessary to stress the perspective under which condition of agroecosystems is addressed. Agroecosystems, in fact, do not have a corresponding "natural state", or degree of intactness that can be set as reference. The reference therefore becomes a fully functioning system, able to support biodiversity and deliver a range of services: "*agroecosystems are modified ecosystems, they are in good condition when they support biodiversity, abiotic resources (soil-water-air) are not depleted, and they provide a balanced supply of ecosystem services (provisioning, regulating, cultural). Sustainable management is key to reaching or maintaining a good condition, with the aim to increase resilience and maintain the capacity of delivering services to current and future generations*." (Maes et al., 2018).

Several EU policies impact farming and farmland. The main EU policy affecting agroecosystems is the Common Agricultural Policy (CAP). For over 50 years it has been distributing subsidies steering the sector to meet the goals which through time have been identified (e.g. supporting production, promoting jobs), and within which concerns for the environment, including biodiversity and in recent times climate, have gained increasing importance. In the European Commission's legislative proposal on the CAP beyond 2020 (COM/2018/392 final - 2018/0216 (COD)) the preservation of landscapes and biodiversity is one of the nine identified overarching objectives. The EU Habitats and Birds Directives aim at preserving Europe's most endangered species and valuable natural habitats. A significant number of Natura 2000 sites have been designated to protect species or habitats that depend upon, or are closely associated with, agriculture (over 50 habitat types and 260 species respectively), this corresponds to approximately 40% of the land within the Natura 2000 Network (DG ENV, 2017). The Nitrates Directive and the Water Framework Directive prescriptions are integrated in the CAP and aim at limiting or cancelling negative impacts from agriculture. Energy and climate policies have an impact on farmers' choices as well (e.g. increase in energy crops production).

3.2.2 Ecosystem extent and change

The extent of agroecosystems according to CORINE Land Cover (all eleven level-3 classes 2.x, of which ten are assigned to cropland ecosystems, and one -class 2.3.1 "Pastures"- assigned to grassland ecosystems) corresponds to almost 48% (2018) of total EU land area. Within such share, 24% is represented by grassland and 76% by cropland. The area of agroecosystems as measured by CORINE Land Cover is stable across time, with only a variation of -0.30% in the period 2000-2018 and a decrease of 0.23% in the short term (Table 3.2.1). The ration cropland/grassland is stable as well. Due to CORINE land cover mapping protocol and in particular its minimum mapping unit of 25 ha, the estimated area includes features not necessarily related to farming activities such as roads, railways, groups of houses, small woodlots.

Alternatively, the Utilised Agricultural Area, defined as “total area taken up by arable land, permanent grassland, permanent crops and kitchen gardens used by the holding, regardless of the type of tenure or of whether it is used as a part of common land” (Eurostat glossary), provides a stricter quantification of the extent of agroecosystems, since it quantifies the area directly managed by farmers. The UAA amounted to 1,787,360 km^2 in 2016 (Eurostat[13]), compared to CORINE Land Cover estimate of 2,096,616 km^2.

Table 3.2.1. Surface area of agroecosystems based on CORINE Land Cover accounting layers for 2000, 2006, 2012 and 2018. In brackets the percentage share in relation to the area of total terrestrial ecosystems

Area (km^2) (% share)	**2000**	**2006**	**2012**	**2018**
Total terrestrial ecosystems	4,381,107 (100%)	4,381,117 (100%)	4,381,117 (100%)	4,381,117 (100%)
Grassland	504,778 (11.5%)	503,411 (11.5%)	502,454 (11.5%)	500,566 (11.4%)
Cropland	1,604,793 (36.6%)	1,600,732 (36.5%)	1,596,331 (36.4%)	1,596,050 (36.4%)

The UAA has been declining by 6% between 2000 and 2016 (long term trend). It has to be noted that the UAA decreased only by 0.78% in the period 2010-2016, that corresponds to a 1.3% decrease per 10 years. The downward trend has therefore flattened in the short term compared to the long-term trend.

Soil sealing by urbanization is an important component of land take, worth analysing. Starting from a 0.03% of agricultural soil sealed in 2010 (633 km2/year), such trend decreased by 32.4% in the short term, compared to a 40.8% in the 2000-2018 period. This figure represents a very small share of the total area of agroecosystems, but on the ground it means nevertheless about 4200 km^2 of agroecosystems irreversibly lost to urbanization in a decade. This figure relates to the v20 version of CORINE Land Cover used in the present assessment. A more detailed estimate is provided by the Global Human Settlement layer based on Landsat imagery (Pesaresi et al., 2016), according to which 5970 km^2 of agroecosystems have been converted in 10 years to artificial areas, corresponding to 18 m^2 per second.

3.2.3 Data

Pressure and condition indicators for agroecosystems were identified in the fifth MAES report (MAES, 2018). In this assessment we collected an array of available data and indicators summarised in Table 3.2.2 for pressures and in Table 3.2.3 for condition. The tables show the fact sheet number of each indicator, where detailed information can be accessed regarding the characteristics of the input data and the indicator. In addition, the tables show information on the unit of measure, the data period and the spatial resolution of the input data used for creating the indicators.

[13] https://ec.europa.eu/eurostat/databrowser/view/tag00025/default/table?lang=en

Table 3.2.2. Agroecosystem pressures indicators, units, time-series and spatial resolution of the input data used for creating the indicator. All fact sheets are available as a supplement to this report.

Pressure class	Indicator (Fact sheet number)	Unit	Data period	Spatial resolution of input data
Habitat conversion and degradation (land conversion)	Land take (3.2.101)	ha/year	2000, 2006, 2012, 2018	MS
	Utilised Agricultural Area (3.2.102)	ha	2000-2016	MS
	Intensification / Extensification	NA	NA	NA
	Ecosystem extent (3.2.104)	ha	2000, 2006, 2012, 2018	MS
Climate change	Annual mean temperature (4.1.101)	°C	1960-2018	10 km
	Effective rainfall (4.1.101)	mm	1960-2018	25 km
	Summer days (4.1.101)	number of days	1985-2018	25 km
	Soil moisture (soil water deficit) (4.1.101)	%	1951-2013	5 km
	Growing season length (4.1.101)	number of days	1985-2018	25 km
Pollution and nutrient enrichment	Exceedances of critical loads for acidification(3.2.107)	eq/ha/year	2000, 2005, 2010, 2016	25 km
	Exceedances of critical loads for eutrophication (3.2.108)	eq/ha/year	2000, 2005, 2010, 2016	25 km
	Gross nitrogen balance (3.2.109)	kg/ha UAA/year	2004-2015	MS
	Gross phosphorus balance (3.2.110)	kg/ha UAA/year	2004-2015	MS
	Mineral fertilizer consumption, nitrogen (3.2.111)	tons/year	2010-2017	MS
	Mineral fertilizer consumption, phosphorus (3.2.111)	tons/year	2010-2017	MS
	Pesticide use (3.2.112)	kg/year	2011-2017	MS

NA: Data are not available or data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.2.3. Agroecosystem condition indicator, units, time-series and spatial resolution of the input data used for creating the indicator. All fact sheets are available as a supplement to this report.

Condition class	Indicator (Fact sheet number)	Unit	Data period	Spatial resolution of input data
Environmental quality (physical and chemical quality)	Nitrogen concentration in groundwater (3.2.201)	% stations > 50 mg/l	2004-2007, 2008-2011, 2012-2015	EU-28
Structural ecosystem attributes (general)	Landscape mosaic (4.3.201)	index	2000, 2006, 2012, 2018	100 m
	Crop diversity (3.2.202)	SDI index (0-1)	2000-2017	25 km
	Share of dominant crop	%	2000-2017	25 km
	Share of fallow land in utilised agricultural area (3.2.206)	%	2000-2017 (EU aggregate: 2000-2016)	NUTS2
	HNV farmland area (3.2.207)	ha	2000, 2006, 2012, 2018	100 m
	Share of organic farming in UAA (3.2.208)	%	2005 - 2017	MS
	Livestock density (3.2.209)	LU/ha	2005, 2007, 2010, 2013, 2016	MS
Structural ecosystem attributes based on species diversity and abundance	Farmland Bird Indicator (3.2.210)	index	1990-2015, Regional indicators: 1980- / 1982- /1989 - 2016	EU-26, 4 geographical region of EU-28
	Grassland Butterfly Indicator (3.2.211)	index	1990-2017	EU-15
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Share of grassland habitats listed under Annex 1 of the Habitats Directive in favourable conservation status (3.5.203)	%	2013 - 2018	EU-28
	Trends in unfavourable conservation status of grassland habitats listed under Annex 1 of the Habitats Directive (3.5.203)	%	2013 - 2018	EU-28
	Percentage of agroecosystems covered by Natura 2000 (3.2.213)	%	2000, 2006, 2012, 2018	MS
	Percentage of agroecosystems covered by Nationally designated areas (CDDA) (3.2.214)	%	2000, 2006, 2012, 2018	MS
Structural ecosystem attributes of which soil related	Topsoil organic carbon content (3.2.216)	tonnes/ C ha	1980, 1990, 2000, 2010, 2008, 2010, 2015, 2020* (*extrapolated)	1 km
Functional ecosystem attributes	Gross primary production (3.2.217)	kJ/ha/year	2001-2018	100 m

3.2.4 Drivers and pressures: spatial heterogeneity and change over time

In this section pressure indicator trends will be presented and discussed. The reference table in the 5th MAES report (Table 4.2, Maes et al., 2018) lists 16 pressure indicators. Compared to such list, availability of data allowed expanding the description of climate trends, and calculating thus trends for 22 indicators, of which 15 describe climate trends, seven describe trends in pollution and nutrient enrichment.

3.2.4.1 Assessment at the level of EU-28

The assessment of pressures on agroecosystems focuses on three categories of pressures, deriving from: climate change, land conversion, pollution and nutrient enrichment. Results are presented in Table 3.2.4.

The relation of agroecosystems with climate is twofold: farming activities shaping agroecosystems depend directly on climatic conditions (e.g. planting and sowing dates, water availability and irrigation, choice of species varieties better adapted to climate extremes etc.). Moreover, changing climatic conditions affect plant community traits and composition, leading to species range shifts e.g. in grassland habitats (Tardella et al, 2016; Choler P., 2018), and change in their usage (e.g. duration and intensity of grazing season) driving therefore a whole range of impacts on biodiversity. Assessing these multiple interactions required a set of indicators, with preference given to indicators based on the longest time series available for this assessment, covering five to seven decades. The indicators assessed (fact sheet 4.1.101) cover the key aspects of climate impacting agroecosystems. We used indicators describing changes in the magnitude of average and extreme events, as well as shifts in seasonality, or the frequency of climate events. The indicators were classified in three categories: climate anomalies, climate extremes and seasonality. The perspective adopted in this assessment is that climate change creates a disturbance, leading to changes in the physiological responses of ecosystems, their time responses (e.g. phenology), and spatial distribution (Bellard et al. 2012). Therefore, even though beneficial effects for ecosystems are possible, e.g. in terms of increased primary productivity at the regional scale, significant changes are overall considered pressures resulting in negative impacts on agroecosystem condition.

Overall, 60% of climate indicator trends show degradation, of these increasing mean annual temperature (+0.342 °C/decade in the long term), number of summer days (+3.76 days/decade), and length of growing season (+5.46 days/decade) show statistically significant changes over the available time series according to Mann-Kendall trend test. Generally, EU climate goes in the direction of having longer warm periods, higher temperatures, milder winters, and higher frequency of drought events.

The analysis shows that in the case of exceedance of critical loads, indicator trends for eutrophication by nitrogen and for acidification by nitrogen and sulphur have improved both in the short term and since 2000 (long-term trend). It means that depositions of pollutants causing acidification and eutrophication on agroecosystems have decreased. High deposition levels can in fact impact grassland structure and function, in particular by inducing changes in plant species composition, eutrophication and soil acidification (Henry and Aherne, 2014). The improvement is significant, 47% decrease per decade for the acidification component, 20% decrease for the eutrophication component.

The gross nitrogen balance, calculated from the total inputs minus total outputs to the soil, represents the total potential threat to the environment of nitrogen surplus or deficit in agricultural soils. A negative balance (lack of nitrogen) may cause degradation in soil fertility and erosion, while a positive balance (excess of nitrogen) may cause surface and groundwater (including drinking water) pollution and eutrophication. Moreover, nitrogen in excess can be lost to air as ammonia and other greenhouse gases (EEA, 2018). Gross nitrogen balance value is quite stable at around 50 kg N/UAA ha/year at EU level (fact sheet 3.2.109).

The gross phosphorus balance provides an insight into the links between agricultural phosphorus use, losses of phosphorus to the environment, and the sustainable use of soil phosphorus resources. A positive phosphorus balance shows phosphorus surplus that can be leached to water bodies causing pollution and eutrophication. A negative balance can mean risk for soil depletion but this has to be assessed in the context of the long-term trend. If decades of excess phosphorus applications have built up large reserves of phosphorus in the soil, maintaining a negative balance ("phosphorus mining") can be a sustainable management for years without reducing crop yield potential. Phosphorous balance showed a significant downward trend of -0.25 kgP/UAA ha/yr from 2004 to 2015 at EU level, but since 2010 no significant change has occurred (fact sheet 3.2.110).

Mineral fertilizer consumption has increased by 16% in the short term, with values higher than 5% in most of EU countries. The trend in the consumption of inorganic phosphorus fertilisers is not statistically significant, however the percentage change in the short term is equal to 16% (fact sheet 3.2.111).

Data on pesticide sold quantities show that there is no significant trend in any of the six main types of pesticides sales between 2011 and 2017, for the analysed 18 countries, nor for the total at EU level, which remains stable at around 380,000 tonne/yr (fact sheet 3.2.112).

Lastly, indicator of intensification/extensification and loss of organic matter are part of the MAES indicators list, but time series for such indicators are not available and trends cannot be calculated.

Table 3.2.4. EU aggregated pressure data in relation to agroecosystems.

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation (land conversion)	Land take	ha/year	69,341	-37.10	↑	7	-36.06	↑	ha/year
	Utilised Agricultural Area	ha	180,137	-0.96	→	8	-4.64	↓	ha
	Intensification / Extensification				unresolved			unresolved	
	Ecosystem extent	ha	2,100,571	-0.094	→	7	-0.34	→	%
Climate anomalies	Annual mean temperature	°C	9.5		↓	7	+0.342 °C/decade	↓	9
	Effective rainfall	mm	-32	-56.57	↓	6	-38	↓	8
	Summer days (number of days where daily max. temp > 25 °C)		44.46	8.12	unresolved	7	7.96	↓	9
	Soil moisture (soil water deficit)	%	13.5	NA	unresolved	7	-0.35	→	9
Change in seasonality	Growing season length	number of days	242.55		unresolved	7	+5.46 d	↓	9
Pollution and nutrient enrichment	Exceedance of critical loads for acidification	eq/ha/year	98.1	-47	↑	5	-77	↑	5
	Exceedance of critical loads for eutrophication	eq/ha/year	466.7	-20	↑	5	-24	↑	5
	Gross nitrogen balance	kg/ha UAA/year	49	0	→	4	0	→	6
	Gross phosphorus balance	kg/ha UAA/year	2	0	→	4	-117.6	↑	6
	Mineral fertilizer consumption	tons/year	10,401,900	15.79	↓	6		unresolved	
	Phosphorus input	tons/year	1,198,800	16.15	↓	6		unresolved	
	Pesticide sales	kg/year	381,071,739	0	→	5		unresolved	
	Loss of organic matter				unresolved			unresolved	

↑: Significant improvement (significant downward trend of pressure indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

3.2.4.2 In depth assessment

As explained in the previous section, 60% of climate indicators show statistically significant changes. The analysis that follows focuses on five indicators: annual mean temperature, effective rainfall, summer days, soil water deficit, growing season length.

The most relevant results are evident in the trend of annual mean temperature. Figure 3.2.1 shows that there is hardly any area in the EU that is not affected by increasing temperature, in some cases exceeding 0.4 °C per decade. Notably, it is remarkable that almost the whole of Scandinavian and Baltic countries are characterized by an increase in temperature of the coldest quarter that exceeds 0.4 °C per decade (Figure 3.2.2).

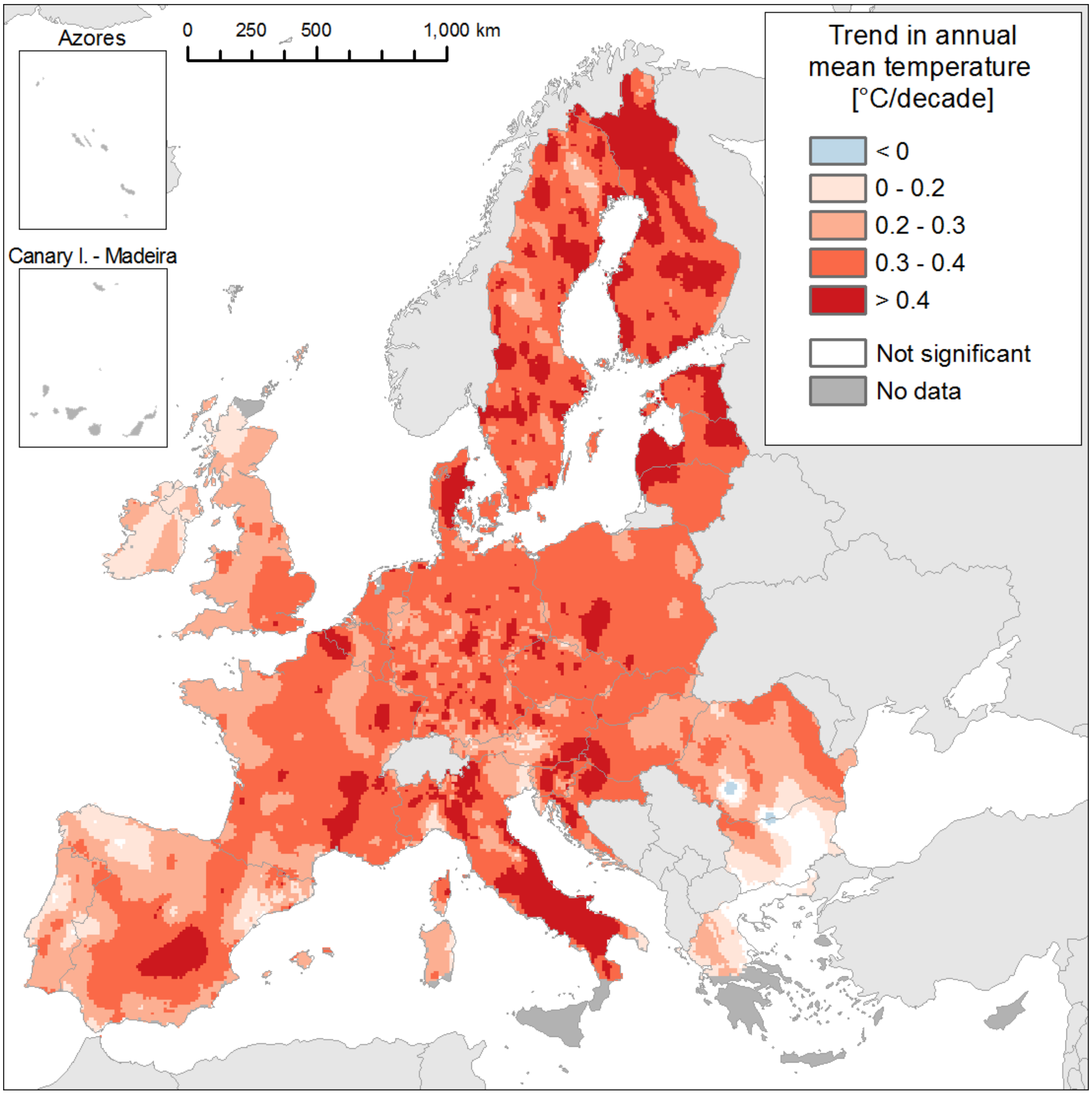

Figure 3.2.1. Trends in annual mean temperature 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

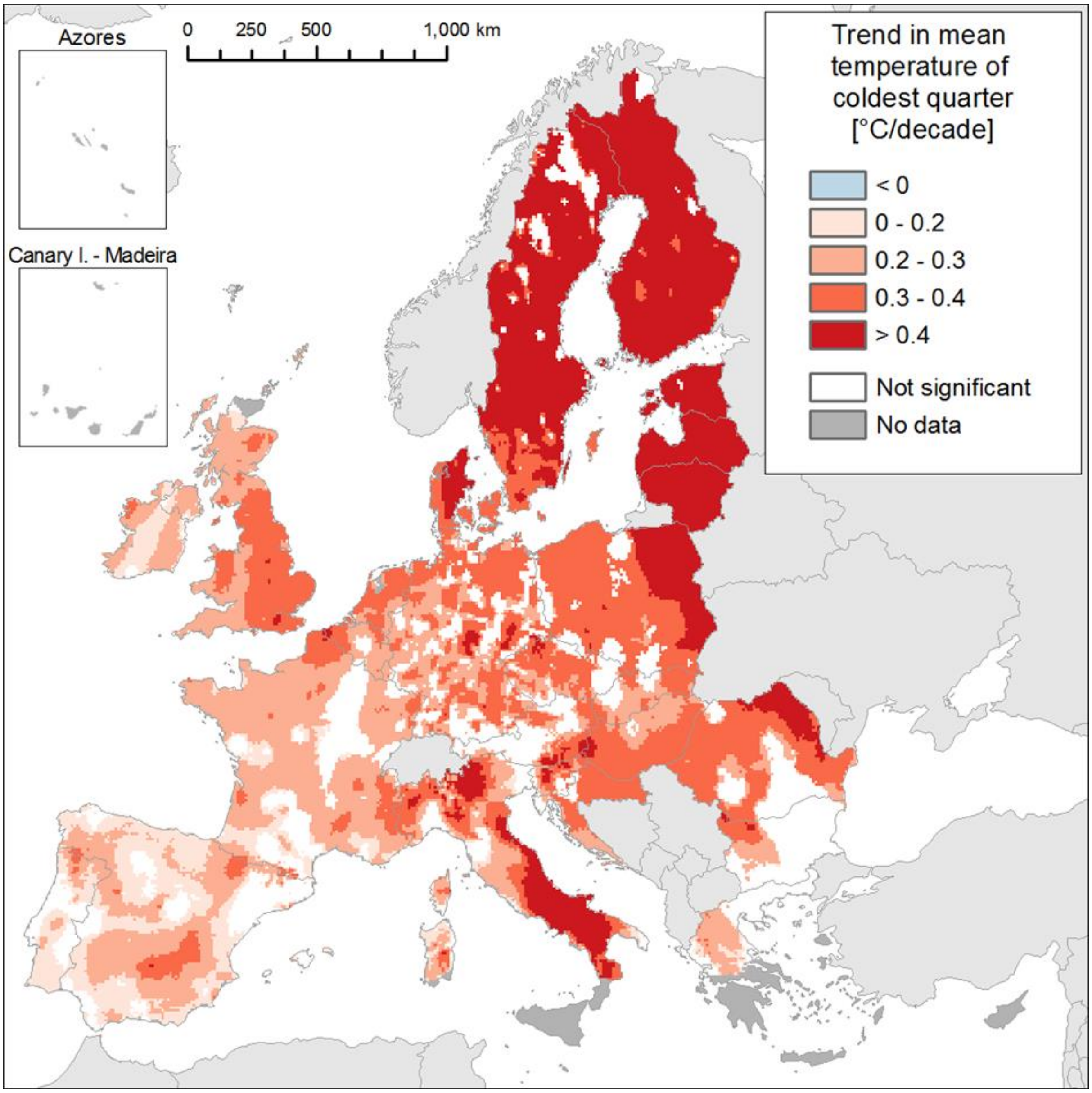

Figure 3.2.2. Trends in mean temperature of coldest quarter 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

Despite the fact that annual precipitation does not show a significant trend at EU level (Figure 3.2.3), effective rainfall is declining (Figure 3.2.4). Effective rainfall is the difference between mean annual precipitation and mean annual potential evapotranspiration. It is considered an index of plant productivity, where values below zero indicate that evaporative demand exceeds precipitation and values above zero that precipitation exceeds evaporative demands. Therefore, it is a quantitative indicator of the degree of water deficiency at a given location. The Iberian Peninsula, Central Italy and Southern France are significantly affected by decreases in effective rainfall. By contrast, an increase in effective rainfall is evident in some areas of Northern Europe.

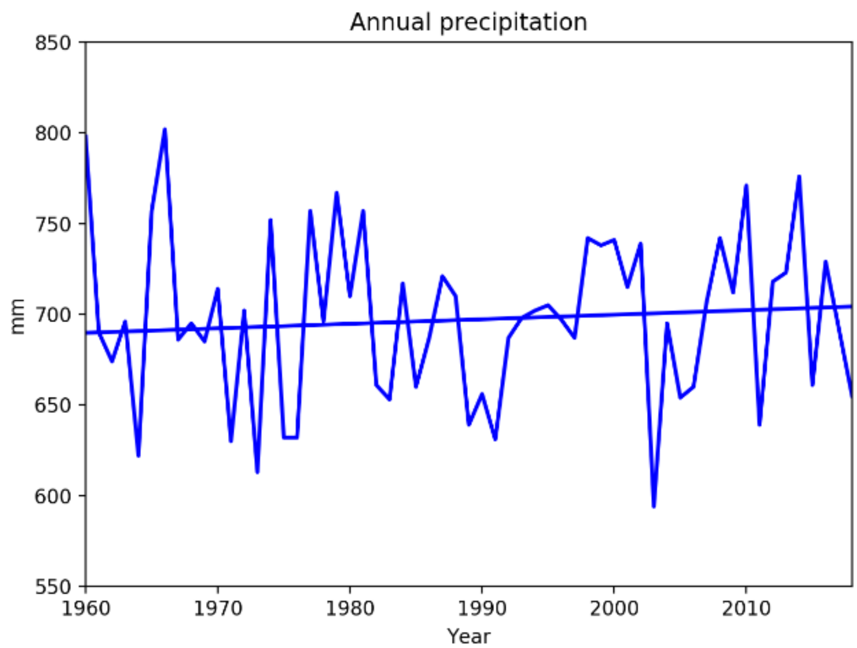

Figure 3.2.3. Trend of annual precipitation 1960-2018 in the EU. Trend line computed using the Theil–Sen non-parametric estimator. Increasing trend not significant at 5% according to Mann-Kendall trend test.

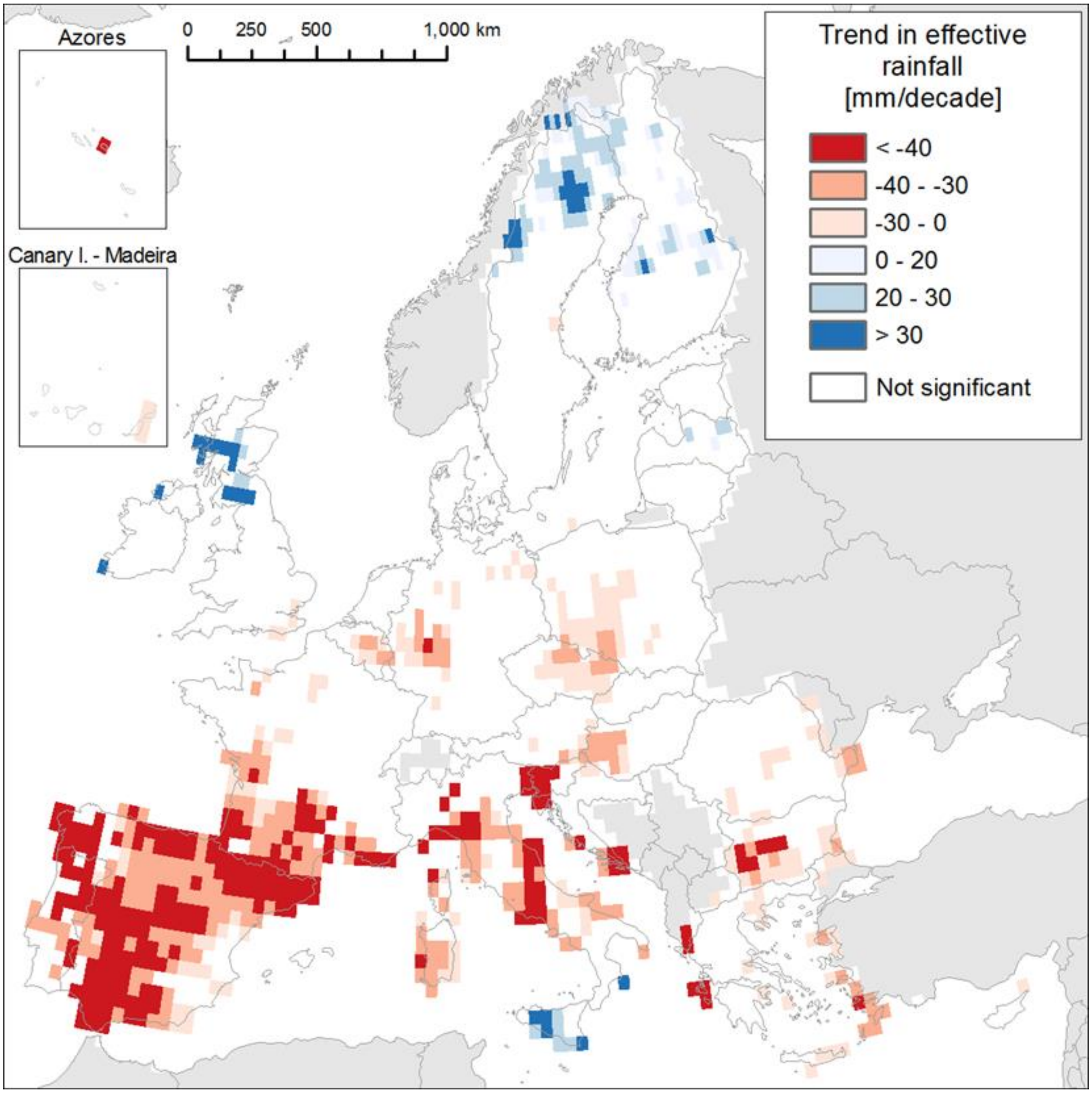

Figure 3.2.4. Trends in effective rainfall 1960-2016 (significant at the 5% level according to the Mann-Kendall test).

The frequency of drought events and extreme drought events (fact sheet 4.1.101) has been increasing in large areas of Mediterranean, Central and Eastern Europe.

Finally, changes in seasonality, i.e. increasing number of summer days (Figure 3.2.5) or growing season length (Figure 3.2.6), indicate that the extent of areas at the upper range (more than seven additional summer days per decade or an addition of more than 10 days to the growing season) is not negligible. Particularly, an expansion of summer is mostly visible in central and eastern Europe (continental climate) as well as southern Europe (Mediterranean); whereas changes in growing season length are observable in south-eastern and north-western Europe.

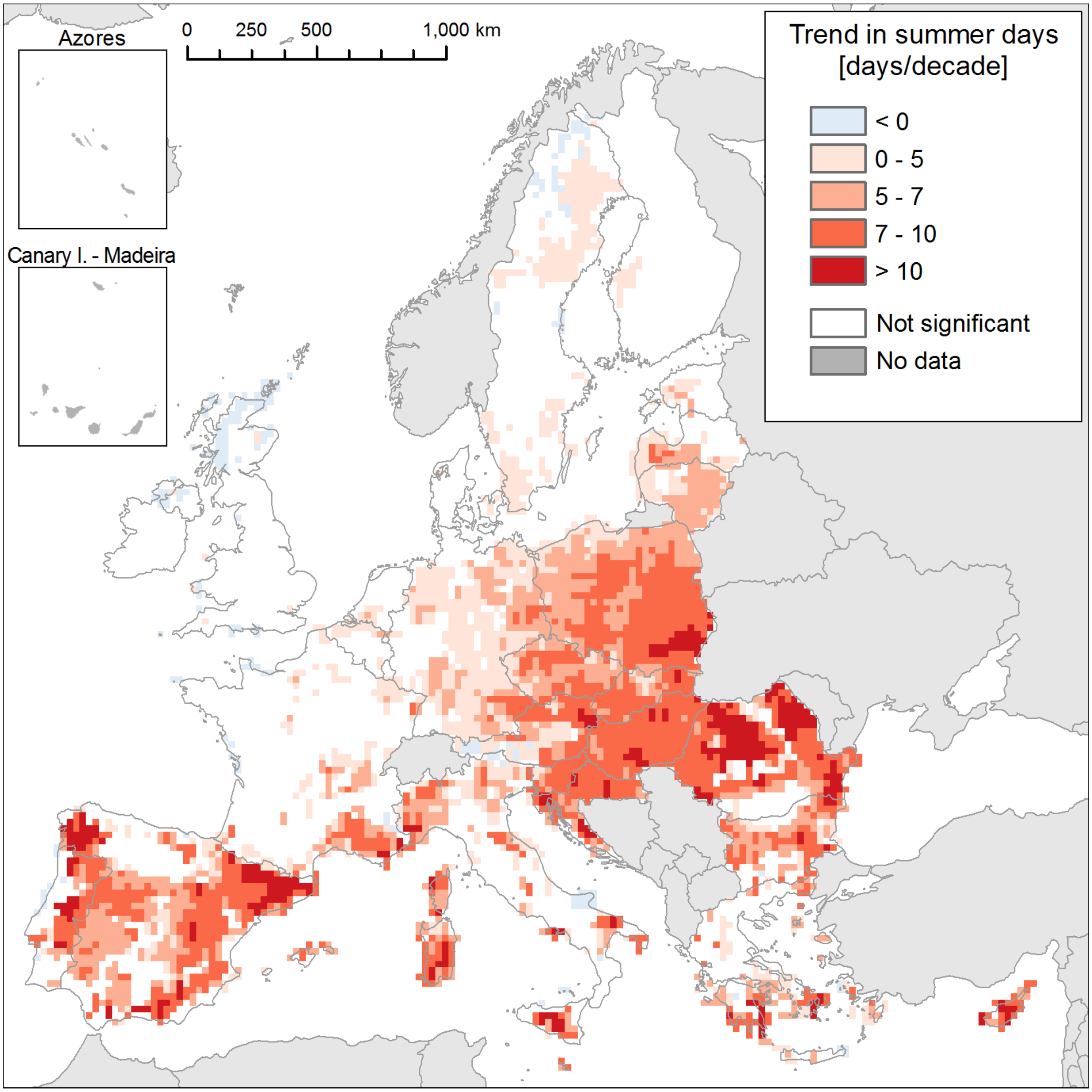

Figure 3.2.5. Trends in summer days (days with daily maximum temperature > 25 °C) 1985-2018 (significant at the 5% level according to the Mann-Kendall test)

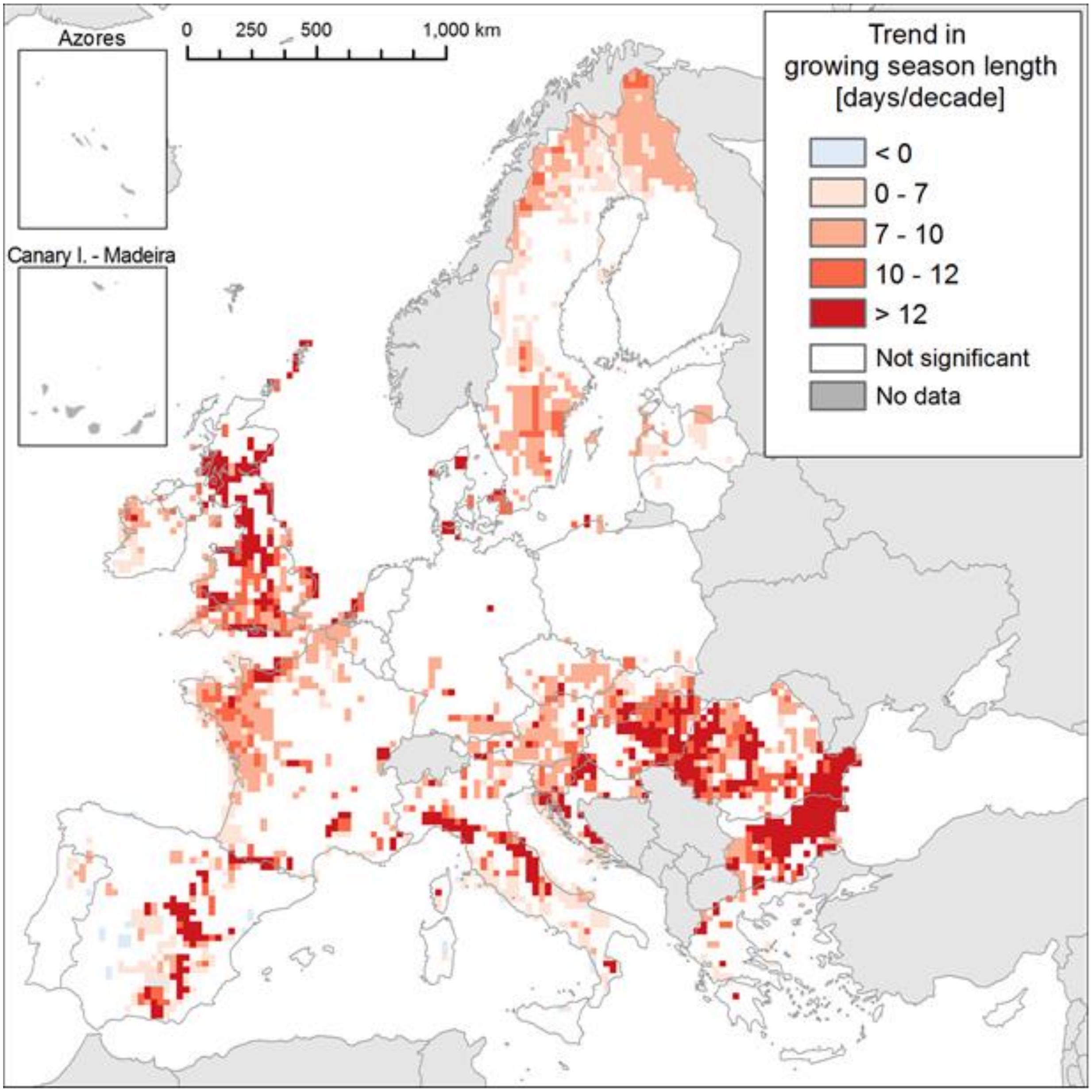

Figure 3.2.6. Trends in growing season length 1985-2018 (significant at the 5% level according to the Mann-Kendall test)

Impacts on agriculture of changes in climate are described in EEA, 2019: climate change has already negatively affected the agriculture sector in Europe, though this might also have some positive effects due to longer growing seasons and more suitable crop conditions, the number of climate extreme events negatively affecting agriculture in Europe is projected to increase. Moreover, there is evidence (Ceglar et al., 2019) that agro-climatic zones have migrated North, and that such migration is likely to further accelerate, with higher migration velocities of up to 100 km per 10 years in Eastern and Northeastern Europe, while Western Europe has seen a strong northward shift of Atlantic climate zones, which is also moving central-northern Germany, replacing thus continental climate. The magnitude of the impacts of these changes on biodiversity and condition of agroecosystems is still to be fully analysed. However, some evidence is available especially for those taxa that are regularly monitored. Northward shifts and changes in community composition are recorded in birds and butterflies communities (Jørgensen et al., 2016; Devictor et al., 2012) yet indicating lagging responses compared to the extent of climate-shifts; in mountain areas the more cold-adapted plant species decline and the more warm-adapted species increase (Gottfried et al., 2012).

Regarding inputs on agroecosystems, our assessment indicates that despite previous efforts to reduce the impact of pollutants and nutrients on ecosystems (CAP, Water Framework Directive, Nitrates Directive), their impact level is still high. In fact, it should be noted that, in relation to pollution, critical loads for eutrophication are exceeded in virtually all countries and in 73% of the ecosystem area in the EU (2016 data; Fagerli et al., 2018).

With respect to gross nitrogen balance, the decrease that was visible until 2010 has stopped, and the balance remained roughly stable since then (Figure 3.2.7). The analysis at Country level (fact sheet 3.2.109) shows that Latvia and Cyprus have a statistically significant increasing trend, while of the seven countries showing statistically significant decreasing trends (therefore an improvement) since 2004, only in Denmark the decrease is statistically significant in the short term as well. Overall, values remain high to very high: five countries (Belgium, Cyprus, Luxembourg, Malta and Netherlands) exceed 100 kgN/ha UAA/year; except Romania and Bulgaria all countries have a balance higher than 20 kgN/ha UAA/year.

The consumption of mineral fertilisers is increasing at EU level (Figure 3.2.8), resulting from an increase in 12 EU countries out of 28.

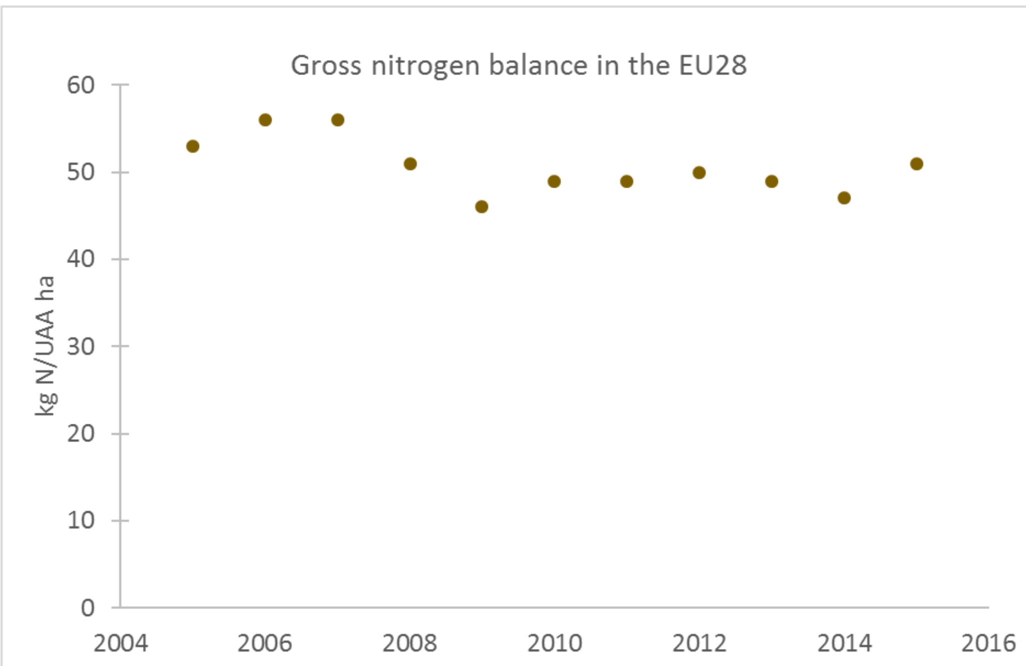

Figure 3.2.7. Gross Nitrogen balance in the EU-28

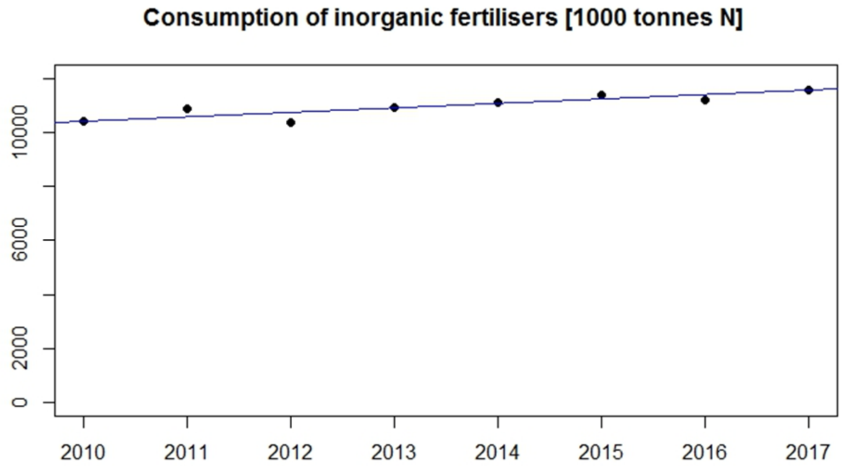

Figure 3.2.8. Consumption of inorganic nitrogen fertilisers in the EU-28

Finally, pesticide sales were stable at EU level (Figure 3.2.9), with some countries decreasing the purchased quantities (Figure 3.2.10), notably Denmark, Portugal, Greece, Croatia and Czech Republic where sales have decreased by 40% or more (the linear trend derived from 2010-2017 annual data marks a -102% for Denmark, due to a steep decline in the period 2012-2014, the difference between last and first year is in fact -34%). In other countries such as Austria, Finland and Latvia, purchases have increased by more than 40%. The total quantity sold is approximately 380.000 tonnes/year in the EU. It is worth noting that the Harmonised Risk Indicator for pesticides in the EU[14] is showing a 20% reduction in the risk to human health and the environment from pesticides in the same period. The Harmonised Risk Indicator is calculated by multiplying the quantities of active substances placed on the market in plant protection products by a weighting factor reflecting policy on the use of pesticides. Nevertheless, quantities of active substances present in the sold volume are not available due to EU statistical legislation force[15], therefore it is not possible to derive further indications about e.g. toxicity to non-target species, or potential for residues of pesticide mixtures. Insect loss, pollinators decline (Uhl and Brül, 2019), presence of residues in the soils (Silva et al., 2018; Silva et al., 2019) suggest a persistence of such substances in the environment.

Information on trends on Invasive Alien Species (IAS) of Union Concern is not yet available, therefore the indicator is not part of the present assessment. Nevertheless, the baseline is known and is worth mentioning as complementary information: 46% of cropland area and 66% of grasslands are impacted by IAS. The assessment is based on information on the 49 IAS listed on the Union list up to 2017 (EU, 2017) (23 plant and 26 animal species). Their pressure was assessed as the summed occurrence of the IAS present in an area, weighted by the extent of the affected cropland and grassland ecosystems (fact sheet 4.2.101).

[14]https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides/harmonised-risk-indicators/trends-hri-eu_en

[15] Article 3(4) of Regulation (EC) No 1185/2009 requires the Commission to aggregate data in predefined groups and categories before publishing.

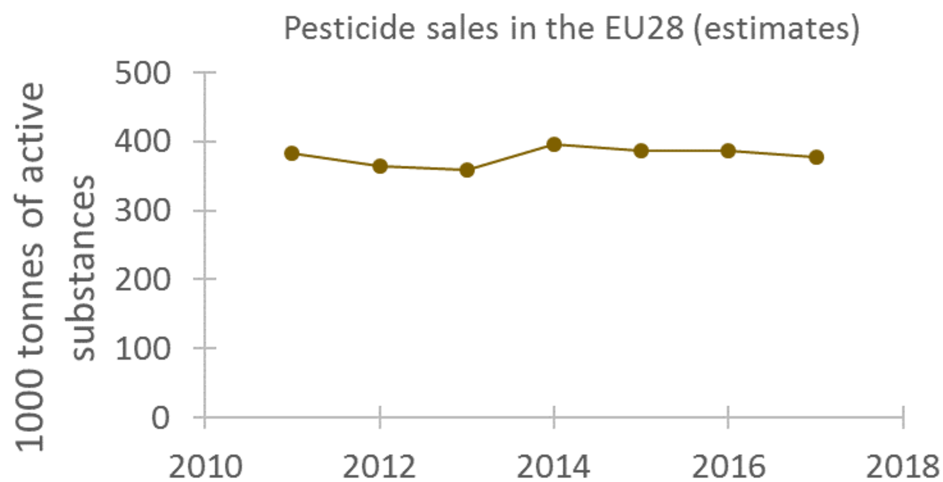

Figure 3.2.9. Estimates of pesticide sales in the EU-28 between 2011 and 2017 excluding confidential data representing < 3% of the total of sales over the entire time series (source: Eurostat).

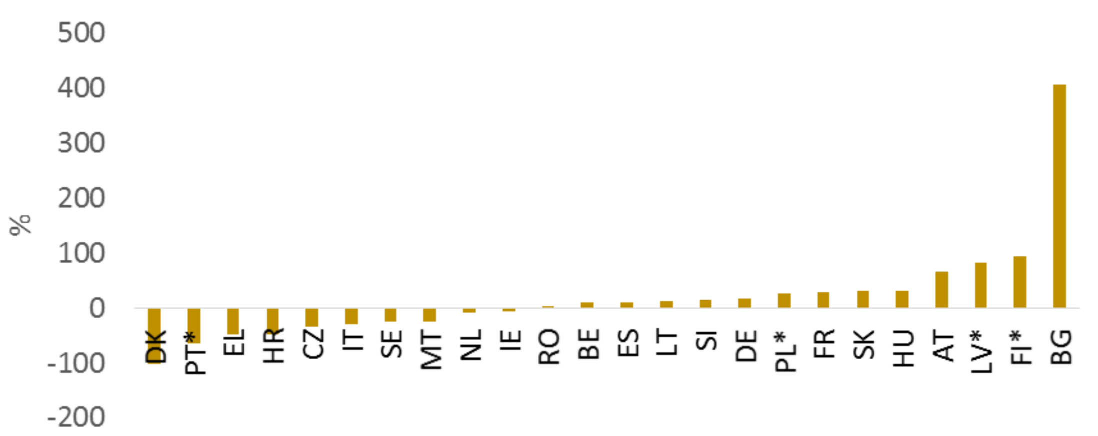

Figure 3.2.10. Decadal % change in pesticide sales in EU Member States, calculated from Sen's slope and intercept. In LT, SI, DE, PL, FR: Other Plant Protection Products or Molluscicides (that are usually used in negligible amounts compared to the total) excluded in one or more years due to missing data. BG, CZ, EL, HR, HU, MT: there is one year data gap. Baseline year: 2011, in BG, CZ, EL: 2012, HR: 2013 due to missing data. *: significant trend according to the Mann-Kendall test. Data source: Eurostat.

3.2.5 Ecosystem condition: spatial heterogeneity and change over time

3.2.5.1 Assessment at the level of EU-28

The assessment of condition of agroecosystems is based on 14 indicators for which, except for one, short and long term trends are available. The indicators assess three main characteristics of the agroecosystems: environmental quality, structure and function. Table 3.2.5 shows the values of the indicators aggregated at EU level, and includes indicators for which either data or trends are not currently available. Four indicators show an improvement: nitrogen concentration in groundwater, share of organic farming, livestock density and gross primary production.

Nitrogen concentration in groundwater is based on data reported under the Nitrates Directive[16]. In summary, the percentage of stations exceeding 50 mg nitrates per litre has decreased by 12% in the short term, consolidating the positive long-term trend which started in the monitoring period 2004-2007 (fact sheet 3.2.201).

The share of organic farming has shown a marked improvement (Figure 3.2.11), increasing significantly between 2010 and 2017 in 19 Member States and decreasing in the United Kingdom (fact sheet 3.2.208). The share of organic farming in 2017 is 7.03% of the UAA, with an increase of 46% in the short term.

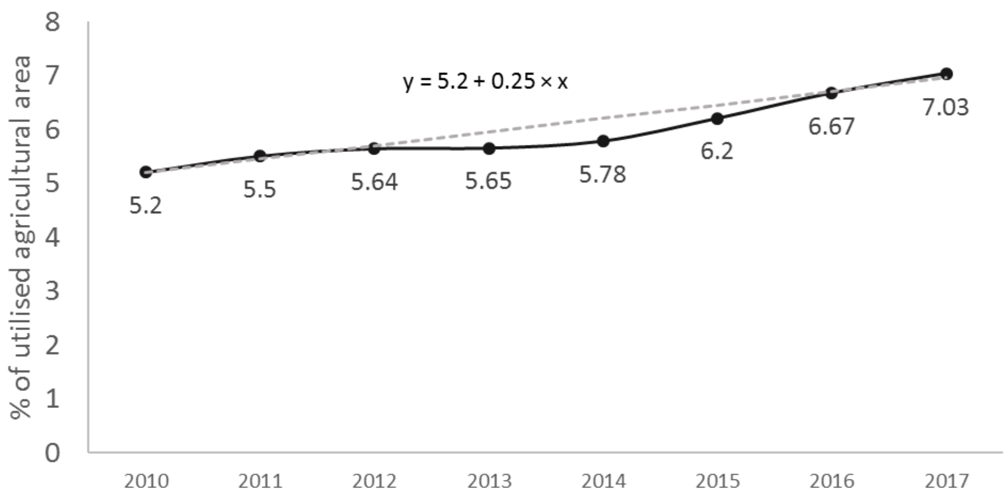

Figure 3.2.11. Trend in share of organic farming in utilized agricultural area in the EU (%) for the period 2010-2017 (Eurostat)

Livestock density has been decreasing, from 0.79 LU (Livestock Unit)/ha in 2004 to 0.75 LU/ha UAA in 2016. While, in general, lower density is considered positive for agroecosystem condition, it is interesting to note that the decrease has stopped in 2013 (fact sheet 3.2.209).

Gross primary production (GPP) has overall increased. This trend is further discussed in the following chapter (see section 3.4.5.2).

Biodiversity indicators show mostly downward trends: the farmland bird index shows a decline both in the short term (-7.4%) and in the long term (1990-2016, on average -13.5% per decade); the grassland butterfly index does not show a statistically significant trend in the short term, potentially implying that the decrease registered in the long term (-21.6% per decade) may have slowed.

Two indicators are directly derived from the Art.17 reporting on the conservation status of habitats under the Habitats Directive: the share of grassland habitats in a favourable conservation status and the trends in conservation status of grassland habitats that are in an unfavourable status (poor and bad). The total area of grasslands that is covered under Annex 1 of the Habitats Directive is 234,300 km^2 (See chapter 2, Table 2.2). This corresponds to 11% of the total extent of agroecosystem in the EU-28 and to 46% of the total extent of grassland in the EU-28 (see table 3.2.1). The EU level assessment of the conservation status of 32 grassland habitats concluded that 14.3% are in good (or favourable) conservation status. The remaining habitats are in poor status (32.5%), a bad status (49.2%) or unknown (4.0%) (State of Nature report for the period 2013-2018, forthcoming). Only 7.4% of the grassland habitats that is in an unfavourable status is showing improving trends. Just over 50% of the grassland habitats that is in an unfavourable status is showing deteriorating trends. In addition, Annex I habitats dependent on adequate agricultural management are assessed as bad (45 %) and poor

[16] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:01991L0676-20081211&from=EN

(38 %). Trends of only 8 % of these habitats are assessed as improving, whereas 45 % are deteriorating (State of Nature report for the period 2013-2018, forthcoming).

The majority of indicators shows no significant trend. It must be noted that this is sometimes related to limitations of the adopted approach, for example High Nature Value (HNV) farmland maps record losses of HNV farmland linked to changes in land cover, but not yet to increasing management pressures (fact sheet 3.2.207). This is likely to underestimate ongoing intensification processes, since the information on management intensity is not embedded in CORINE Land Cover, which is the basis for HNV farmland maps used in this assessment. On the contrary, abandonment is mapped to the extent that an agricultural land cover class converts through time to a natural class (e.g. grassland to transitional woodland shrub).

Table 3.2.5 EU aggregated agroecosystems condition indicators.

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Environmental quality (physical and chemical quality)	Nitrogen concentration in groundwater	% stations > 50 mg/l	14.4 (2008-2011)	-11.90	↑	6	-10.91	↑	7
Structural ecosystem attributes (general)	Landscape mosaic	index	See fact sheet 4.3.201	0	→	7	0	→	8
	Crop diversity	SDI index (0-1)	0.5859	0	→	5	0	→	6
	Share of dominant crop	%	41.05	0	→	5	-1.95	→	6
	Crop rotation				unresolved			unresolved	
	Share of semi-natural elements (%/ha)				unresolved			unresolved	
	Connectivity of semi-natural elements (index)				unresolved			unresolved	
	Share of fallow land in utilised agricultural area	%	4.96	-37.84	↓	6	-60.53	↓	7
	HNV farmland area	ha	75,167,308*	0	→	5	0	→	6
	Share of organic farming in UAA	%	5.2	45.87	↑	6	56.28	↑	7
	Livestock density	LU/ha	0.79	-2.96	→	5	-6.51	↑	5
Structural ecosystem attributes based on species diversity and abundance	Farmland Bird Index	index	72.15	-7.38	↓	5	-13.47	↓	6
	Grassland Butterfly Indicator	index	66	-9.36	unresolved	6	-21.63	↓	7
	Wild pollinators indicator				unresolved			unresolved	

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Share of grassland habitats listed under Annex 1 of the Habitats Directive in favourable conservation status**	%	14.3						
	Trends in un unfavourable conservation status of grassland habitats listed under Annex 1 of the Habitats Directive**	% improving		7.4	↑				
		% stable		16.7	→				
		% deteriorating		50.9	↓				
		% unknown		25.0	unresolved				
	Percentage of agroecosystems covered by Natura 2000	Percentage	Cropland: 5.78 Grassland: 10.03	Cropland: 0 Grassland: 0	→	7	Cropland: 0 grassland: 0	→	8
	Percentage of agroecosystems covered by Nationally designated areas (CDDA)	%	Cropland: 6.41 Grassland: 12.94	Cropland: -0.04 Grassland: 0.44	→	7	Cropland: 0.02 Grassland: 0.33	→	8
Structural soil attributes	Soil organic matter content	tonnes/ha	80.5	-0.36	→	5	-0.353	→	6
	Soil biodiversity				unresolved			unresolved	
Functional ecosystem attributes	Gross primary production (kJ/ha/year)	kJ/ha/year	Cropland: 0.9213 Grassland: 0.9983	Cropland: 12.5 Grassland: 14.5	↑	6	Cropland: 6.72 Grassland: 6.15	↑	7

↑: Significant improvement (significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

*baseline 2012; ** The indicators on grassland habitat conservation status have been treated differently than the other indicators with a different baseline year and different time period (2013–2018); so the percent change is expressed for a period of 6 years instead of 10 as for the other indicators. The trends in conservation status are only available for grassland habitats in an unfavourable conservation status. Please check chapter 2 for details.

3.2.5.2 In-depth assessment

One key outcome emerging from the assessment on agroecosystem condition is that there is no sign of reversal of biodiversity loss. The farmland bird index shows a decline not only when aggregated at EU level, but to different degrees at regional level as well (fact sheet 3.2.210 and Figure 3.2.12). The index for the four regions is based on the EU list of farmland birds (39 species). Decadal changes, indicating a loss, are all above 10%, with a maximum of 21% in West Europe. Compared to long term trends (1990-2016), the rate of decline has slowed in recent years (2010-2016). Similarly, the grassland butterfly indicator shows an equivalent decrease in the long term (1990-2017; -15%), which has slowed in the short term (2010-2017; fact sheet 3.2.211).

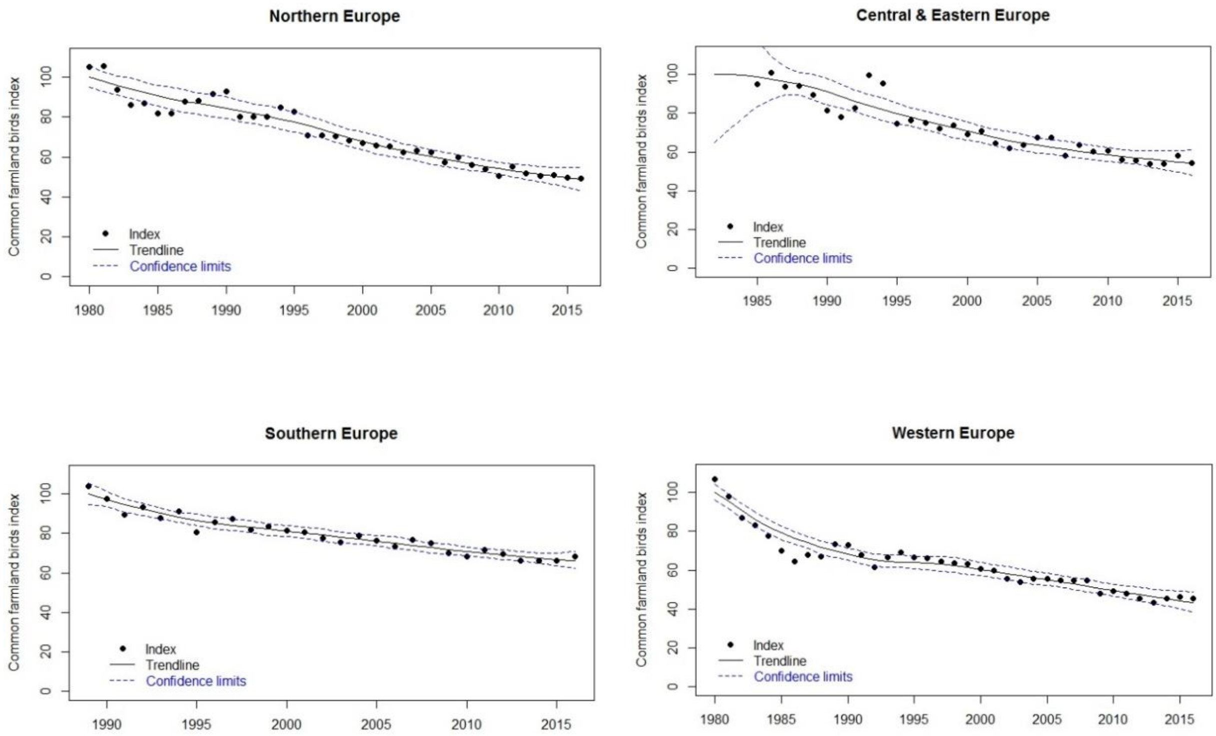

Figure 3.2.12. Regional farmland bird indices (EU-28 Countries, with Switzerland included in West Europe, and Norway in North Europe).

Three condition indicators show improvement, these are: nitrogen concentration in groundwater, share of organic farming, and gross primary production. It is worth analysing such trends in relation to agroecosystem condition.

The first indicator, nitrogen concentration in groundwater, is based on data reported under the Nitrates Directive. In the reporting period 2012-2015, the total number of reported groundwater monitoring stations in EU-28 was 34,901, nearly the same as in the previous reporting period. Approximately 66% of the monitored stations are located in MAES agroecosystems. Overall, the percentage of stations exceeding 50 mg nitrates per litre has decreased by 11.9% in the short term, consolidating the long-term trend starting in the 2004-2007 monitoring period. At the same time, stations recording a value less than 25 mg nitrates per liter have increased by 3.6%. Notwithstanding water monitoring results from the periods 2012–2015 and 2008–2011 show either a stable or improving water quality in 74% of the stations, it has to be noted that *"nutrients overload from agriculture continues to be one of the biggest pressures on the aquatic environment"* (EC, 2018).

Since 2010 the share of organic farming has increased significantly (Figure 3.2.13). Given the proven positive links of organic farming with biodiversity (e.g. Pfiffner and Balmer, 2011, Tuck et al., 2014) this is considered a positive trend. In a perspective of reversing biodiversity decline though, it must be noted that the current share of organic farming (7.03%, 2017 data) is still a small share of the UAA.

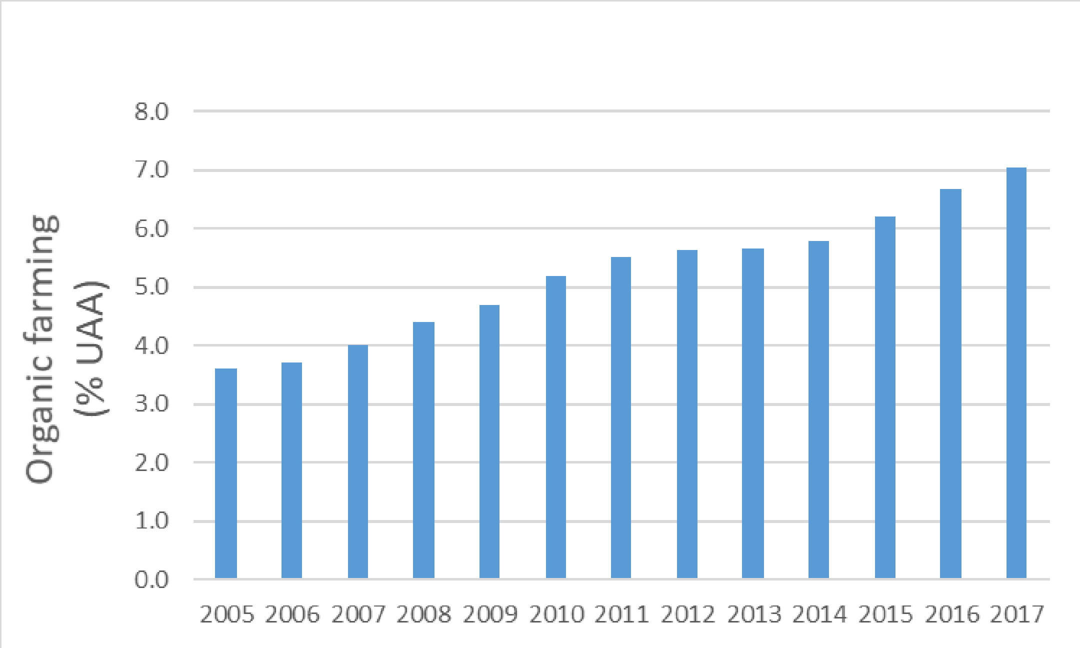

Figure 3.2.13. Share of organic farming in utilized agricultural area in the EU (%UAA). 2005-2011: 27 countries, 2012-2017: 28 countries

Gross primary production (GPP) needs some insight. The indicator describes the trend in annual cumulative GPP values, computed from MODIS satellite images (Fact sheet 3.2.217 and Figure 3.2.14). In general the trend is positive, with a short term trend showing a steeper increase compared to the long term trend (2001-2018). The decadal percentage change calculated from the short-term trend is 12.48% for croplands and 14.53% for grasslands. These increases are considered positive in this assessment, though some caution should be adopted, and a more in-depth analysis of the drivers behind the increase in biomass productivity should be performed. In fact, increased productivity can be attributed to climate, as well as to factors linked to land management: increased use of fertilisers, use of irrigation plants, and changes in crop rotation, intercropping, or in general to the introduction of practices aiming at leaving the soil covered, which can lead to an increased biomass production per areal unit.

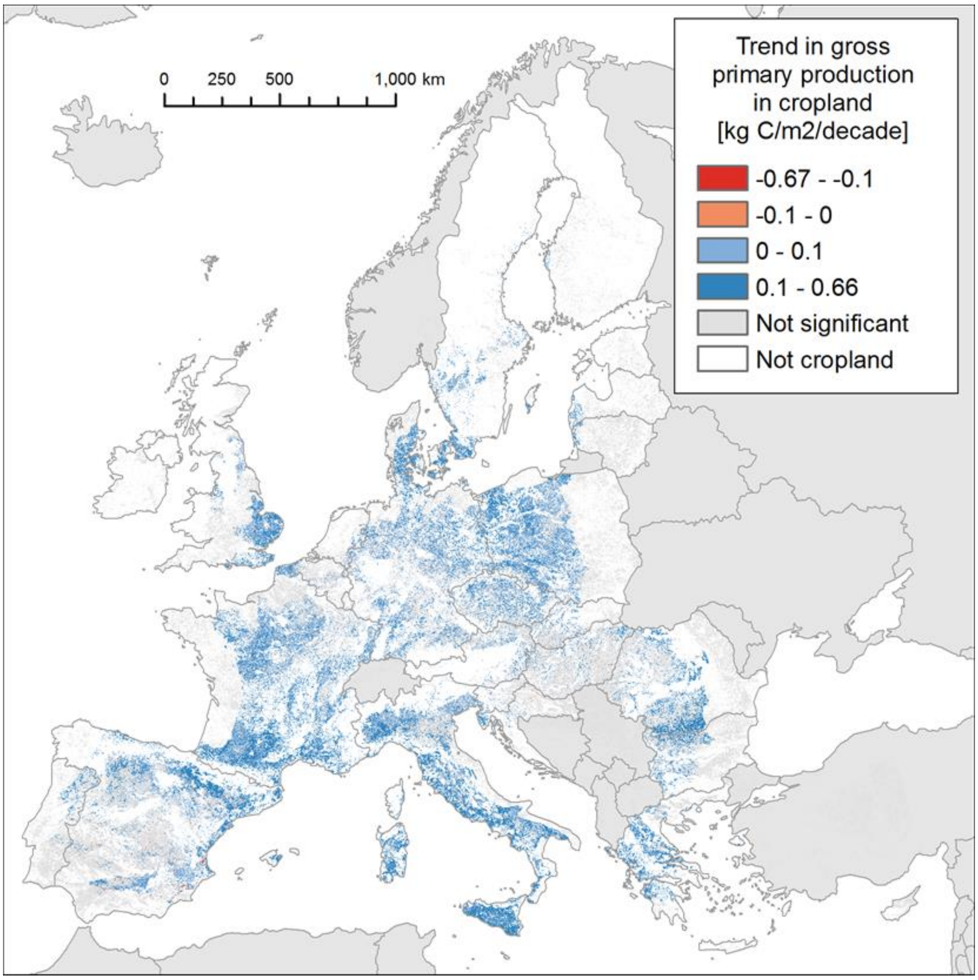

Figure 3.2.14. Trend in gross primary production in cropland (JRC, 2019)

Due to policy reasons (abolishment of the set aside requirements in 2009), fallow land in the EU has massively declined (-46% in the current decade). This trend may have negative impacts on biodiversity, as reported in Traba and Morales (2019) who found a positive correlation between the decrease of fallow land in Spain and the decline of the Little Bustard, the Cereal Bird Index, and a statistically significant correlation with the Farmland Bird Index.

The remaining indicators show no significant changes.

3.2.6 Convergence of evidence

3.2.6.1 Summary of the trends in pressure and condition

Table 3.2.6 summarizes the short and long term trends of pressures and condition indicators. The table does not include the indicators on conservation status of habitats, species and birds as they do not result in a single trend (but rather a proportion for each trend).

Trends of pressures on agroecosystems were calculated using 16 indicators with available data (one indicator, Loss of organic matter, could not be quantified). The assessment reveals that in the short-term trend, four of these 16 indicators show negative change resulting in degradation, four indicators show no change, three indicators exhibited a positive change resulting in improvement, and for five indicators data are not available or the trend is unresolved. In the long-term trend, five indicators show negative change resulting in degradation, three no change, four a positive change resulting in improvement, and four indicators remain unresolved or have no data.

Trends of agroecosystem condition were calculated using 14 indicators with available data (the trends of 5 indicators could not be quantified). In the short-term trend, two indicators show further degradation, eight show no change relative to 2010, three suggest an improvement, and one indicator remains unresolved. In the long-term trend four indicators indicate improvement, seven show no change, and three degradation.

Table 3.2.6. Summary of trends in pressure and condition of agroecosystems in the EU-28

	Indicator	**Short-term trend - Since 2010**	**Long-term trend**
Pressures	Land take	↑	↑
	Utilised agricultural area	→	↓
	Intensification / Extensification	unresolved	unresolved
	Ecosystem extent	→	→
	Annual mean temperature	↓	↓
	Effective rainfall	↓	↓
	Summer days	unresolved	↓
	Soil moisture (soil water deficit)	unresolved	→
	Growing season length	unresolved	↓
	Exceedances of critical loads for acidification	↑	↑
	Exceedances of critical loads for eutrophication	↑	↑
	Gross nitrogen balance	→	→
	Gross phosphorus balance	→	↑
	Mineral fertilizer consumption	↓	unresolved
	Phosphorus input	↓	unresolved
	Pesticide sales	→	unresolved
	Loss of organic matter	unresolved	unresolved
Condition	Nitrogen concentration in surface and groundwater	↑	↑
	Landscape mosaic	→	→
	Crop diversity	→	→
	Share of dominant crop	→	→
	Crop rotation	unresolved	unresolved
	Share of semi-natural elements (%/ha)	unresolved	unresolved
	Connectivity of semi-natural elements (index)	unresolved	unresolved
	Share of fallow land in utilised agricultural area	↓	↓
	HNV farmland area	→	→
	Share of organic farming in UAA	↑	↑
	Livestock density	→	↑
	Farmland Bird Indicator	↓	↓
	Grassland Butterfly Indicator	unresolved	↓
	Wild pollinators indicator	unresolved	unresolved
	Percentage of agroecosystems covered by Natura 2000	→	→
	Percentage of agroecosystems covered by Nationally designated areas (CDDA)	→	→
	Soil organic matter content	→	→
	Soil biodiversity	unresolved	unresolved
	Gross primary production (kJ/ha/year)	↑	↑

↑: Significant improvement (significant downward trend of pressure indicator; significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator; significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment. Indicators of conservation status of habitats, species and birds are excluded.

3.2.6.2 Mapping convergence of evidence

The indicator trends available as geospatial layers have been aggregated to provide information about areas in the EU affected by degradation or improvement. Results are shown in Figures 16, 17 and 18. The maps were created by overlaying trend maps of the following indicators:

- Effective rainfall
- Summer days
- Soil water deficit
- Drought indicators (frequency or total severity)
- Drought impact
- Growing season length
- Eutrophication
- Acidification
- Gross nitrogen balance
- Mineral fertilizer consumption
- Crop diversity
- Landscape mosaic
- Carbon stock

Indicators used to map gross nitrogen balance and mineral fertilizer consumption in this part of the assessment are based on time series maps provided by the spatial disaggregation module of the Common Agricultural Policy Regionalised Impact (CAPRI) modelling system (Leip et al., 2008) and cover the period 2000-2012, having thus limited capacity of representing the current decade compared to the reference datasets used in chapter 3.4.4.1.

According to the results, 22% of the agroecosystems area shows improvement in at least three indicators (Figure 3.2.16), most of these are concentrated in the Northern part of the EU (Figure 3.2.15). Conversely, 27% of the agroecosystems area shows degradation in at least three indicators (Figure 3.2.18), mostly concentrated in the Southern part of the EU (Figure 3.2.17). In 28% of agroecosystems area five indicators show no change (Figures 3.2.19 and 3.2.20).

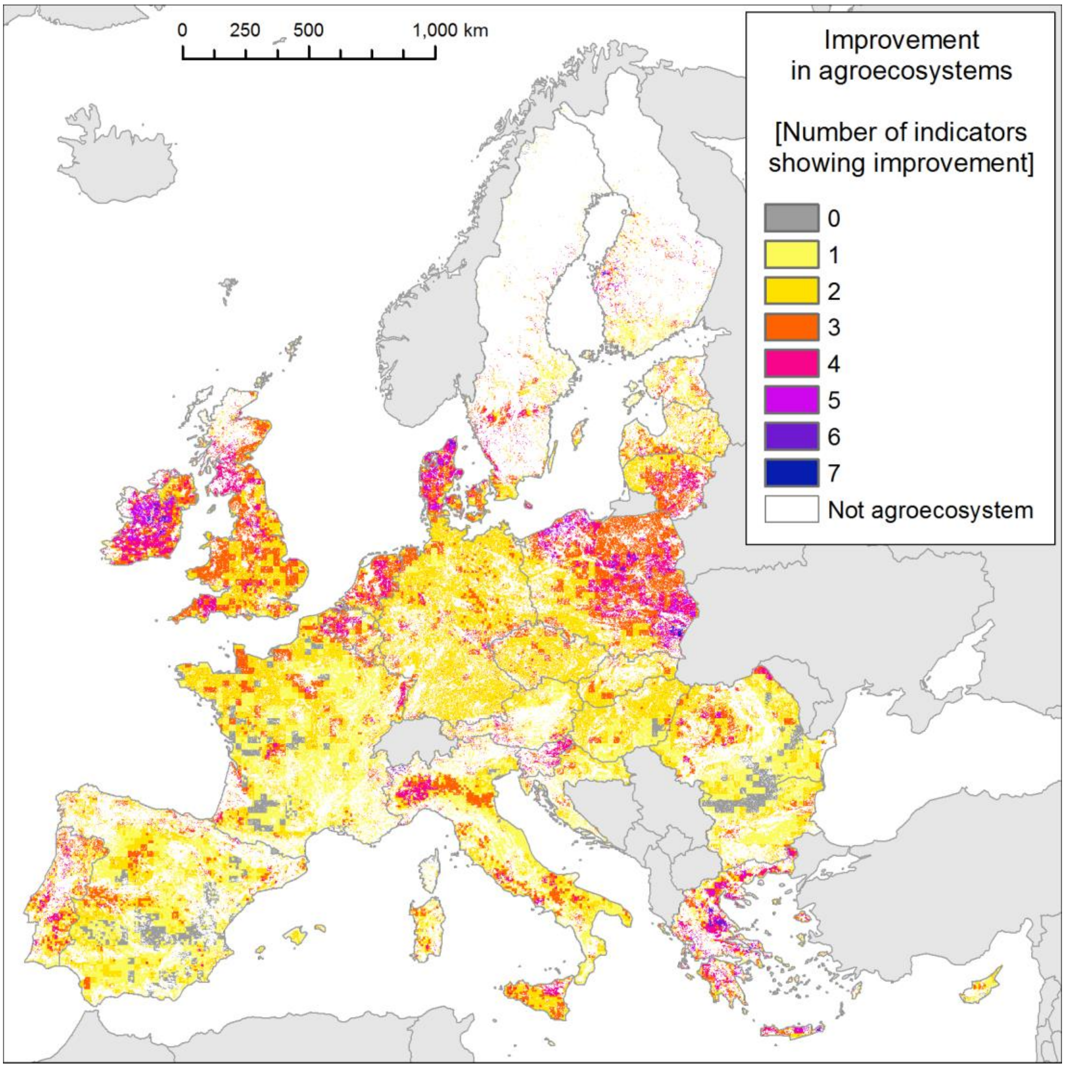

Figure 3.2.15. Number of indicators showing improvement per 1 km cell

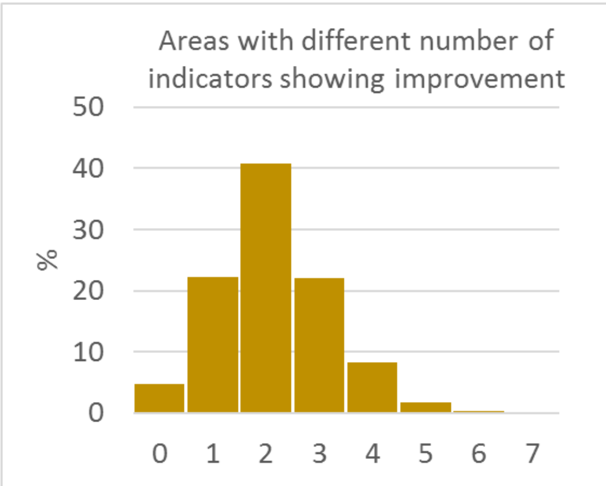

Figure 3.2.16. Agroecosystem area showing improvement, per number of indicators per share of area

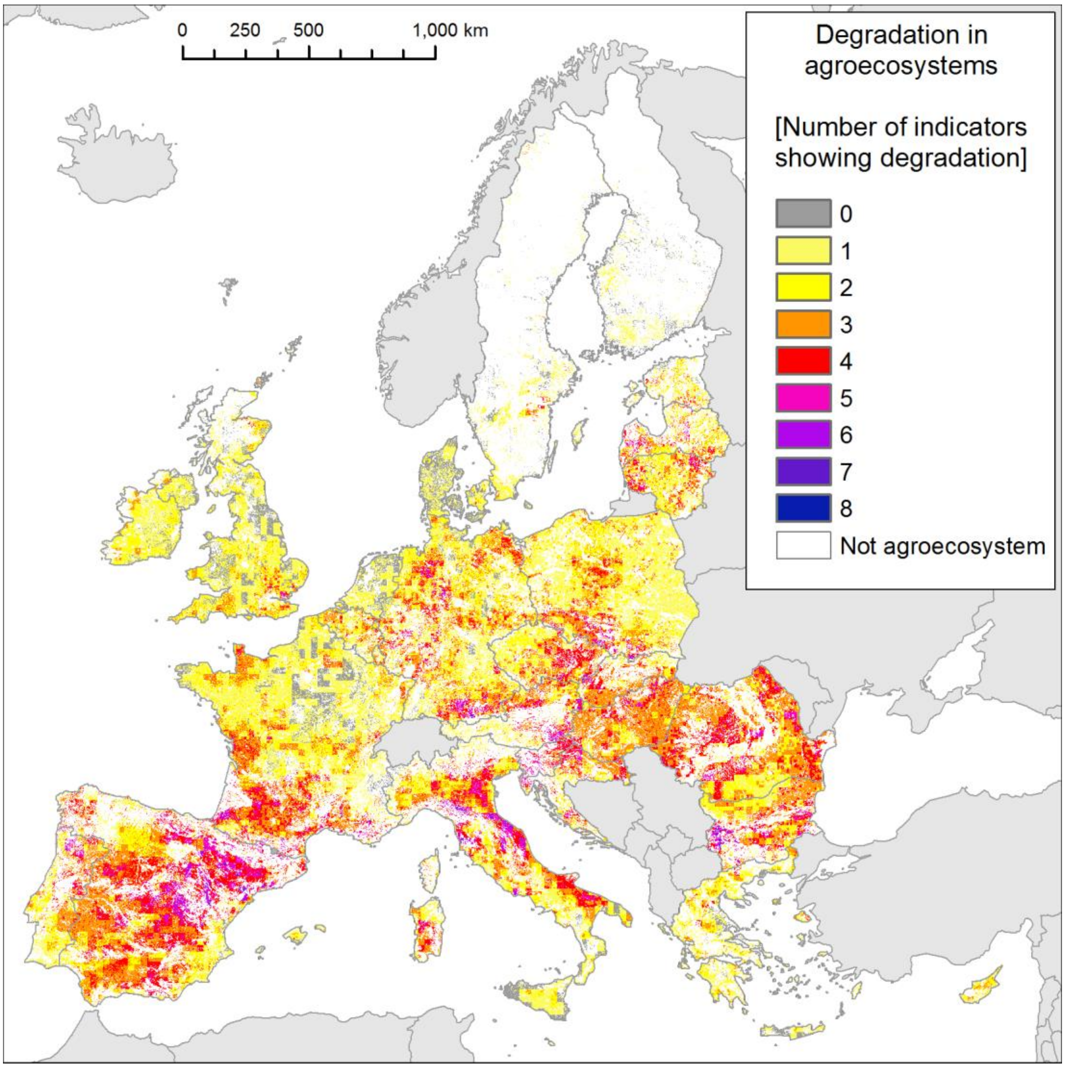

Figure 3.2.17. Number of indicators showing degradation per 1 km cell

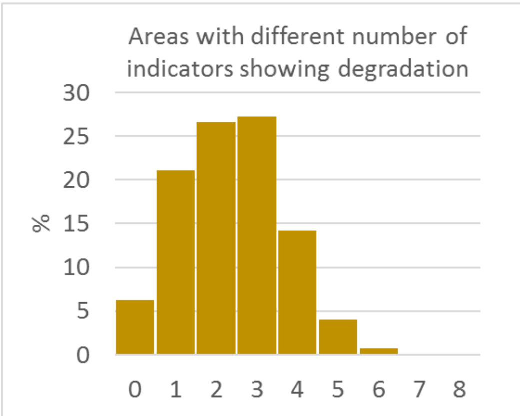

Figure 3.2.18 Agroecosystem area showing degradation, per number of indicators per share of area

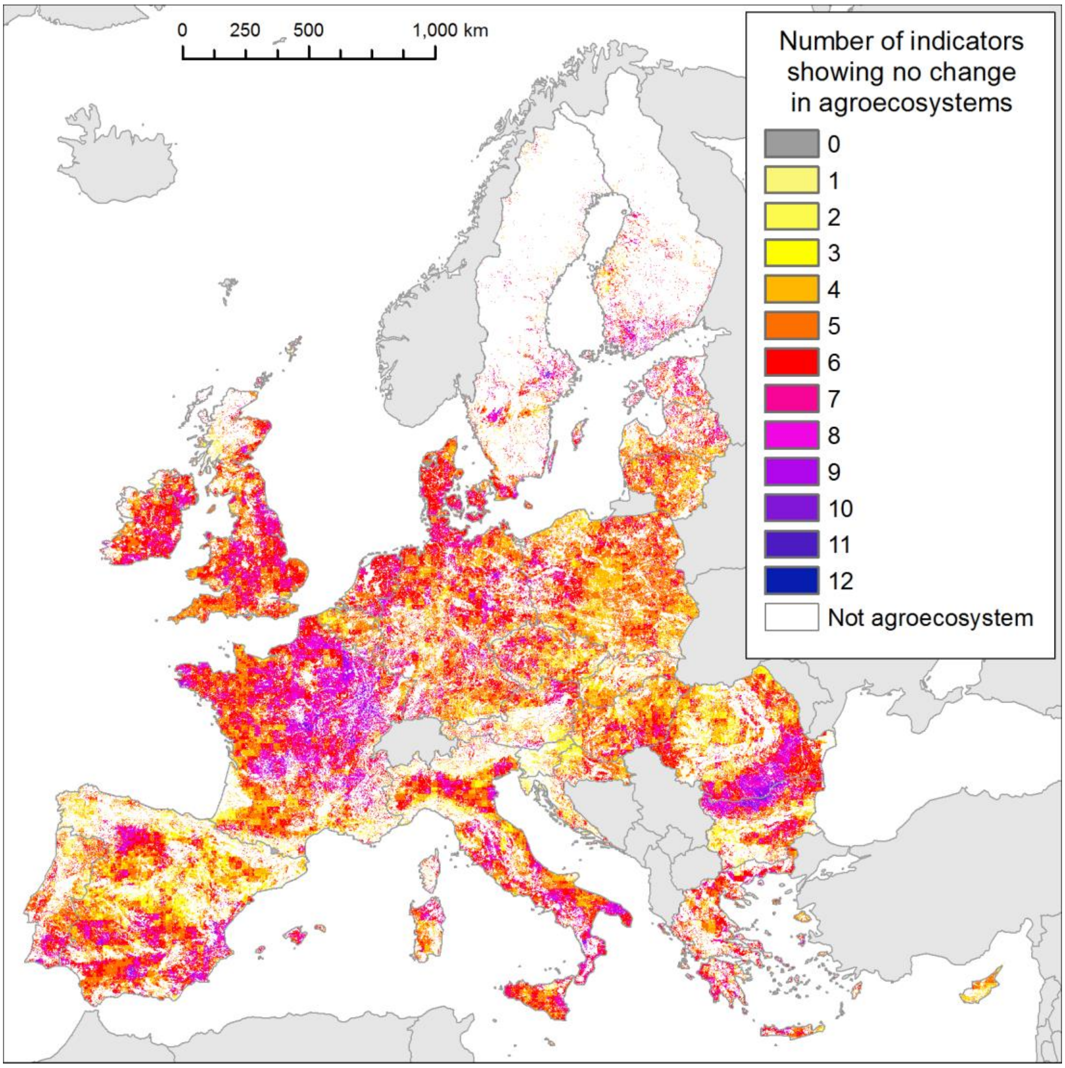

Figure 3.2.19. Number of indicators showing No change per 1 km cell

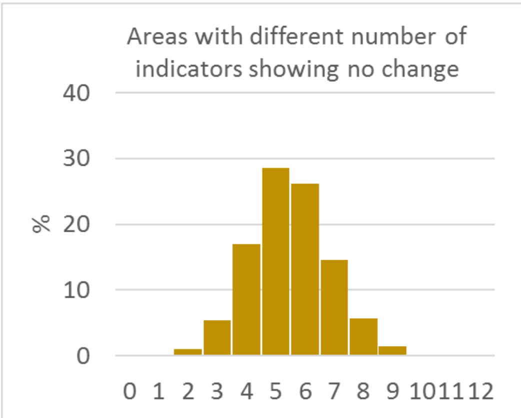

Figure 3.2.20. Agroecosystem area showing no change, per number of indicators per share of area

3.2.7 Options for policy

Nature policies and the CAP have addressed for a few decades the issue of biodiversity loss and the need to maintain the functionality of agroecosystems. Despite positive effects have been observed, especially in terms of nature protection and conservation (EC, 2016), and benefits deriving from the implementation of agrienvironmental schemes (Batari et al., 2015; Gamero et al., 2017), the analysis of indicator trends shows that what was done is not sufficient to register an overall improvement of agroecosystems condition. In fact, while pressures on agroecosystems have largely remained unchanged throughout the 2010-2020 decade, two thirds of condition indicators show either stable or declining trends.

The European Court of Auditors (ECA) in its 2020 assessment on the contribution made by the CAP to maintaining and enhancing biodiversity (ECA, 2020), found that the CAP has so far been insufficient to counteract declining biodiversity on farmland. The ECA recommendations to the European Commission are to:

1. improve coordination and design for the post-2020 EU biodiversity strategy – to this end also tracking expenditure more accurately;
2. enhance the contribution of direct payments to farmland biodiversity;
3. increase the contribution of rural development to farmland biodiversity;
4. develop reliable indicators to assess the impact of the CAP on farmland biodiversity.

Many authors (institutional, scholars, experts, researchers, analysts) have expressed their view about options for the CAP that would lead to a more sustainable management of agroecosystems. Though the proposed solutions may differ in the identification of follow-up actions, they widely recognise the primary need to support biodiversity and environmental public goods and stem from the assumption that major changes are needed in policy to reach such targets, for example: "*Member States should make use of the full range of CAP instruments and measures to support biodiversity including the co-existence of agriculture with protected species*" (Alliance Environnement, 2019); "*Transform Direct Payments into payments for public goods" (*Pe'er et al., 2020); *"The main part of CAP budgets should pay for the production of public goods*" (Agroecology Europe, 2020); "*For the next CAP reform, the Commission should develop a complete intervention logic for the EU environmental and climate-related action regarding agriculture, including specific targets and based on up-to-date scientific understanding of the phenomena concerned*" (ECA, 2017); "*Increasing the share of the CAP budget devoted to higher level environmental payments, potentially becoming the largest element*" (Buckwell et al. 2017).

Moreover, it is also clear that a cross-policy approach is needed, to identify synergies, to handle trade-offs and coordinate actions impacting land use and landscape management in order to move towards a shared, common goal.

The preparation for the post-2020 policy started with a public survey about the CAP in December 2017[17], which highlighted a strong interest of the public opinion for a higher environmental performance of the CAP; soon after, in 2018, the legislative proposal for the CAP beyond 2020[18] was published, which lists, among its nine objectives, the need to preserve landscapes and biodiversity. In 2019 the publication of the European Green Deal[19] set the reference framework for two main legislation pieces to cross-reference and mutually reinforce their action: the Farm to Fork Strategy[20] and the EU Biodiversity Strategy[21]. These two strategies identify in detail on which points policies must act to release pressures on agroecosystems, to enhance biodiversity and condition of agroecosystems: a sustainable management of nutrients, reducing pesticides use and risk, bringing back agricultural area under high-diversity landscape features, increasing the area under organic farming and the uptake of agro-ecological practices, reversing the decline of genetic diversity of plants and animals, protecting soil fertility, reducing soil erosion and increase soil organic matter. It is therefore crucial that the future CAP is aligned with the environmental ambitions established by these Strategies[22]. The architecture of the CAP post-2020 is based on a new delivery model aiming at achieving more subsidiarity and simplification. Member States will elaborate national CAP Strategic Plans that will define the specific measures and interventions in both CAP pillars, i.e. direct payments and rural development. A new system of conditionality will be in place, subjecting payment eligibility to increased environmental standards. Eco-schemes will be introduced under Pillar I, aiming at encouraging farmers to adopt more ecological approaches or specific practices, in line with the Green Deal objectives on climate change,

[17]https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance/eurobarometer_en

[18] https://ec.europa.eu/commission/publications/natural-resources-and-environment

[19] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

[20] https://ec.europa.eu/info/sites/info/files/communication-annex-farm-fork-green-deal_en.pdf

[21] https://ec.europa.eu/info/sites/info/files/communication-annex-eu-biodiversity-strategy-2030_en.pdf

[22] https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/sustainability_and_natural_resources/documents/analysis-of-links-between-cap-and-green-deal_en.pdf

management of natural resources, and biodiversity. As in the previous period, agri-climatic environmental measures in Pillar II will compensate farmers for the voluntary implementation of stricter environmental commitments. Under the new delivery model, they will also be used to support result-based payments schemes.

Compared to the past, the legislative setting offers a higher potential to put in place those transformative changes the EU Green Deal is advocating: "*To achieve these aims, it is essential to increase the value given to protecting and restoring natural ecosystems, to the sustainable use of resources and to improving human health. This is where transformational change is most needed and potentially most beneficial for the EU economy, society and natural environment*". Agroecosystems need to regain resilience and the supply of ecosystem services needs to be enhanced; moreover, by representing 47% of terrestrial ecosystems, an improvement in agroecosystem condition is essential to meet restoration goals. This is the last call before the impact of climate change requires a much higher toll. Missing the target and postponing the problem to the next round of policy drafting is not an option.

3.2.8 Knowledge gaps and future research challenges

The assessment would have benefited of indicators originally identified in the 5th MAES report, but not available for the following reasons:

- the indicator is not (yet) available (connectivity of semi-natural features; wild pollinators)
- the indicator is in an initial phase of its development (soil biodiversity)
- trends or updated trends (fitting MAES temporal requirements) of existing indicators (e.g. introduction of invasive alien species, Human Appropriation of Net Primary Production, soil erosion) are planned but not currently available
- data are available but show limitations (e.g. pesticides, for which use data are not available, and available resolution is extremely coarse)
- data or proxies are available but processing efforts exceeded the capacity of the present exercise (e.g. analysing LUCAS transect data to derive trends in landscape elements density)
- data are not sufficiently up-to-date or do not date long enough in the past to reliably indicate long-term trends.

Moreover, data used in this assessment in some cases do not consistently cover all EU countries (e.g. Grassland Butterfly Index, pesticides).

It is important to notice that for some indicators, actions are in place or in preparation to fill the knowledge gap. This is the case of soil biodiversity, being developed within the LUCAS survey[23], the pollinators indicator under development within the EU Pollinators Initiative[24]; the CAP I.20 indicator "share of UAA covered with landscape features"[25]; ecological quality of cropland and grassland habitats (under European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL)[26] and LUCAS grassland module[27]). For others, e.g. pesticides, the data gap is likely to remain for a longer time.

Monitoring biodiversity is essential to be able to assess if policy targets have been met (e.g. halting biodiversity loss). While availability of information on species and habitats is improving, indicators on genetic diversity are still missing from the overall picture, and in particular organised information, at the EU level, on the number, amount and geographical distribution of traditional breeds, cultivars, landraces, wild crop relatives, traditional and ancient varieties.

In a perspective of climate change, knowledge is needed to assess the net effects of policy action, to understand through which processes specific agricultural practices, or combination of these, can enhance the

[23] https://esdac.jrc.ec.europa.eu/projects/lucas
[24] https://ec.europa.eu/environment/nature/conservation/species/pollinators/index_en.htm
[25] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en#documents
[26] https://ec.europa.eu/environment/nature/knowledge/pdf/embal_report.pdf
[27] https://ec.europa.eu/eurostat/documents/205002/8072634/LUCAS2018-C6-Grassland-LUCAS-species-photoguidance.pdf

resilience of agroecosystems, and which are the nature based solutions fostering ecosystem services, including the provisioning ones.

3.2.9 Conclusions

In conclusion, to understand the scale of the results presented in this report, a detailed trend description is following, which includes baseline information and pressures trends.

Improving trends:

- exceedances of critical loads have been reducing in the EU, though acidity exceedances occur in 6.6% in the EU-28 (2016 data), critical loads for eutrophication are exceeded in about 73% of the EU-28 area. In summary, despite the trends show an improvement, "*a lot remains to be done in terms of emission reductions to achieve non-exceedance of critical loads everywhere*" (Fagerli et al., 2018).
- nitrogen concentration in groundwater has decreased, but as mentioned in 3.4.5.1 it is acknowledged that nutrients overload from agriculture continues to be one of the biggest pressures on the aquatic environment;
- gross phosphorus balance steadily decreased;
- share of organic farming steadily increased; nevertheless organic farming covers less than 8% of the UAA;
- livestock density decreased by 6.5% and corresponds to 0.75 LU/ha (2016 data);
- gross primary production notably increased in the short term by around 12% per decade

No Change trends:

- gross nitrogen balance remained stable around 50 kg/ha UAA/year;
- pesticide use remained unchanged, with a reduction in the risk to human health and the environment. Quantities used amount to 380 000 tons/year
- farmland structural parameters, landscape mosaic and crop distribution remained within the no-change limits defined in the present assessment
- the share of agroecosystems under protection by EU and national legislation did not increase, though it has to be noted that the share is not negligible: 6.5% of croplands and 13% of grasslands are included in nationally designated areas.
- Soil organic matter is a parameter that has a much slower dynamics than the assessed period and shows a no change signal.

Declining trends (degradation):

- concerning climate trends, the assessed data show changes that affect, to different degrees, large extents of the EU area. For agroecosystems this means increasing length of the growing season, northern shift of agro-climatic zones, changes in community composition, shift in animal and plant species ranges;
- biodiversity trends show a decline, though not as pronounced as for the long-term trend. The farmland bird index has declined by 7.4% in this decade (17.8% in Western Europe). In all four European regions for which the farmland bird index is available, the decline appears to be more moderate in recent years, hinting to a slowing of the declining trend. The same happens for the grassland butterfly index. The reasons for this and especially the role played by different factors are not fully disentangled (e.g. policy action, shifts in community composition, decline of vulnerable species etc.).
- regarding biodiversity it is worth mentioning, that 46% of cropland and 66% of grasslands are impacted by invasive alien species of Union Concern[28]. The situation is expected to become more critical, since there is increasing evidence that climate change is projected to intensify processes underlying biological invasion (Capdevila-Argüelles and Zilletti, 2008);

[28] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014R1143&from=EN

- lastly, the EU level assessment of the conservation status of 32 grassland habitats concluded that 14.3% are in good (or favourable) conservation status. The remaining habitats are in poor status (32.5%), a bad status (49.2%) or unknown (4.0%). Furthermore, almost 51% of the grassland habitats that is in an unfavourable status is showing deteriorating trends

The assessment presented in this report is based on trends calculated on the basis of available data, and therefore may overlook factors that would describe in a more complete way the dynamics of agroecosystem condition. Nevertheless, many relevant variables are taken into account and the main conclusion is that the degradation trend of agroecosystems was not halted in the 2010-2020 decade. Such trend departs from a condition of agroecosystems that had already been suffering long-term degradation and important biodiversity losses, while pressure levels are to a large degree unchanged or increasing. These are the same pressures that contributed in the past decades to biodiversity loss, which is still ongoing, as clearly shown by available biodiversity indicators. Therefore, when increasing pressures from a changing climate are added to the picture, there is no evidence that reversal of biodiversity trends and improvement of ecosystem condition will take place, if appropriate actions are not taken.

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3.3 Forest ecosystems

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Summary: This chapter assesses trends in indicators of forest pressures and condition in the EU-28. The assessment describes quantitatively the current condition of forests, key drivers of degradation and options for improvement. Forests are the largest terrestrial ecosystem in the EU-28 covering around 38% of the land area, hosting a dominant part of Europe's terrestrial biodiversity, and contributing significantly to climate change mitigation. Nevertheless, after millennia of forest use, currently only around 2% to 4% of EU-28 forests are primary forests. Nowadays, most EU-28 forests are semi-natural (89%) and the remaining share is covered by plantations. In the years after the Second World War, and up to now, the forest area has increased in Europe. The area of forests has increased by 13 million hectares in the period 1990-2015 in the EU-28 due to both natural processes and to active afforestation. This does not necessarily mean that the condition of forests in Europe is good. Forest ecosystems have been subject to change due to human activities and other natural dynamics. In general, the condition of EU forests is poor[29], and there are serious concerns regarding upward trends of several pressures and degrading condition indicators. Changes in climate and tree cover loss (due to wildfire, storms, harvesting) have been increasing notably over the recent years. Likewise, pollutants remain a concern even if the trends point in the right direction.

The effects of upward trends in pressures are evident in forest condition. For example, one out of four trees shows defoliation levels indicating damage, due predominantly to unidentified drivers, followed by insects and abiotic factors, mostly drought. Additionally, the trend in defoliation over the period 1998-2017 is upward revealing further degradation of forest ecosystems. Likewise, other parameters such as evapotranspiration suggest functional changes in ecosystems. However, there are also some positive signals. Some structural indicators of condition have shown improvement in the long and short term, for example forest area[30], biomass volume and deadwood. Likewise, ecosystems productivity is increasing. Regarding biodiversity indicators, the abundance of common forest birds did not show significant changes in the long-term period, though a 3% decrease was reported since 1990. Nevertheless, the situation seems to be improving in the last few years.

The EU level assessment of the conservation status of 81 forest habitats concluded that 14.2% are in good (or favourable) conservation status. The remaining habitats are in poor status (53.9%), a bad status (30.6%) or unknown (1.3%).

Similarly, the findings of this assessment suggest that 47% of EU-28 forest land is exposed to at least three drivers of degradation (indicators), and 20% to at least four, in contrast only 20% of forest land is exposed to one or no degradation drivers.

An important number to consider is the ratio between forest available for wood supply (FAWS) and forests protected for biodiversity in the EU-28: 1:6 (own calculation with data from FOREST EUROPE (2015b)). In other words, for each square kilometre of forests protected for biodiversity there are six square kilometres of potentially productive forest land. The low share of protected forests depicts well the patchy character of biodiversity valuable forests in the EU.

The analysis of EU forests in the perspective of the identified pressures such as the effects of pollutants, projected impacts of climate change, and the foreseen increased demand of forest resources (e.g. for renewable energy or other sectors), call for a coordinated response at EU level. The response should aim at more ambitious, clear and measurable goals and targets at EU scale to enhance biodiversity and the provision of forest public goods in support of more sustainable forests, along with an appropriate monitoring framework.

[29] Ecosystem condition: The physical, chemical and biological condition or quality of an ecosystem at a particular point in time.
[30] Includes areas with young trees and areas that are temporarily unstocked due to cuttings as part of a forest management practice or natural disasters.

3.3.1 Introduction and description of forest ecosystems

Forests are the largest terrestrial ecosystem in the EU-28 covering around 161[31] million ha (FOREST EUROPE 2015b), corresponding to 38% of the EU-28's land area, hosting a dominant part of Europe's terrestrial biodiversity, and contributing significantly to climate change mitigation. Due to both natural processes and to active afforestation, the area of forests has increased by 13 million hectares in the period 1990-2015 in the EU-28. Nevertheless, in Europe humans have modified forests since the mid-Holocene by clearing for cropland and pasture, and have used them as a source of fuelwood and construction materials (Kaplan et al. 2009). After a long history of forest management, currently only around 2%—4% are primary forests in the EU-28 (FOREST EUROPE 2015b; Sabatini et al. 2018). Nowadays, the major part of EU-28's forests is semi-natural[32] (89%) and the remaining share is covered by plantations (FOREST EUROPE 2015b).

According to FOREST EUROPE (2015b), most EU-28 forests, 84%, are available for wood supply (FAWS), i.e. potential sources of wood. FOREST EUROPE (2015a: 10) defines FAWS as "forests where any environmental, social or economic restrictions do not have a significant impact on the current or potential supply of wood. These restrictions can be established by legal rules, managerial/owner's decisions or because of other reasons". In contrast, only around 14% of EU-28 forests are protected for biodiversity and nature conservation[33] (FOREST EUROPE 2015b).

In the last available reporting period of the Habitat Directive, 2013-2018, the EU-28 Member States (MS) indicated that only 30% of forest habitats of EU interest[34] is in favourable conservation status, and only 13% shows an improving trend. Additionally, the International Union for Conservation of Nature (IUCN) estimated that 160 out of 431 (37%) native tree species are threatened with extinction, and 57 (13%) are data deficient in the EU-28. Regarding endemic tree species, 147 out or 252 (58%) are threatened, of which 25% are critically endangered, and 34 (13%) are data deficient. Note that of the 147 endemic threatened species, 122 (83%) are part of the *Sorbus* genus (Rivers et al. 2019). Finally, in line with these findings, the last report from the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) (Michel A 2018) indicates that one out of four (25.1%) of all assessed trees showed defoliation levels suggesting damaged trees. Furthermore, all the 10 groups of the most abundant tree species exhibited upward trends of defoliation between 1998 and 2017, of which seven groups showed statistically significant trends.

In line with the overall objective of this report, the aim of this chapter is to determine and report the trends in the pressures and condition of forests relative to the baseline year 2010. This chapter can thus be used to evaluate the targets of the EU Biodiversity Strategy to 2020. It is important to stress that this assessment is primarily based on indicators for which European wide, harmonized datasets have been collected. Where needed more context is provided by citing to relevant literature. However, this chapter did not make a systematic review of the literature on pressures on biodiversity and ecosystems.

This chapter delivers the baseline data to establish a (legally binding) methodology for mapping and assessment of ecosystems and their capacity to deliver services and to determine the minimum criteria for good ecosystem condition of forests as required by the new EU Biodiversity Strategy to 2030. Determining these criteria of forest ecosystems requires also agreeing on a reference condition against which the past or present condition can be evaluated. More work will be needed to determine the target and reference levels of pressure and condition indicators in agreement with stakeholders, scientists and policymakers.

EU forest policy

"Preserving, protecting and improving the quality of the environment" and the "prudent and rational utilisation of natural resources", which include forests, fall under the EU environmental policy (Treaty on the functioning of the EU, article 191). The European Court of Justice confirmed this in 1999. Several pieces of EU legislation affect forests and forest management directly or indirectly[35]. Moreover, there is a variety of forest-related

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[31] 182 million ha of forest and other wooded land (OWL).

[32] Semi-natural forests: Forests which are neither forest undisturbed by man nor plantations (FOREST EUROPE 2015a).

[33] Equivalent to above 23 million hectares in the EU-28 (not including data for Austria and Romania).

[34] Forest habitats of EU interest are forest habitats listed in Annex I of the Habitats Directive. According to MAES figures, forest habitats of EU interest cover around 28% of the EU's forest area.

[35] e.g. Environmental Impact Assessment Directive:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0052
Strategic Environmental Assessment (SEA) Directive:

policies that contribute to the sustainable management of forest ecosystems in synergy with the Biodiversity Strategy to 2020 (European Commission 2011)[36]. The aims of the Strategy include the commitments taken by the EU to meet the Aichi targets of the Convention of Biodiversity[37].

The Biodiversity Strategy recognises the key role of forests in biodiversity protection and of the dependency of human well-being on natural capital from forest ecosystems (Guerry et al., 2015). The Strategy aims to halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020. It also aims to restore them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss. The Biodiversity Strategy requests that MSs achieve a significant and measurable improvement in the conservation status of forest species and habitats, among other targets, by fully implementing EU nature legislation[38] and ensuring that Forest Management Plans[39] contribute to the adequate management of the Natura 2000 network. The new Biodiversity Strategy to 2030[40] aims to increase the quantity of forests and improve their health and resilience. It calls for protecting all remaining EU primary and old-growth forests, propose a new forest strategy in 2021 and sets an objective of planting at least 3 billion additional trees in the EU by 2030,

The EU Forest Strategy 2014-2020 (European Commission 2013)[41] looks at promoting multifunctional and sustainable forest management, with the aim of safeguarding forest functions with a balanced and efficient use of forest ecosystem services. In addition, it also looks at ensuring that forest management contributes to the achievement of the objectives assigned to the Natura 2000 network. The mid-term report on the progress in the implementation of the EU Forest Strategy[42] refers, however, to the fact that “despite the action taken so far, the implementation of the EU biodiversity policy remains a major challenge”. It further states that “further efforts are needed to enhance the role of Forest Management Plans in achieving biodiversity targets and support the provision of ecosystem services”.

Other EU policies with direct effects in forest ecosystems are for instance the Birds[43] and Habitats[44] Directives. These are the pillars of EU’s nature legislation, furthermore they define the provisions of the Natura 2000 network[45]. Other examples are the Timber Regulation[46], the Invasive Alien Species Regulation[47] and the LULUCF regulation[48]. The provisions of the mentioned policies are also relevant for the Common Agricultural Policy (CAP) and rural development policies regarding forest[49]. Forests should also play an important role in the achievements of the EU’s 2030 climate and energy framework[50], because of their contribution to climate change mitigation efforts and their role as a source of renewable bioenergy. Certainly, multiple policy drivers on forests create challenges for compliance based on sectoral aims. One example is

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https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32001L0042
Access to Environmental Information Directive:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32003L0004
Habitats Directive:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31992L0043
Birds Directive:
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0147
Timber Regulation:
https://ec.europa.eu/environment/forests/timber_regulation.htm

[36] https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm

[37] https://www.cbd.int/sp/targets/

[38] https://ec.europa.eu/environment/nature/legislation/index_en.htm

[39] https://ec.europa.eu/environment/forests/information.htm

[40] https://ec.europa.eu/info/files/communication-eu-biodiversity-strategy-2030-bringing-nature-back-our-lives_en

[41] https://ec.europa.eu/info/food-farming-fisheries/forestry/forestry-explained#theeuforeststrategy

[42] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0811

[43] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0147

[44] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31992L0043&from=EN

[45] https://ec.europa.eu/environment/nature/index_en.htm

[46] https://ec.europa.eu/environment/forests/timber_regulation.htm

[47] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1417443504720&uri=CELEX:32014R1143

[48] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018R0841&from=EN

[49] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en

[50] https://ec.europa.eu/clima/policies/strategies/2030_en

the potential conflicts due to trade-offs between biodiversity conservation and biomass extraction for energy (EEA 2016).

3.3.2 Ecosystem extent and change

Information on changes in the cover of forest ecosystems is an essential element for assessing the sustainability of land management. The focus of this section is on forest dynamics resulting from land cover changes. This is a key piece of information for a better understanding of the overall state of forests, their resources and ecosystem services. The assessment presented in this section is based entirely on data from Corine Land Cover (CLC) (EEA, 2000). In accordance with the First MAES report (2013), the used definition of forest corresponds to the three CLC forest categories and the "transitional woodland shrub" category (EEA 2000), i.e. the sum of the broadleaves (CLC 311), conifers (CLC 312), mixed forest (CLC 313), and the transitional woodland and shrub (CLC 324) classes. We acknowledge that CLC provides forest area accounts not necessarily in fully agreement with national forest definitions[51]. Therefore, some discrepancies are possible.

Within the scope of the assessment in this section, the dynamics of forests have two components. First, forest cover loss, the conversion from forest land cover classes to other land cover classes. Forest loss includes losses caused by both temporary changes due to human interventions, e.g. forest operations, and natural disturbances such as fires, storms, pests and diseases, and permanent changes due to e.g. deforestation. The second component is forest gain that includes the conversion from non-forest cover classes to forest cover classes. The gain of forest land includes regeneration after forest operations, natural expansion and afforestation. The last, according to most forest laws in the EU-28, means a permanent change to forest land.

The forest ecosystem extent and change, loss and gain, were calculated for the periods 2000-2006, 2006-2012, 2012-2018, and 2000-2018 for the EU-28 based on the CLC accounting layers[52] available for the years 2000, 2006, 2012 and 2018. Net changes are accounted for as the difference between forest cover loss and forest cover gain. The net change is considered a proxy of forest cover dynamics as it describes the balance resulting from gain and loss. Transitions between the four CLC categories representing forests are not considered as changes in the present assessment.

According to CLC data, forest are one of the main ecosystems in the EU-28 covering around 1.6 million km^2 of the land surface. The extent of forest varies substantially across the EU-28 territory with large differences in the percentage of forest cover found in different countries.

The changes and trends in forest ecosystems cover are calculated as the cumulated change across the EU-28. Table 3.3.1 and Figure 3.3.1 show the aggregated values. The relative changes in the extent of forest cover over the period from 2000 to 2018 are negligible, meaning that the total extent of forest land cover did not show significant changes in that period. The net change represents the balance of changes, both gains and losses, caused by human interventions and natural disturbances. Therefore, gains counterbalance losses in the net change.

Forests experienced turnovers in ecosystem extent in all three periods. Turnover is the sum of forest cover area loss and forest cover area gain. Turnovers of 5.5%, 8.2% and 6% with respect to the initial forest extent of each period were found in the 2000-2006, 2006-2012 and 2012-2018, respectively. These turnovers reflects forest cover dynamics in the EU-28 resulting from e.g. forest management cycles, fellings, regeneration, as well as disturbances due to e.g. storms and fires. The total turnover for the period 2000 to 2018 is equivalent to 18% of the extent of forest ecosystems.

CLC is a valuable tool for land cover accounting providing data systemically from 1990 to 2018, nevertheless some discrepancies emerged regarding the forest area provided by National Forest Inventories (NFIs) of EU MSs. The total area of forests in 2018 as provided by the CLC is in line with the area provided by NFI in 2015. However, data form NFIs (fact sheet 3.3.203 of forest area) indicate a pronounced increase of forest area between 1990 and 2015, and between 2000 and 2015 that is not captured in CLC. In fact, according to the NFIs the forest area expanded by nearly 130,000 km^2 over the period 1990-2015 in the EU-28, an area

[51] Corine Land Cover (CLC) data represents forest land cover. Land cover is the observed biophysical cover on the earth's surface and should not be confused with the term land use. Land use shows how people use the landscape, i.e. for development, agriculture, conservation, forestry, etc. Therefore, cleared forest resulting from forestry are not represented as forest in land cover data, while these zones are considered forest area in the statistics of National Forest Inventories as long as their use remains forestry.

[52] https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers

equivalent to the size of Greece, from 1.48 to 1.61 million km^2. In the period 2000-2015, comparable to the period 2000-2018 of the CLC data, the net increase was 62,000 km^2, in contrast with the 572 km^2 reported by CLC data (Table 3.3.1). One reason explaining this discrepancy would be that CLC accounts for forest land cover, while NFIs represent forest area including areas with young trees and cleared areas resulting from e.g. forest management or natural disasters. In consequence, cleared forestry areas that do not correspond to the forest categories of CLC and are therefore not mapped as forests in CLC, are in contrast included as forest area in NFIs statistics. Nevertheless, to investigate the reasons of the discrepancy is beyond the scope of the present report. The NFIs is the recommended data for forest area assessment and targets within the scope of this report.

Table 3.3.1. Tier 1 ecosystem extent account of forests for the periods 2000-2006, 2006-2012, 2012-2018, and 2000-2018 in the EU-28 based on Corine Land Cover accounting. Source: EEA[53].

Area (km^2 unless otherwise indicated)	2000-2006	2006-2012	2012-2018	2000-2018
Ecosystem extent (first year of the period)	1,596,961	1,597,954	1,598,768	1,596,961
Forest loss	43,496	65,007	48,718	142,374
Forest gain	44,489	65,822	47,483	142,946
Net change (gain-loss)	993	815	-1,235	572
Net changes as percentage of initial extent (%)	0.06	0.05	-0.08	0.04
Total turnover of ecosystems extent (loss + gain)	87,985	130,829	96,201	285,348
Total turnover as percentage of initial extent (%)	5.5	8.2	6.0	17.9
Stable ecosystem stock	1,553,465	1,532,946	1,550,050	1,454,587
Stable ecosystem stock as percentage of initial stock (%)	97.3	95.9	97.0	91.1
Ecosystem extent (second year of the period)	1,597,954	1,598,768	1,597,533	1,597,533

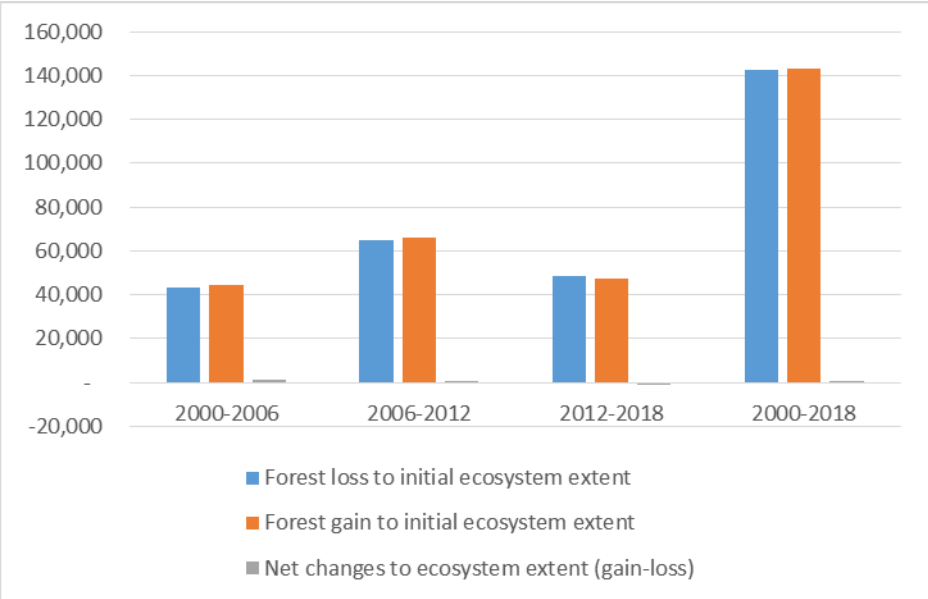


Figure 3.3.1. Trends of forest cover change 2000–2018 in the EU-28. Data source: Corine Land Cover accounting layers (EEA).

[53] https://www.eea.europa.eu/data-and-maps/indicators/ecosystem-coverage-3/assessment

3.3.3 Data

Forest pressures and condition indicators were identified in the 5th MAES report (MAES, 2018). In this assessment we collected an array of available data and indicators summarised in Table 3.3.2 for pressures and in Table 3.3.3 for condition. The tables show the fact sheet number of each indicator, where detailed information can be accessed regarding the characteristics of the input data and the indicator. In addition, the tables show information on the unit of measure, the data period and the spatial resolution of the input data used for creating the indicators.

3.3.4 Drivers and pressures: spatial heterogeneity and change over time

This section shows the results of the assessment of pressures on forest ecosystems. The first part describes the results at EU-28 level. The second part is an in depth assessment showing examples of selected pressure indicators. Indicators are reported in fact sheets describing the underlying data and scope of the indicator, maps of trends, and the values aggregated at EU-28 level. The fact sheets are available as a supplement to this report.

3.3.4.1 Assessment at the level of EU-28

Forests have evolved historically while experiencing pressures (disturbances) such as fire, drought, storms, insect and disease outbreaks, human-driven pressures. Therefore, forests are considered resilient systems able to recover from catastrophic events as long as these occur within natural historic boundaries (Innes and Tikina 2017). In this section, we report a general overview of the indicators of forest pressures summarised at the level of either the EU-28 forest land, or the total EU-28 land in the case of cross-cutting indicators. It is worth noting that an indicator showing a significant trend at EU-28 level should exhibit a rather consistent change across large parts, or most, of the EU-28 area. This is because the trend at EU-28 level was calculated using the mean of the corresponding grid cells on each year (see methodology in chapter 2).

Table 3.3.4 shows the results of the assessment of 20 pressure indicators, including five indicators for which data was not available. In the short term six indicators show negative change resulting in degradation, two no change, five a positive change resulting in improvement, and eight indicators are not available. Among other parameters, the table includes a confidence score for each indicator in both the long term and the short term. In the long term, five indicators show negative change resulting in degradation, five no change, five a positive change resulting in improvement, and five indicators are not available.

Both in the short term and in the long term, the largest number of indicators suggesting degradation falls within the category of climate change indicators. In this category, five and four out of seven indicators in the short and long term, respectively, indicate a path towards degradation. In contrast, in the pollution category, all three indicators suggest a change towards improvement. Finally, tree cover loss has been increasing notably in both the long term and short term suggesting the possibility of a degradation path. In this indicator the loss may be for any reason e.g. wildfires, storms, harvesting, land use change.

Whereas the short-term trend information responds to a policy requirement, the findings derived from the short-term trend should be considered with caution because of the small number of years, usually 10, used for its calculation. Many indicators exhibit large variability over time, e.g. climatic indicators, therefore longer series of more than 30-year would be required for obtaining robust results (WMO 2017). The assessment using the long-term trend responds to this requirement.

Table 3.3.2. Forest pressures indicators, units, time-series and spatial resolution of the input data used for creating the indicator. All fact sheets are available as a supplement to this report.

Pressure class	Indicator (fact sheet number)	Unit	Data period	Spatial resolution of input data[1]
Habitat conversion and degradation (land conversion)	Forest cover change (net change) (3.3.101)	ha/km^2	2000, 2006, 2012, 2018	100 m grid size
	Tree cover loss (3.3.102)	ha/y	2001-2018	30 m grid size
	Forest fragmentation (3.3.103)	% (AV-FAD)	2000, 2006, 2012, 2018	100 m grid size
	Forest land take (3.3.104)	ha/y	2000, 2006, 2012, 2018	100 m grid size
Climate change	Fires – burnt area (3.3.105)	ha/y	1980-2017 2000-2017	Country 250 m grid size
	Number of fires (3.3.105)	Fires/y	1980-2017	Country
	Effective rainfall (annual) (3.3.111)	mm	1960–2016	0.5 degree grid size (~50 km)
	Mean annual temperature (4.1.101)	°C	1960-2018	0.1 degree grid size (~10 km)
	Extreme drought events (4.1.101)	5-year acc. Events	1950-2018	0.25 degree grid size (~25 km)
	Soil moisture (soil water deficit) (4.1.101)	%	1985-2018	5 km grid size
	Drought and heat induced tree mortality (3.3.106)	NA	NA	NA
	Storms (N.A.)	NA	NA	NA
	Effect of drought on forest productivity* (3.3.107)	Index	2000-2016	500 m grid size
Pollution and nutrient enrichment	Tropospheric ozone (AOT40) (3.3.108)	ppb.hours	2000-2017	7 km x 9 km grid size
	Exceedances of critical loads for acidification (3.3.109)	eq/ha y	2000, 2005, 2010, 2016	0.1 degree grid size (~10 km)
	Exceedances of critical loads for eutrophication (3.3.109)	eq/ha y	2000, 2005, 2010, 2016	0.1 degree grid size (~10 km)
Over-harvesting	Ratio of annual fellings to annual increment (3.3.110)	%	1990, 2000, 2005, 2010	Country
Introductions of invasive alien species	Pressure by invasive alien species (4.2.101)	% of affected area	Many years centred in 2010	10 km grid size
Other pressures	Forest pests, parasites, insect infestations	NA	NA	NA
	Soil erosion	NA	NA	NA

NA: Data are not available or data are available but still need to be adapted to the ecosystem typology used in this assessment.
* In drought impacted areas only.
[1] Note that indicators created using input data of less than one kilometre were up-scaled to at least one kilometre grid size, see fact sheets for further details.

Table 3.3.3. Forest condition indicator, units, time-series and spatial resolution of the input data used for creating the indicator. All fact sheets are available as a supplement to this report.

Condition class	Indicator (fact sheet number)	Unit	Data period	Spatial resolution of input data[1]
Environmental quality (physical and chemical quality)	See pressures in Table 3.3.2			
Structural ecosystem attributes (general)	Dead wood (3.3.201)	Tonnes/ha	1990, 2000, 2005, 2010, 2015	Country
	Landscape mosaic (index) (4.3.201)	%	2000, 2006, 2012, 2018	100 m grid size
	Biomass volume (growing stock) (3.3.202)	m^3/ha	1990, 2000, 2005, 2010, 2015	Country
	Forest area (3.3.203)	Million ha	1990, 2000, 2005, 2010, 2015	Country
	Defoliation (3.3.204)	Mean % defoliation	1998—2017	Plot level (5496 plots)
Structural ecosystem attributes based on species diversity and abundance	Abundance of common forest birds (3.3.205)	Index (1990=100)	1990-2016	EU, four EU regions
Structural ecosystem attributes monitored under the EU Nature directives and national legislation	Forests covered by Natura 2000 (3.3.206)	%	2000, 2006, 2012, 2018	100 m grid size
	Forest covered by Nationally Designated Areas (3.3.207)	%	2000, 2006, 2012, 2018	100 m grid size
	Share of forest habitats listed under Annex 1 of the Habitats Directive in favourable conservation status (3.5.203)	%	2013 - 2018	EU-28
	Trends of unfavourable conservation status of forest habitats listed under Annex 1 of the Habitats Directive (3.5.203)	%	2013 - 2018	EU-28
Structural soil attributes	Soil organic carbon in forests	%	NA	NA
Functional ecosystem attributes (general)	Dry matter productivity (3.3.208)	kg/ha y	1999-2018	1 km grid size
	Evapotranspiration (3.3.209)	mm/y	1980-2017	0.25 degree grid size (~25 km)
	Land Productivity Dynamics (NDVI) (3.3.210)	Index	1999-2013	1 km grid size
Functional soil attributes	Nutrient availability	NA	NA	NA

NA: Data are not available or data are available but still need to be adapted to the ecosystem typology used in this assessment.
[1] Note that indicators created using input data of less than one kilometre were up-scaled to at least one kilometre grid size, see fact sheets for further details.

Table 3.3.4. EU-28 aggregated forest pressures indicators.

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation (land conversion)	Forest cover change (net change)	ha/km^2	< 1	~0	→	7	~0	→	8
	Tree cover loss	ha/y	746,000	73.5	↓	7	26.1	↓	5
	Forest fragmentation (average forest area density)	%	72	0.1	→	7	-0.2	→	8
	Forest land take	ha/y	12,738	-37	↑	7	-31	↑	8
Climate change	Fires – burnt area	ha/y	331,000	46.2	↓	6	-19.5	↑	8
	Number of fires	Fires/y	51,000	-24.7	↑	6	5.3	↓	8
	Effective rainfall (annual)	mm	-32	-56.6	↓	6	-38	↓	8
	Mean annual temperature	°C	9.5	12.7	↓	7	3.42	↓	9
	Extreme drought events	5-year acc. Events	0.2	67.5	↓	7	8.98	↓	9
	Soil moisture (soil water deficit)	%	13.5		unresolved		-0.35	→	6
	Drought and heat induced tree mortality				unresolved			unresolved	
	Storms				unresolved			unresolved	
	Effect of drought on forest productivity*	Index	94.0	9.1	↓	5	0.54	→	6
Pollution and nutrient enrichment	Tropospheric ozone (AOT40)	ppb.hours	19,265	-31	↑	6	-28	↑	7
	Exceedances of critical loads for acidification	eq/ha y	47.6	-68	↑	5	-93	↑	5
	Exceedances of critical loads for eutrophication	eq/ha y	251.8	-31	↑	5	-34	↑	5
Over-harvesting	Ratio of annual fellings to annual increment	%	65		unresolved		2.1	→	5

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Introductions of invasive alien species	Pressure by invasive alien species	% of affected area	44		unresolved			unresolved	
Other pressures	Forest pests, parasites, insect infestations				unresolved			unresolved	
	Soil erosion				unresolved			unresolved	

↑: Significant improvement (significant downward trend of pressure indicator)
→: No change (the change is not significantly different from 0% per decade)
↓: Significant degradation (significant upward trend of pressure indicator)
Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment
* In drought impacted areas only

3.3.4.2 In-depth assessment

The most relevant pressures in EU-28 forests are related to climate and habitat conversion, where all indicators with trends towards degradation were found. Climate change may affect forest disturbance regimes directly, indirectly and via interaction effects (Lambers 2015; Seidl et al. 2017). For instance, warmer and drier conditions tend to facilitate wildfires, drought, and insect disturbances, while warmer and wetter conditions may increase the risk of wind and pathogens. Chapter 4.1 on bioclimatic indicators offers a comprehensive picture of significant changes in 15 indicators. In the present chapter we used a selected number of bioclimatic indicators that were included in the climate change category of Table 3.3.4. Effective rainfall (fact sheet 3.3.111), annual mean temperature (fact sheet 4.1.101) and extreme drought events (fact sheet 4.1.101) exhibited significant trends toward conditions favouring forest degradation in both the long term and short term. Additionally, wildfires (fact sheet 3.3.105) and the effect of drought on forest productivity (fact sheet 3.3.107) exhibited significant trends towards degradation in one of the two periods assessed. The indicator of burnt area (that covers the Mediterranean area) shows a downward long-term trend. In contrast, the short term-trend exhibits an upward direction. The short term-trend should be assessed with caution due to the limited number of years used in its calculation. However, evidence indicates that anthropogenic climate change is increasing fire danger across large parts of the EU (de Rigo et al. 2017). This is an aspect deserving close attention in view of the potential harmful effects of fires under warmer conditions.

Despite information on the trends at EU-28 level are useful instruments for assessment, strong spatial variability is common in the indicators. We use effective rainfall as an example for describing the spatial variability of the indicators; however, we suggest referring to the indicator fact sheets for a more comprehensive view. Effective rainfall is the difference between mean annual precipitation and mean annual potential evapotranspiration (PET) (Archibald et al. 2013; Santhi et al. 2008; Wolock et al. 2004). It is considered an index of plant productivity, where values below zero indicate that evaporative demands exceeds precipitation and values above zero that precipitation exceeds evaporative demands. Therefore, effective rainfall is a quantitative indicator of the degree of water deficiency at a given location. Despite a significant trend was found at EU-28 level (Figure 3.3.2), strong spatial variations exists as shown in Figure 3.3.3. The map shows areas where significant changes in effective rainfall have occurred. Changes below 0 mm/decade indicate a drying climate and changes above 0 mm/decade a wetter climate. Within the Mediterranean biogeographical region large areas of the Iberian Peninsula, France, Italy, major Mediterranean islands and the Balkans, exhibit a downward trend of effective rainfall. Additionally, other regions beyond the Mediterranean such as zones of Belgium, Germany, Poland, Czech Republic, Hungary, Bulgaria, and Romania also exhibit downward significant trends. In these zones, an increasing climatic water deficit indicates evaporative demands not met by precipitation. In contrast, some zones of northern Europe show a significant upward trend of effective rainfall, for instance, parts of Sweden, Finland, and North Britain. In these areas, an upward wetter trend prevails.

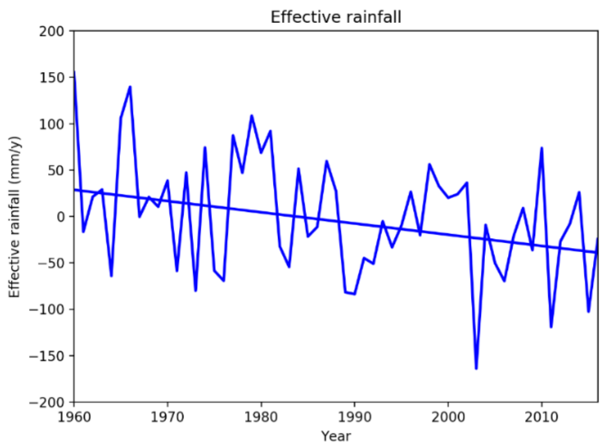


Figure 3.3.2. Trend of annual effective rainfall 1960–2016 in the EU-28. Trend line computed using the Theil–Sen non-parametric estimator. Downward trend (-1.2 mm/y) significant at 5% according to Mann-Kendall trend test. Data source: see Figure 3.3.3.

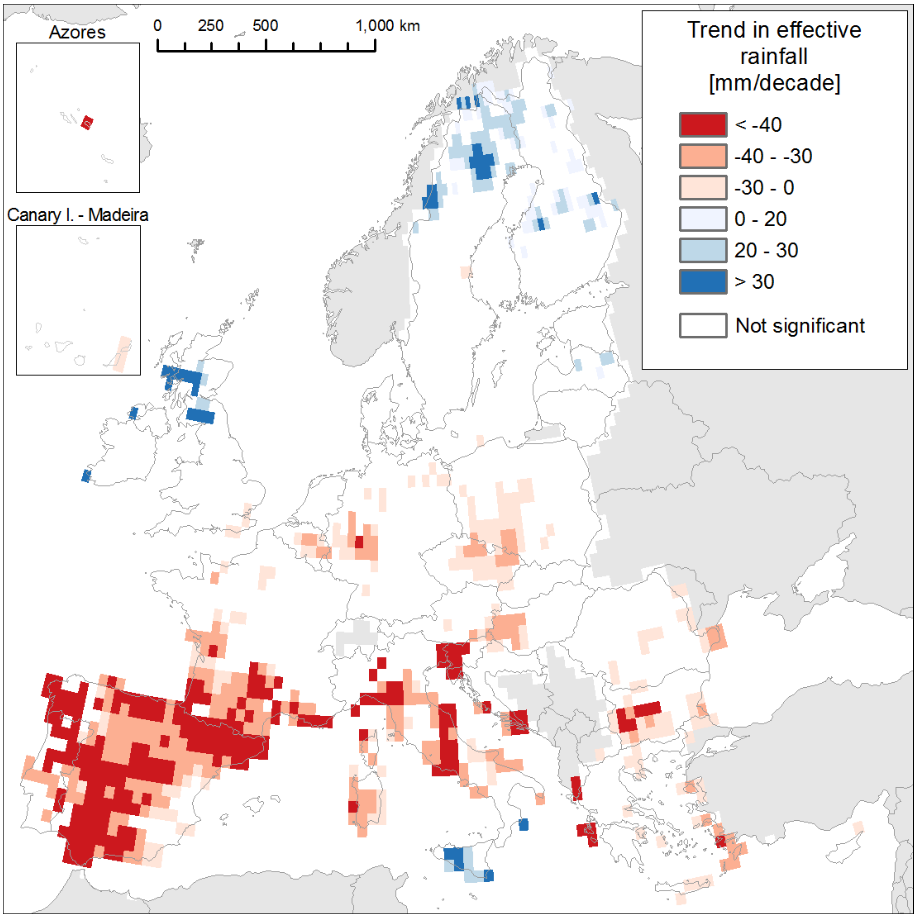


Figure 3.3.3. Trends in annual effective rainfall 1960–2016 in the EU-28 (significant at the 5% level according to the Mann-Kendall test). Light grey: outside area of interest. Data source: PET, University of East Anglia Climatic Research Unit (CRU) Time-Series (TS) (1901–2016) version 4.01 gridded monthly data at 0.5 degree (~43 km at 40° N) spatial resolution (Harris et al. 2014). Precipitation: Full Data Monthly Product Version 2018 provided by the Global Precipitation Climatology Centre (GPCC) of the Deutscher Wetterdienst (DWD) (Schneider et al. 2018; Schneider et al. 2017).

Changes in climatic parameters suggest changes in disturbance dynamics. However, there is an incomplete knowledge of the effects in these dynamics (Seidl et al. 2017). When the magnitude and frequency of pressures shift beyond background (historical) conditions, forest systems enter in a declining state (degradation) and their functional capacity is reduced. Pressures may occur concomitantly in time and space exhibiting many interactions. Therefore, their effects in forests are not independent, on the contrary, they interact producing non-linear feedbacks with the forest system and its functions (Carpenter et al. 2009; Lausch et al. 2016; Trumbore et al. 2015). For instance, long-term changes in the frequency, duration and severity of drought and heat stress could alter the composition, structure and function of forest ecosystems (Lindner et al. 2010; Seidl et al. 2017; Urban et al. 2012). Indeed, documented evidence of drought and heat induced forest mortality in Europe accounted for around 300 tree/stand mortality occurrences in the period 1970-2017 (Caudullo and Barredo 2019) (fact sheet 3.3.106).

Regarding the indicators of habitat conversion and degradation, tree cover loss increased by 26% per decade in the period 2001-2012, and by 74% per decade in 2009-2018. The aim of this indicator is to assess the spatial distribution and temporal trends of tree cover loss in the EU-28 forest area using observational data acquired by remotely sensed imagery at 30 m spatial resolution. Despite the assessed period is short to formulate more robust conclusions, the increase of this pressure may affect the condition of forest ecosystems in the EU-28 (fact sheet 3.3.102). An upward trend of tree cover loss could leads to reductions of the delivery of important ecosystem services, including habitat for biodiversity, climate regulation, carbon storage, and water supplies (Hansen et al. 2013). The information provided by the indicator of tree cover loss is complementary to the information provided by the indicator of forest cover change (net change). Forest cover change (net change) describes the balance between forest gain and loss departing from CLC data that have a spatial resolution of 25 ha, i.e. the equivalent of a square of 500 m x 500 m. Therefore, the forest dynamics represented in this indicator are coarser than the information of tree cover loss that was created using data at 30 m x 30 m spatial resolution. In other words, many local level changes captured in the tree cover loss indicator might be underrepresented in the forest cover change indicator. The assessment of tree cover loss using trends at grid cell level shows areas where this pressure is increasing (i.e. significant upward trends) across the EU-28. These areas were equivalent to around 25% of the EU-28 forest area in the period 2001-2012.

Forest land take by urban and other artificial land development is marginal if compare with the extent of forest in the EU-28. The pressure from land take on forest decreased from 80,331 ha in 2000-2006 to 54,070 ha in 2012-2018 (by 46%). Therefore, a downward trend is observed in both the long and short-term periods. However, forest land take continues to occur, though at a slower rate (fact sheet 3.3.104).

Notable progress has been achieved in limiting pollutants and nutrient enrichment in EU-28 ecosystems. Trends of critical loads exceedance and the area exceeded for acidification and eutrophication in EU-28 forests indicate a decrease from 2000 onwards (Table 3.3.4). The trends point in the right direction, however more efforts are needed in terms of emissions reductions to reach non-exceedance of critical loads in European forests and other ecosystems. For instance, in 2016, 30% and 74% of the EU-28 forests area was exceeded for acidification and eutrophication, respectively. A similar situation exists for tropospheric ozone. The greatest part of Europe is characterised by downward trends of tropospheric ozone (AOT40) exposure. However, in 2017 around 72% of the EU-28 forest area was exposed to AOT40 levels above the critical value of 5,000 ppb.hours (note high uncertainty in the modelling approach that may lead to bias in the computation of the area exposed) (fact sheet 3.3.109).

Capturing changes in forest fragmentation in large areas is constrained by the local character of this pressure. Indeed, the EU-28 level trends indicate no change in both the short term and long term. However, local changes of this indicator have been assessed in the maps available in the fact sheet 3.3.103.

Information on trends of invasive alien species[54] (IAS) of Union Concern in forests is not available. However, the assessment using data from EASIN[55] indicates that IAS are present in around 44% of EU-28 forests (see fact sheet 4.2.101 on IAS and chapter 4.2).

3.3.5 Ecosystem condition: spatial heterogeneity and change over time

This section shows the results of the assessment of forest condition indicators. The first part describes the results at EU-28 level. The second part is an in depth assessment showing examples of selected condition indicators. Indicators are fully described in the fact sheets.

3.3.5.1 Assessment at the level of EU-28

Table 3.3.5 contains 15 condition indicators, however trends of forest condition were calculated for 11 indicators of different types, i.e. excluding no data indicators, and “change in unfavourable conservation status of forest habitats” and “share of forest habitats listed under Annex 1 of the Habitats Directive in favourable conservation” that were built using a different method. In the short-term trend, five indicators show improvement and four no change. While in the long-term trend five indicators indicate improvement, four show no change and two degradation.

The condition of forests is the result of a multiplicity of pressures and drivers of forest change. However, attributing direct causal-effect relationships between forest pressures and condition is challenging due to several reasons (Carpenter et al. 2009; MA 2005). First, pressures can be the result of many interrelated factors such as drought and insect pests, or fragmentation and water cycling. In most cases, there is not a simple causal chain between pressures and forest condition; on the contrary, pressures are often interrelated by complex feedbacks with ecosystems. Second, pressures occur at different temporal and spatial scales, from sub-daily to seasonal or multi-annual, and from single-tree to stand/patch or landscape scale. Finally, pressures can adopt different configurations depending on range, scope, duration, intensity, continuity, dominance, and overlap. It is not the focus of this assessment to establish causal relationships between the pressures of Table 3.3.4 and the condition indicators of Table 3.3.5.

[54] https://ec.europa.eu/environment/nature/invasivealien/index_en.htm
[55] https://easin.jrc.ec.europa.eu/easin

Structural indicators suggest improvement of forest condition in three out of five indicators. However, defoliation (fact sheet 3.3.204), a key parameter of forest condition, shows a degrading long-term trend, a point to which we shall return in the next section. Regarding the other types of indicators, it is important to mention the not significant 3% decrease in the long-term trend of the abundance of common forest birds (fact sheet 3.3.205) resulting in stability. A situation that seems to be improving in the last few years. The trends in the short term should be seen with caution because of the small number of years used for its calculation.

Two indicators are directly derived from the Art. 17 reporting on the conservation status of habitats under the Habitats Directive: the share of forest habitats in a favourable conservation status and the trends in conservation status of forest habitats that are in an unfavourable status (poor and bad). The total area of forests that is covered under Annex 1 of the Habitats Directive is 492,735 km^2 (See chapter 2, Table 2.2). This corresponds to 28% of the total extent of forest in the EU-28. The EU level assessment of the conservation status of 81 forest habitats concluded that 14.2% are in good (or favourable) conservation status. The remaining habitats are in poor status (53.9%), in bad status (30.6%) or unknown (1.3%) (State of Nature report for the period 2013-2018, forthcoming). Only 13.1% of the forest habitats that is in an unfavourable status is showing improving trends (Table 3.3.5).

Table 3.3.5. EU-28 aggregated forest condition indicators.

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Environmental quality (physical and chemical quality)	See pressures in Table 3.3.4.								
Structural ecosystem attributes (general)	Dead wood	Tonnes/ha	4.09	10.3	↑	6	18.3	↑	6
	Landscape mosaic (index)	%	43.12	0.02	→	7	0.34	→	8
	Biomass volume (growing stock)	m^3/ha	200	10	↑	6	10	↑	7
	Forest area	Million ha	159.24	2.1	↑	6	3.3	↑	7
	Defoliation	Mean % defoliation	~20		unresolved		3.4—16.5	↓	8
Structural ecosystem attributes based on species diversity and abundance	Abundance of common forest birds	Index (1990=100)	94	11.2	↑	6	-3	→	7
Structural ecosystem attributes monitored under the EU Nature directives and national legislation	Forests covered by Natura 2000	%	22.8	-0.3	→	8	-0.1	→	8
	Forest covered by Nationally Designated Areas	%	21.2	0.01	→	8	0	→	8
	Share of forest habitats listed under Annex 1 of the Habitats Directive in favourable conservation status*	%	14.2						
	Trends in unfavourable conservation status of forest habitats listed under Annex 1 of the Habitats Directive*	% improving		13.1	↑				
		% stable		42.2	→				
		% deteriorating		25.6	↓				
		% unknown		19.1	unresolved				

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Structural soil attributes	Soil organic carbon in forests	%			unresolved			unresolved	
Functional ecosystem attributes (general)	Dry matter productivity	kg/ha y	11,829	11.1	↑	7	8.3	↑	8
	Evapotranspiration	mm/y	482	-2	→	5	1.7	↓	7
	Land Productivity Dynamics (NDVI)	Index			unresolved			↑	6
Functional soil attributes	Nutrient availability				unresolved			unresolved	

↑: Significant improvement (significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

* The indicators on forest habitat conservation status have been treated differently than the other indicators with a different baseline year and different time period (2013–2018); so the percent change is expressed for a period of 6 years instead of 10 as for the other indicators. The trends in conservation status are only available for forest habitats in an unfavourable conservation status. Please check chapter 2 for details.

3.3.5.2 In-depth assessment

Structural indicators such as forest area, biomass volume and amount of deadwood show improvement trends in both periods. Forests[56] in the EU-28 expanded by nearly 13 million hectares over the last 25 years, an area equivalent to the size of Greece, from 148 to 161 million hectares (fact sheet 3.3.203). The forest expansion is the net balance of afforestation, natural forest expansion, regeneration and deforestation (FOREST EUROPE 2015b). The increase is equivalent to 520,000 ha (0.35%) per year. The rate of increase in forest area was higher in the first decade (1990-2000) than in the 2000-2015 period, around 680,000 ha/y versus 410,000 ha/y. This indicates that forest area continues to increase but at a lower rate than in the first sub-period. However, this increase is not evidenced in forest land cover data from CLC. The possible reason of this discrepancy is mentioned above.

Biomass volume (growing stock per unit area) shows improving trends in both periods (fact sheet 3.3.202). Growing stock represents the living tree component of the standing volume. This indicator is a fundamental parameter of forest inventories and is considered a proxy for biodiversity (FOREST EUROPE 2015b). Also dry matter productivity and land productivity dynamics, both functional attributes indicators (fact sheets 3.3.208 and 3.3.210), suggest upward trends. In fact, ecosystem productivity is a key ecological parameter considered to be at the core of numerous ecological processes including decomposition, biomass production, nutrient cycling, and fluxes of nutrients and energy (Running 2012). In consequence, upward trends in productivity have important implications on ecosystem services such as carbon sequestration and storage, biodiversity, water supply, erosion control, recreation and provisioning services. Drivers behind the upward trend of dry matter productivity are warmer temperatures, lengthening of the growing season, the CO_2 fertilisation effect and management.

Dead wood, another important proxy for biodiversity, exhibits improving trends in both periods (Table 3.3.5) (fact sheet 3.3.201). Dead wood is an important trait of forest ecosystems representing the substrate for a large number of animal and plant species (FOREST EUROPE 2015b). For example, a conservative estimate for the total number of species dependent on deadwood habitats is around 20-25% of all forest species in the Nordic countries (mainly fungi and invertebrates)(Siitone, 2001). Large amounts of deadwood are favourable to certain forest species. For instance, fungi, mosses or insects in forest are closely dependent on the presence of dead wood or very specific microhabitats frequently found on very large trees, such as cavities or sap flows.

Dead wood contributes to several forest features and functions such as structural stability of soils, microhabitats, carbon sequestration, nutrient supply and water retention (Lachat et al. 2013). There are noticeable differences in dead wood between MSs. However, at EU-28 scale the increase is evident. Dead wood is a key trait of maturity in forest, yet amounts of dead wood can vary due to several factors ranging from the effect of disturbances such as windstorms, forest fires or insect outbreaks, or due to sustainable forest management practices oriented to conserve more dead wood in place after fellings. Throughout Europe, the volume of deadwood in intensively managed forests is less than 10% of comparable types of natural forests (Stokland et al., 2012). We acknowledge that according to the source of data, i.e. FOREST EUROPE (2015b), information on deadwood is available only for 16 EU-28 countries, in addition, the information is aggregated at country level. Therefore, these limitations restrain the conclusions that can be drawn from this indicator.

Other structural indicator is landscape mosaic, which shows no change in both the long-term trend and the short-term trend. Nevertheless, changes in this indicator should be assessed at local level where hotspot areas can be identified in the maps available in the fact sheet 4.3.201.

Despite the improving trends observed in the previous structural indicators, the degrading trend of defoliation is a worrying concern (fact sheet 3.3.204). Defoliation is a parameter of tree vitality, which can be affected by a number of human and natural factors (abiotic and biotic). Therefore, defoliation is a natural bioindicator that can be used as warning signal of forest condition. Defoliation can occur, for example, when trees are exposed to insect infestations, fungi, deposition of pollutants, abiotic factors such as heat and drought, frost, wind, snow/ice, or the action of man (FOREST EUROPE 2015b; Michel et al., 2018).

The defoliation survey from the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in 2017 assessed 5496 plots in 26 European countries, 101,779

[56] Forest as defined by FOREST EUROPE (2015a, 2015b) includes areas with young trees and cleared areas resulting from e.g. forest management and/or natural disasters.

trees in total (Michel A 2018). Of the 26 countries assessed, 20[57] are MSs of the EU-28, the other six countries are: Moldova, Montenegro, Norway, Serbia, Switzerland and Turkey. The reporting from ICP indicates that 25.1% of all assessed trees had needle of leaf loss exceeding 25%, thus classified as either damaged or dead. However, dead trees were only 595 (0.6% of all tress). In other words, one out of four trees in the assessment is considered damaged. In addition, around 29% of the plots had a mean defoliation above 25% i.e. the damage threshold. The assessment of mean plot defoliation from 1998 to 2017, per group of tree species, indicates that the totality of the 10 groups of tree species exhibited upward trends of defoliation, of which seven statistically significant trends. The groups exhibiting significant upward trends represent around 70% of all the trees of the survey.

The degrading trend of defoliation is consistent with the upward trend of some forest pressures shown in Table 3.3.4. For example, the climate indicators, but also those indicators where significant degrading trends are not present at EU-28 level, but the extent of forests exposed is considerable, such as in the case of exceedances of critical loads for eutrophication and acidification.

The indicator on common forest birds shows improvement in the short-term trend and no change in the long-term trend. Between 1990 and 2016 (long term) the common forest bird index decreased by 3% (not significant) in the 26 EU-28 MSs having bird population monitoring schemes. Meanwhile, starting around 2005 the index remains in a stable situation and improves in the most recent years at EU-28 level (Figure 3.3.4). While the forest bird indicator uses 1990 as the baseline of the time series, it should be considered that a (not-significant) decrease of 4% had already occurred since 1980. In fact, the index value in 2016 is below the value in 1990 and 1980. A regional overview of the common forest birds indicator shows that only in the North European region (Finland, Norway and Sweden) a significant downward trend of 12% was found in the period 1980-2016. In the other three European regions the changes reported were not significant (fact sheet 3.3.205).

Structural indicators regarding forests covered by Natura 2000 (fact sheet 3.3.206) or Nationally Designated Areas (fact sheet 3.3.207) show no change in both the long term and short term. This indicates that the share of protected forest areas has been stable since 2000.

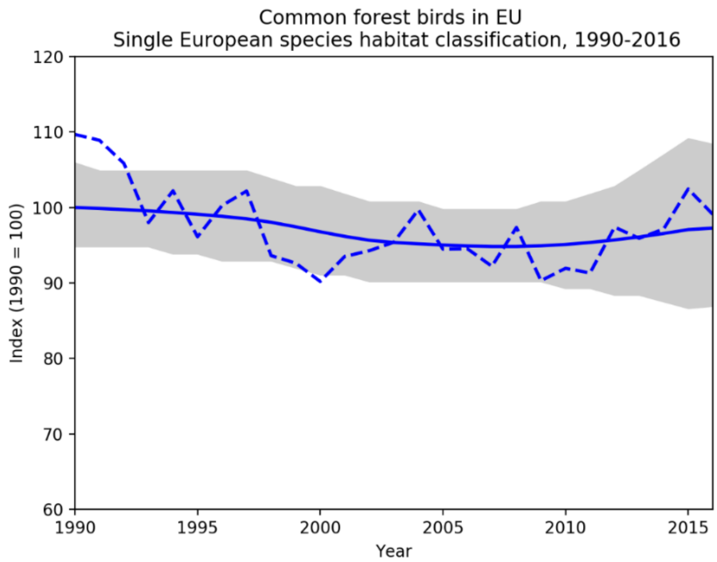


Figure 3.3.4. EU-28 common forest bird indicator, single European species habitat classification, 34 species, 1990-2016. Blue line: smoothed index; blue broken line: unsmoothed index; grey area: upper and lower confidence limits. The indicator was created using data from EU-28 countries with the exception of Croatia and Malta. Data source: European Bird Census Council (EBCC), BirdLife International, Royal Society for the Protection of Birds (RSPB) and Czech Society for Ornithology (CSO).

Regarding functional indicators, evapotranspiration shows an upward trend (degradation) in the long-term trend and no change in the short-term trend (fact sheet 3.3.209). Evapotranspiration was assessed in all the EU-28 terrestrial area across ecosystems because it is considered a cross-ecosystem indicator. Increases in

[57] The eight MS of the EU-28 not included in the 2017's defoliation data are Malta, Portugal, Austria, Cyprus, Finland, Ireland, Netherlands and UK.

evapotranspiration are consistent with an amplification of warming through the water vapour feedback and changes in water resources availability (Huntington 2006).

Evapotranspiration is one of the most significant processes of the hydrological cycle as it returns about 60% of global land surface precipitation and consumes more than half of absorbed solar radiation (Trenberth et al. 2009). Therefore, evapotranspiration is a fundamental component of the energy and water cycles with important implications for ecosystem services such as fresh water availability and micro and regional climate regulation (Goulden and Bales 2014; Pan et al. 2015; Seneviratne et al. 2006).

Changes in terrestrial evapotranspiration are expected to impact land surface temperature, having implications on regional and global warming (Wang and Dickinson 2012). Additionally, evapotranspiration is a driver of air humidity, cloud formation and precipitation (Miralles et al. 2012; Seneviratne et al. 2010; Taylor et al. 2012). Plants take up water from ground and transpire it back to the atmosphere, therefore affecting ground water supply and influencing regional precipitation (Jung et al. 2010). Empirical evidence indicates that around 74% of the terrestrial evapotranspiration comes from plant transpiration (Martens et al. 2017).

Climate change is expected to intensify the hydrological water cycle (Huntington 2006), and hence to alter evapotranspiration with implications for ecosystem condition and services and complex feedbacks to regional and global climate. Additionally, climate, atmospheric CO_2 concentration, and functional, structural and compositional traits of vegetation affect terrestrial evapotranspiration.

The assessment of annual evapotranspiration in the EU-28 indicates a significant upward trend of 0.8 mm/y (Figure 3.3.5). Spatial changes of evapotranspiration are shown in the map of Figure 3.3.6, where areas with significant trends are exhibited. Although the drivers of the significant changes in evapotranspiration in Europe have yet to be elucidated at local level, increases in evapotranspiration are consistent with warming and the lengthening of the growing season, both showing significant upward trends (see chapter 4.1 on bioclimatic indicators). Therefore, evapotranspiration is a sensitive bioindicator of ecosystem function and services due to the consistent relationship between ecosystem change (temperature, plant traits, land cover), evapotranspiration, water supply and temperature regulation (Goulden and Bales 2014). Impacts on forests will depend greatly on how insects, diseases, IAS, nutrient cycling, and heat stress are affected by the intensification of the hydrologic cycle.

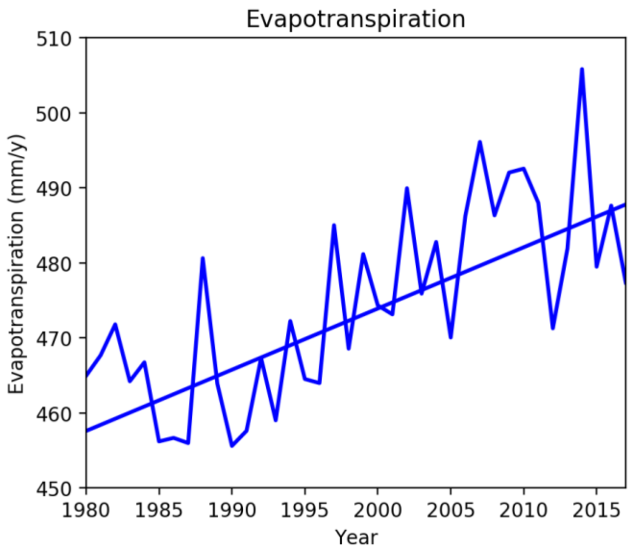


Figure 3.3.5. Trend of annual evapotranspiration 1980-2017 in the EU-28. Trend line computed using the Theil–Sen non-parametric estimator. Upward trend (0.8 mm/y) significant at 5% according to Mann-Kendall trend test. Source of baseline data: GLEAM dataset (Martens et al. 2017).

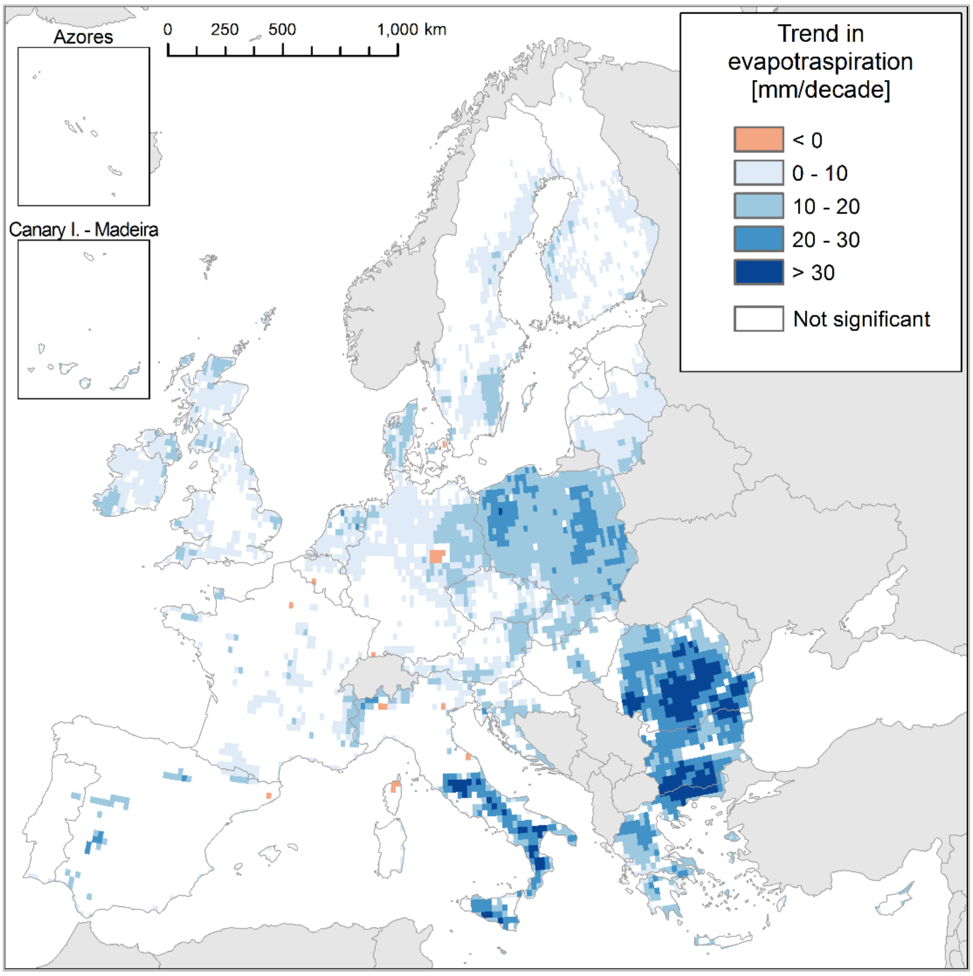


Figure 3.3.6. Trends in annual evapotranspiration 1980-2017 (significant at the 5% level according to the Mann-Kendall test). Light grey: outside area of interest. Source of baseline data: GLEAM dataset (Martens et al. 2017).

3.3.6 Convergence of evidence

3.3.6.1 Summary of the trends in pressure and condition

Table 3.3.6 summarizes the short and long term trends of pressures and condition indicators. The table does not include the indicators on habitat conservation status as they do not result in a single trend.

Trends of forest pressures were calculated using 15 indicators with available data for either or both short and long term (there was a data deficiency for 5 indicators). The assessment reveals that in the short-term trend, six indicators show negative change resulting in degradation, two no change, five a positive change resulting in improvement, and two are unresolved. In the long-term trend, five indicators show negative change resulting in degradation, five no change, and five a positive change resulting in improvement.

Trends of forest condition were calculated using 11 indicators with available data for either or both short and long term (there was a data deficiency for 2 indicators). In the short-term trend, five indicators show improvement, four no change, and two indicators are unresolved. While in the long-term trend five indicators indicate improvement, four show no change, and two degradation.

Table 3.3.6. Summary of trends in pressure and condition of forests in the EU-28.

	Indicator	Short-term trend - Since 2010	Long-term trend
Pressures	Forest cover change (net change)	→	→
	Tree cover loss	↓	↓
	Forest fragmentation	→	→
	Forest land take	↑	↑
	Fires – burnt area	↓	↑
	Number of fires	↑	↓
	Effective rainfall (annual)	↓	↓
	Mean annual temperature	↓	↓
	Extreme drought events	↓	↓
	Soil moisture (soil water deficit)	unresolved	→
	Drought and heat induced tree mortality	unresolved	unresolved
	Storms	unresolved	unresolved
	Effect of drought on forest productivity*	↓	→
	Tropospheric ozone (AOT40)	↑	↑
	Exceedances of critical loads for acidification	↑	↑
	Exceedances of critical loads for eutrophication	↑	↑
	Ratio of annual fellings to annual increment	unresolved	→
	Pressure by invasive alien species	unresolved	unresolved
	Forest pests, parasites, insect infestations	unresolved	unresolved
	Soil erosion	unresolved	unresolved
Condition	Dead wood	↑	↑
	Landscape mosaic (index)	→	→
	Biomass volume	↑	↑
	Forest area	↑	↑
	Defoliation	unresolved	↓
	Abundance of common forest birds	↑	→
	Forests covered by Natura 2000	→	→
	Forest covered by Nationally Designated Areas	→	→
	Soil organic carbon in forests	unresolved	unresolved
	Dry matter productivity	↑	↑
	Evapotranspiration	→	↓
	Land Productivity Dynamics – (NDVI)	unresolved	↑
	Nutrient availability	unresolved	unresolved

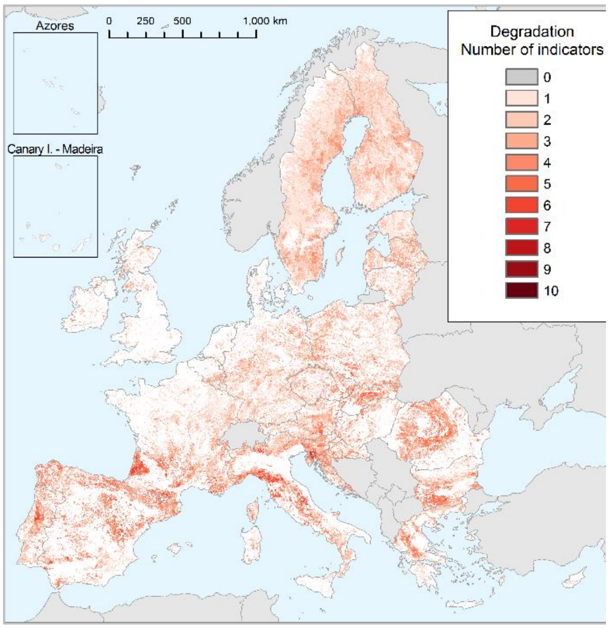
↑: Significant improvement (significant downward trend of pressure indicator; significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator; significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment
Indicators of conservation status of habitats, species and birds are excluded.

3.3.6.2 Mapping convergence of evidence

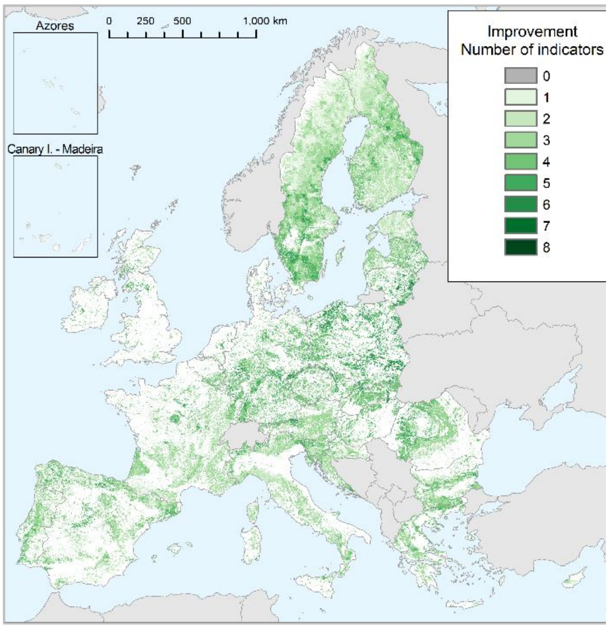
The convergence of evidence mapping was done using those 14 indicators (11 pressures and 3 condition) that provided spatially-explicit data (maps). The maps describe degradation, improvement and no change trends (long-term) at the grid cell level and were recoded according to Table A1 (in annex). Then, the maps of the indicators were overlaid for producing summary maps describing the number of indicators showing improvement, degradation and no change (Figure 3.3.13). Note that the maps of the indicators were sourced from different datasets, therefore some differences are expected regarding their spatial extent (see Figure 3.3.A1 in annex).

Key summary figures computed from the maps indicate, for example, that 47% of EU-28 forests are exposed to at least three degradation drivers (indicators), and 20% to at least four (Figure 3.3.14). Likewise, only 20% of forests are exposed to one or none degradation drivers. Regarding improvement, around 42% of forests exhibit at least four improvement indicators, nevertheless this number decreases to 20% if we select forest areas where at least four indicators suggest improvement and at most 2 indicators suggest degradation.

A



B



C

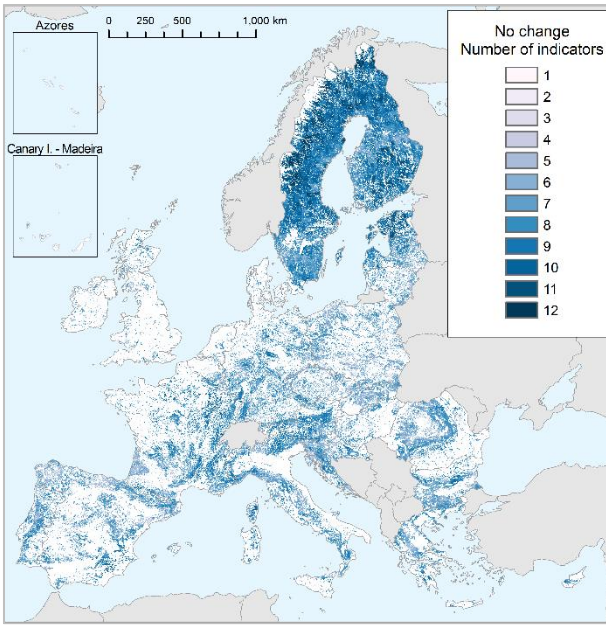


Figure 3.3.13. Convergence of evidence mapping: Summary of indicators. A) Degradation; B) Improvement and C) No change. The numbers in the legends indicate the number of indicators where significant trends were found.

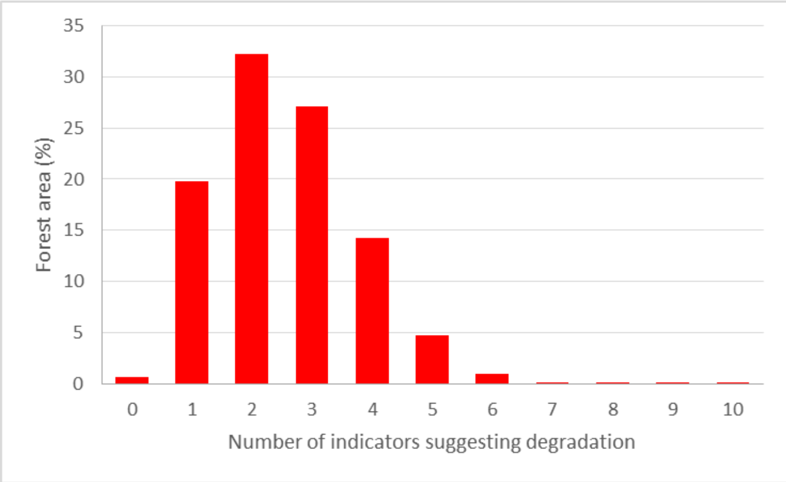


Figure 3.3.14. Convergence of evidence. Share of EU-28 forest area in relation to the number of indicators suggesting degradation. Note that no forest area was mapped showing more than 10 indicators suggesting degradation.

3.3.7 Options for policy

The current condition of EU-28 forests and the trend towards degradation observed in many key indicators calls for an adequate and prompt policy response at EU level. Curving the trend of degrading condition and pressures requires policy action looking at a comprehensive ecosystem-based approach for forests. Policy response should take into consideration the complex interactions between a changing climate and its direct and indirect pressures, the condition of forests (e.g. defoliation) and the degree of use intensity of land and forest ecosystems (Santos-Martín et al. 2019; Schneiders et al. 2012).

The ecosystem-based approach to policy design should look at the evolution of EU forest and their current condition. For example, the integral protection of the remnant primary forests in the EU-28, that represent at best 4% of EU-28 forests, must be one priority. Similarly, looking forward to the next decades, forest genetic resources[58] are of paramount importance for forest adaptation, because they can support the development of more resilient forests. Further work is needed on forest adaptation to climate change to prevent and mitigate adverse impacts caused by changing conditions at local, national and regional scales. In the ecosystem-based approach to policy, urban forests should play an important role. Despite they represent a small share of land (see chapter 3.1 on urban ecosystems), they provide services to a high number of citizens and are essential for the adaptation of the urban environment to climate change. Just to mention two examples, the positive health effects in people (Hartig et al. 2014; Nilsson et al. 2011; WHO 2010) and the climate regulation services.

The capacity of forests to provide public goods should be maintained and enhanced. This aim can be reached only by an integrated ecosystem management that looks at both, provisioning services where required, and the supply of those ecosystem services with public goods characteristics. In this schema, biodiversity is at the core of both provisioning services and regulating services (Isbell et al. 2017). As such, the importance of systematically including biodiversity considerations in Forest Management Plans is crucial. It should be possible to assess these plans before their approval, in terms of both how they will be implemented and their effectiveness. The need to maintain and enhance the provision of forest public goods is even more relevant looking at the increasing demand of forest resources for a transition to a climate-friendly economy (Jonsson et al. 2018). Certainly, the aim should be to live within the limits of the planetary boundaries (Rockström et al. 2009).

Only around 14% of EU-28's forest are protected for biodiversity and nature conservation, this number depicts well the patchy character of biodiversity valuable forests in the EU-28. This situation may restricts connectivity between forest patches of high biodiversity value. Therefore, it is evident that a policy target contributing to improved ecosystem condition as well as connectivity beyond protected areas is required. To

[58] http://www.euforgen.org

this aim, non-protected forests in good condition[59] should also play a role as green corridors. Moreover, the need of this target would be further reinforced if we consider the available evidence on projected impacts of climate change in European forest ecosystems (Lambers 2015; Seidl et al. 2017), that in turn would require increased landscape connectivity as an attempt to safeguard plant and animal species. In summary, with the exception of the Birds and Habitats Directives, there is a policy gap on forest and forest management, which is particularly evident in forests subject to high-intensity use for timber production. A policy framework is needed embedding the multifactorial character of forests. This will facilitate setting goals and targets at EU scale, and bringing biodiversity in synergy with on-going policies involving forest ecosystems. The biodiversity policy targets should address the drivers of forest degradation on the one hand, and propose actions and targets for enhancing the provision of public goods and biodiversity on the other. These two levels of action should contribute to the overarching objective of bending the curve of degradation and biodiversity loss (Mace et al. 2018).

Policy actions in forest ecosystems should include active restoration of degraded forest stands, a change in forest management practices where necessary with a view to increase biodiversity and improve forest condition and its adaptive capacity. In addition, those forest stands that are more vulnerable to natural disasters and pests should be considered for restoration or a change in management practices. These actions should include active advisory services to foresters for more close-to-nature practices with the aim to provide the full range of ecosystem services to society.

A clear monitoring framework, allowing policy-makers to take stock of the situation and to decide on an adequate policy response, should accompany future EU forest policy proposal. Such a framework will also need to rely on current and improved reporting by Member States.

3.3.8 Knowledge gaps and future research challenges

Key data gaps regarding indicators of forest pressures and condition are shown in Table 3.3.4 and Table 3.3.5 (see unresolved in the tables). Regarding pressures, comprehensive, multi-temporal, seamless and spatially explicit indicators on drought and heat induced tree/stand mortality (Caudullo and Barredo 2019) and storm damage in forests (Forzieri et al., 2020) are lacking. Likewise, despite current efforts on the collection of data on invasive alien species (IAS)[60], trend information for monitoring the presence of these species is not available. In fact, IAS is an increasing threat[61] to the condition of forest ecosystems requiring an overview of their evolution. In addition, spatially-explicit information on the presence of exotic tree species would be useful for assessing their impact on the condition of forest ecosystems.

Forest pests, parasites and insect infestations are a worrying concern considering their close interactions with changes in climate, e.g. increases in winter temperature. Spatio-temporal systematically collected and harmonised data across the EU would be of paramount importance for the design of prevention measures and to track the evolution of these pressures at pan European level.

Some gaps have been also identified regarding indicators of forest condition. For instance, common forest birds is a good example of forest biodiversity indicators, nevertheless systematically-collected data of other birds, plant and animal species (including insects) would result in a more accurate view of the different dimensions and trends of forest biodiversity. Evaluating the structure and condition of forest stands would require additional spatially explicit and harmonised data. For instance, biomass volume, tree species diversity, deadwood, age class distribution, harvesting intensity, and soil compaction among other. Likewise, the situation of forest soils indicators seems to be limiting, and indicators on forest soils biodiversity should be developed. Despite previous efforts, consistent data of forest nutrient availability and soil organic carbon seems inadequate at present.

Readily available observational data and maps of forest management intensity, forest habitats, forest ownership, forest plantations, and primary, old-growth and ancient forests (Sabatini et al. 2018) would certainly be a contribution to a better understanding of the dynamics and drivers of forest change, in addition to be important for model building and ecosystem condition assessments. Finally, further efforts are needed for short-time (e.g. yearly) monitoring of forest cover change resulting from both natural and human disturbances, and the ability to separate them.

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[59] Payments for forest-environmental and climate services and forest conservation are supported through the Rural Development Programme (RDP) of the Common Agricultural Policy (CAP).

[60] https://easin.jrc.ec.europa.eu/easin

[61] https://ec.europa.eu/environment/nature/invasivealien/index_en.htm

Despite an important expenditure of around € 50 million per year from MSs together on their national forest inventories, most of the information collected poses challenges for pan European assessments because countries cannot agree on definitions of many forest parameters (Alberdi et al. 2016). In addition, there is a mismatch between the supply and demand of forest information related to biodiversity and nature conservation[62]. This offers opportunities to programmes such as Copernicus[63] or FISE[64] providing seamless forests European data.

3.3.9 Conclusions

The current condition of forest ecosystems in the EU-28 is the result of natural and human-driven pressures taking place since the mid-Holocene. Nevertheless, more recent changes occurring since the mid-twentieth century, including climate and habitat change, result in that only around 2%—4% are primary forest undisturbed by man, whereas 89% are semi-natural forests. As of today, the major proportion of EU-28 forest are FAWS (84%) and only around 14% are protected for biodiversity. In addition, around 23% of EU-28 forests fall within Natura 2000 sites.

EU-28 forests are exposed to several natural and human-driven pressures pointing towards degradation. Direct and indirect effects of changes in climate suggest degradation in six indicators in the long term or the short term. In addition, pollutants remain a concern for EU-28 forests even if the trends point in the right direction. Moreover, IAS affects 44% of the EU-28 forest area. Finally, tree cover loss due to several drivers (wildfire, storms, harvesting) has been increasing notably.

Effects of pressures are evident in forest condition if we consider that one out of four trees of the ICP Forests survey shows defoliation levels indicating damage. Not to mention that the trend points towards increasing defoliation. Likewise, other functional parameters such as evapotranspiration suggest changes in ecosystems consistent with an amplification of warming through the water vapour feedback and changes in water resources availability.

In contrast, some condition indicators show trends towards improvement, for example structural indicators such as forest area[65], biomass volume and, despite limitations in data, deadwood. Likewise, ecosystem productivity is increasing, and the pressure represented by forest land take by artificial structures is decreasing. However, forest soil loss continue to take place even if at a slower rate. Regarding biodiversity indicators, the abundance of common forest birds did not show significant changes in the long-term period, though a not statistically significant 3% decrease was reported since 1990. Nevertheless, the short-term trend suggests improvement.

The EU level assessment of the conservation status of 81 forest habitats concluded that 14.2% are in good (or favourable) conservation status. The remaining habitats are in poor status (53.9%), bad status (30.6%) or unknown (1.3%). Similarly, the converge of evidence mapping suggest that 47% of EU-28 forests are exposed to at least three degradation drivers (indicators), and 20% to at least four, in contrast only 20% of forests are exposed to one or none degradation drivers. Regarding improvement, around 42% of forests exhibit at least four improvement indicators. This number falls to 20% if we select forest areas where at least four indicators suggest improvement and at most 2 indicators suggest degradation.

These results, considered in the perspective of the projected impacts of climate change, its indirect effects, the effects of pollutants, and the foreseen increased demand of forest resources, e.g. for renewable energy (Jonsson et al. 2018), call for a coordinated response at EU level looking for an ecosystem-based approach, including nature based solutions for climate change adaptation. The approach should set the basis for more ambitious, clear and measurable goals and targets at EU scale to enhance biodiversity and the provision of ecosystem services, with emphasis in regulating services, in support of more sustainable forests.

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[62] http://diabolo-project.eu/wp-content/uploads/2019/02/DIABOLO_WP1_Presentation_Koli-1.pdf
[63] https://www.copernicus.eu
[64] https://forest.eea.europa.eu/
[65] Though this increase is not evidenced in forest land cover data from CLC. See comment above.

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Annex 1. Annex to the chapter on forest ecosystems

Table A1. Indicators used in the convergence of evidence mapping.

Indicator – Pressures and condition	Method of trend calculation	Recoding rules	Spatial resolution of the indicator
Tree cover loss	TS-MK	Upward significant: 1 Degradation Downward significant: 2 Improvement Not significant: 3 No change	10 km
Effective rainfall	TS-MK	Upward significant -> 4 Unresolved Downward significant -> 1 Degradation Not significant -> 3 No change	~50 km
Mean annual temperature	TS-MK	Upward significant -> 1 Degradation Downward significant -> 4 Unresolved Not significant -> 3 No change	~10 km
Extreme drought events	TS-MK	0 = no significant change -> 3 No change 1 = decreasing drought (negative slope) -> 2 Improvement 2 = increasing drought (positive slope) -> 1 Degradation	~25 km
Productivity under drought	See Ivits et al. (2016)	1 (Degradation) -> 1 Degradation 2 (No sig) -> 3 No change 3 (Sig positive) -> 3 No change	1 km
Soil Moisture (Soil water deficit)	TS-MK	> 0 -> 1 Degradation 0 -> No change < 0 -> Improvement	5 km
Acidification	5% rule	<= -5 -> 2 Improvement >= 5 -> 1 Degradation -5 to 5 -> 3 No change	~10 km
Eutrophication	5% rule	<= -5 -> 2 Improvement >= 5 -> 1 Degradation -5 to 5 -> 3 No change	~10 km
Tropospheric ozone (AOT40)	TS-MK	Upward significant: 1 Degradation Downward significant: 2 Improvement Not significant: 3 No change	7 km x 9 km
Forest fragmentation (AV-FAD)	5% rule	0b - outside EU-28 -> 0 Background 1b - degradation -> 1 Degradation 2b - improvement -> 2 Improvement 3b - stable -> 3 No change 4b - grey: not forest at both or either times -> 4 Unresolved	1 km
Forest cover change	5% rule	Stable -> 3 No change Improvement -> 2 Improvement Degradation -> 1 Degradation	1 km
Dry matter productivity	TS-MK	Upward significant -> 2 Improvement Downward significant -> 1: Degradation Not significant -> 3 No change	1 km
Evapotranspiration	TS-MK	Upward significant -> 1: Degradation Downward significant -> 1: Degradation Not significant -> 3 No change	~25 km
Landscape mosaic (dominant natural)	5% rule	0b - outside EU-28 -> 0 Background 1b - degradation > 1 Degradation 2b - improvement -> 2 Improvement 3b - stable -> 3 No change	1 km

TS: Theil-Sen slope; MK: Mann-Kendall method.

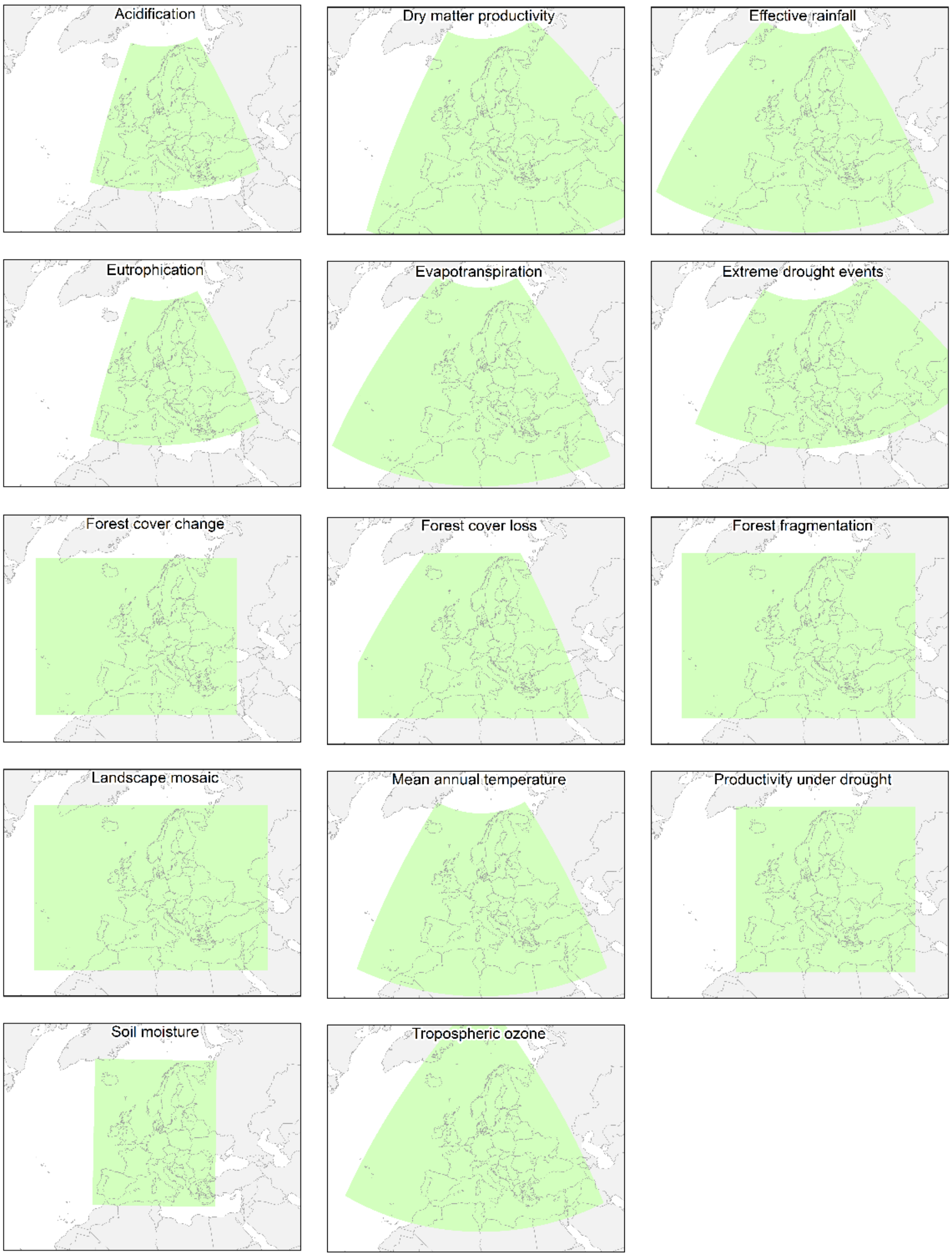

Figure 3.3.A1. Spatial extent of the indicators used in the convergence of evidence mapping.

3.4 Wetlands

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Summary: Despite the broad range of services that healthy wetlands provide to human livelihoods, wetland ecosystems in Europe are in a dire condition. The current policy frameworks, although in principle fit for their purpose, do not always define wetlands properly. The EU Water Framework Directive (WFD) does not define all wetlands as water bodies, and this lack of adequate terminology may have often a controversial implementation, which hampers a holistic conservation and sustainable use of wetlands.

This chapter summarizes the extent, condition, trends and drivers of change in European wetland ecosystems and the steps needed to maintain and/or restore their ecological character. It also draws on the unbalanced knowledge available to assess this ecosystem holistically with a clear gap of information on coastal wetlands, related in particular to their location and classification.

Historically, wetlands in Europe have been suffering from a continued degradation of their habitats from multiple pressures. Despite being already in a poor condition, the wetlands assessed by underpinning data show no improvement in the last two decades, with current trends showing either no changes or yet further degradation. Moreover, even though multiple pressures on wetlands are high, they do not seem to decrease but rather remain unchanged. Among the indicators assessed, only nutrient enrichment shows a significant decrease linked to effective regulation.

The degraded condition of wetlands in Europe is influenced by several factors addressed in this chapter, and is largely linked to the lack of an all-inclusive European policy framework targeting them; the variability in their definitions, the consequent patchy delimitation of their habitats, the limited amount of underpinning data to properly assess them integrally; and the historically low socio-cultural values given to these ecosystems.

Despite wetland restoration efforts in Europe proving their effectiveness in the last decades at local scale against wetland extent loss, tangible improvements in their condition and their full ecological functions are far from being met. This critical situation dominating wetlands requires transformative changes at all levels enabling the implementation of long-term mechanisms and governance models at multiple scales that are implemented founded on ecosystem-based conservation and adaptive monitoring programmes.

Fortunately, upcoming strategies for Europe are carefully considering the inclusion of targeted strategic plans for wetland conservation and restoration. Such strategic plan focusing on wetlands as ecosystems, possibly pushed by the EU 2030 Biodiversity Strategy, would help lay out the foundations for a very much needed and different future for these ecosystems. In that context, comprehensive management, enhanced conservation and targeted restoration could halt and reverse declines recorded and ensure that European wetlands are empowered to play a key role in the European Green Deal and the EU Biodiversity Strategy for 2030.

3.4.1 Introduction and description of wetlands

Wetlands, as defined by the Convention on Wetlands of International Importance (Ramsar, 1971[66]), include a wide variety of inland habitats such as marshes, wet grasslands and peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, intertidal mudflats and seagrass beds, and coral reefs and other marine areas no deeper than six meters at low tide, as well as human-made wetlands such as dams, reservoirs, rice paddies and wastewater treatment ponds and lagoons (Ramsar Convention Secretariat, 2016).

[66] The most comprehensive definition of wetlands is from the convention on wetlands, an intergovernmental treaty ratified by 171 parties (but not the EU) in 1971 that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. In 1995, the commission adopted a communication to the European parliament and the council on the wise use and conservation of wetlands, which recognised the important functions they perform for the protection of water resources and provided the first cross-walk between Ramsar and Corine land cover typologies.

Wetlands are the living space for many (protected) species as well as migratory birds and are crucial in their role of providing habitats and water-related ecosystem services. Erosion control, sediment transport, water filtration and regulation are a few of the many valuable services delivered by this ecosystem. In recent times, the role of healthy (vegetated) wetlands in tackling climate change (mitigation, adaptation, resilience) has been emphasized, namely their capacity to capture and store carbon and so reduce atmospheric greenhouse gases, and provide better resilience to hazards such as flooding, storm surges and coastal inundation (Ramsar Convention on Wetlands, 2018).

However, the potential contributions that wetlands make to both climate change mitigation and adaptation is underappreciated in present policy discussions (Moomaw et al., 2018). Despite their multiple values to humankind, threats to these ecosystems continue to mount in Europe and worldwide.

Whilst there have been transformations for millennia, European wetlands have suffered increasing rates of decline since the middle of the twentieth century and continued degradation and loss are still taking place due to mainly agriculture and forestry (especially in the case of peatlands). Despite wetland restoration efforts over the last decades, degradation and loss of wetlands are still taking place with natural wetlands showing declining trends versus a slight increase in artificial wetlands (Ramsar Convention on Wetlands, 2018). Infrastructure development, including transport routes, fragments existing wetland habitats and disrupts their hydrological functioning. Furthermore, changes in precipitation and rising temperatures are adding to the threats on European wetlands worsening their condition and reducing their current capacity to store carbon and their future carbon sequestration potential.

The degraded condition of wetlands in Europe is influenced by several factors related mainly to a) the lack of a comprehensive European policy framework targeting these ecosystems in a consistent manner, b) the mis-definition and mis-representation of wetlands in different classification systems, and c) the low socio-cultural valuation of these ecosystems, facilitating changes in land uses. Specifically:

a) In Europe, the over-arching policy framework for wetlands that addresses wetland ecosystems holistically dates from 1995 and has not been updated since. Instead, wetland ecosystem management is partially addressed by different legislative instruments (EU Biodiversity Strategy and Nature Directives, Climate Strategy, Water Framework Directive, Flood Directive, Marine Strategy Framework Directive). Though these have some synergetic effects on wetland management and conservation, they nevertheless lack objectives explicitly targeting the whole wetland ecosystem integrity. Instead, they address only parts of this ecosystem for certain purposes: habitats and species of interest; pollution control; flood risks; and/or carbon sequestration.

b) Though the Ramsar Convention is the global framework defining wetland ecosystems, in Europe the term 'wetlands' tends to reflect the differences in landscapes and uses across the continent, often linked to cultural traditions. The existing systems for classifying these habitat units (namely EUNIS, CLC, MAES, LULUCF classifications; Table 3.4.1) have so given way in Europe to a diversity of approaches to their definition over time, hindering a uniform delimitation of wetlands and ultimately leading to a fragmented assessment and management of wetlands.

c) At a socio-cultural and economic level, European wetlands have been historically considered as low productive land that should be subject to dryland forms of cultivation. This profit-driven approach to wetland resources (for example peat extraction, or dryland agriculture) has overlooked the biological, hydro-ecological and socio-economic values and status of wetlands, which as a consequence has degraded this ecosystem, altering its functioning and other undervalued services it provides to people.

This chapter addresses the current state of knowledge on wetland ecosystems in terms of the availability of policy relevant indicators, their condition and the trends in Europe, and highlights unbalanced information and data gaps. Conclusions offer options available for evidence-based policy prioritization and for improving wetland management according to their actual value and the extensive range of ecosystem services provided.

Table 3.4.1. Definitions of the wetland ecosystem adopted by different classification systems at European level

Classification system	Name	Definition
EUNIS (European Nature Information System)	Mires, bogs and fens	Wetlands, with the water table at or above ground level for at least half of the year, dominated by herbaceous or ericoid vegetation. Includes inland saltmarshes and waterlogged habitats where the groundwater is frozen. Excludes the water body and rock structure of springs (C2.1) and waterlogged habitats dominated by trees or large shrubs (F9.2, G1.4, G1.5, G3.D, G3.E). Note that habitats that intimately combine waterlogged mires and vegetation rafts with pools of open water are considered as complexes.
MAES	Wetlands	Inland wetlands are predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites.
LULUCF (Land use, land-use change, and forestry)	Wetlands	The category “wetlands” includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.
CLC (CORINE Land Cover)	Inland wetlands	Areas flooded or liable to flooding during the great part of the year by fresh, brackish or standing water with specific vegetation coverage made of low shrub, semi-ligneous or herbaceous species. Includes water-fringe vegetation of lakes, rivers, and brooks and of fens and eutrophic marshes, vegetation of transition mires and quaking bogs and springs, highly oligotrophic and strongly acidic communities composed mainly of sphagnum growing on peat and deriving moistures of raised bogs and blanket bogs.
	Coastal wetlands	Coastal wetlands are areas that are submerged by high tides at some stage of the annual tidal cycle. They include salt meadows, facies of saltmarsh grass meadows, transitional or not to other communities, vegetation occupying zones of varying salinity and humidity, sands and muds submerged for part of every tide devoid of vascular plants, active or recently abandoned salt-extraction evaporation basins.

3.4.2 Wetland assessment on condition and pressures

The MAES ecosystem types focus the classification of wetlands on the “inland wetlands” category, so coastal wetlands are classified as marine inlets and transitional waters (Box 3.4.1 and Table 3.4.2). This categorization restricts the in-depth assessment of wetlands *per se* within MAES to inland wetland habitats (*i.e.* peatlands and marshes) only.

However, areas that are currently treated as separate ecosystem types by MAES, are ecologically linked by their own water flows. Thus, water is released from upland peatlands into rivers, and then moves through marshes and lakes, before rivers issue into coastal wetlands such as estuaries with their saltmarshes and other coastal habitats.

In addition to the in-depth assessment performed for MAES inland wetlands, this chapter also addresses coastal wetlands to the best possible extent and driven by the available knowledge and data (section 1.1.4).

Furthermore, as a future-looking recommendation to assess wetlands more holistically and as a full ecosystem, section 1.1.5 sets the way forward for the use of an adapted wetlands' nomenclature in Europe, hereafter "extended wetland", based on the Ramsar definition and classification of wetlands, taking stock of the approach set by the Horizon 2020 SWOS initiative[67].

This extended definition of European wetlands according to their hydro-ecological dimension follows the Ramsar classification of wetland habitats that ensures the identification of transitional ecosystem types hydro-ecologically belonging to wetlands (Table 3.4.2). The extended delimitation of wetland ecosystems and the comprehensive delineation of wetland habitats are introduced in section 1.1.5 together with the information currently available on their condition.

Box 3.4.1 refers to the different definitions of wetland habitats considered in this wetland assessment.

Box 3.4.1. Wetland definitions.

Inland wetland habitats are defined in the MAES framework as "Terrestrial" (level 1) and "Wetlands" ecosystem types (level 2). They are defined in the first MAES report, page 24 (Maes et al, 2013), as "predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites".

Coastal wetland habitats are defined in the MAES framework as "Marine" (level 1) and "Marine inlets and transitional waters" ecosystem types (level 2). The Marine inlets and transitional waters ecosystem types are defined in the first MAES report, page 24 (Maes et al, 2013), as "ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5 ‰" which, beside coastal wetlands, also include "lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments".

The **extended wetland** habitats are defined according to the Ramsar Convention, signed by all EU-28 parties, which states that wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six meters". Furthermore, wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".

[67] Horizon 2020 Satellite-based Wetland Observation Service: https://www.swos-service.eu/

Table 3.4.2. A comprehensive classification of wetland ecosystems in Europe including all the habitats linked to their hydro-ecological delimitation. For each class, the relative section in the chapter is specified, while the colour refers to the amount of available knowledge on their condition, from green (maximum amount) to red (minimum amount)

Wetlands definition	What is included	Section	Source of information[68]
Ramsar-based definition (extended wetlands)	MAES wetlands (inland marshes and peatbogs)	3.1	MAES assessment Art.17 assessment
	MAES Marine Inlets and Transitional Waters (coastal wetlands, lagoons, estuaries and other transitional waters)	3.2	Art.17 assessment
	MAES Rivers and Lakes Beaches, Dunes and Sand Managed and natural wet grasslands/pasture Rice fields Riparian, fluvial and swamp forests Wet heaths Riverine and fen scrubs Marine waters < 6m deep	3.3	Art.17 assessment MAES assessment for rivers and lakes

3.4.3 Inland wetlands: introduction and description of the ecosystem

Inland wetland habitats are defined in the MAES framework as "Terrestrial" (level 1) and "Wetlands" ecosystem types (level 2). They are defined in the first MAES report, page 24 (Maes et al, 2013), as "predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites"

In line with the overall objective of this report, the aim of this chapter is to determine and report the trends in the pressures and condition of inland wetlands relative to the baseline year 2010. This chapter can thus be used to evaluate the targets set by the EU Biodiversity Strategy to 2020. It is important to stress that this assessment is primarily based on indicators for which European wide, harmonized datasets have been collected. Where needed, more context is provided by citing relevant literature through a systematic review of literature on pressures on biodiversity and ecosystems.

Furthermore, this chapter delivers the baseline data to establish a (legally binding) methodology for the mapping and assessment of ecosystems and their capacity to deliver services, and to determine the minimum criteria for their good ecosystem condition as required by the new EU Biodiversity Strategy to 2030. Determining these criteria for inland wetland ecosystems however requires agreeing on a reference condition against which the past or present condition can be evaluated. More work to determine the target and reference levels of pressure and condition indicators in agreement with stakeholders, scientists and policymakers will be needed.

[68] The EU Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) cover wetland ecosystem only partially hence they haven't been used as source of information for this assessment. Nevertheless, the WFD is a source of information for the MAES assessment of rivers and lakes.

3.4.3.1 *Inland wetlands ecosystem extent and change*

Generally, the extent of all ecosystems in Europe, as obtained from the Corine Land Cover layers (for more details refer to chapter 2), is stable with approximately 99% of the stock of ecosystems remaining unchanged over the period 2000-2018 while for the same period, inland wetlands show a 0.5% wetland decrease in extent for this same period (Table 3.4.3).

Table 3.4.3. Area extent (km^2) of the inland wetland ecosystem in EU-28 for the period 2000-2018

MAES ecosystem types	**2000**	**2006**	**2012**	**2018**
Inland wetlands (area)	98,452	97,999	98,106	98,003

Inland wetlands, although constituting 2.2% of the total EU-28 land area, are considered an ecosystem of key importance due to their unique ecological and hydrological features. The inland wetland class is made up of peatbogs[69], covering 89% of the entire class, and inland marshes[70] (11%) (Table 3.4.4).

Table 3.4.4. Habitat extent (km^2) of inland marshes and peatbogs for the period 2000-2018

Wetland class	**2000**	**2006**	**2012**	**2018**
Inland marshes	10,593	10,611	10,704	10,641
Peatbogs	87,859	87,388	87,403	87,362

In 2018 the largest surface of inland marshes in Europe is found in Romania (2,897 km^2 and 27.2% of the total EU-28 inland marsh extent), and in Poland (1,021 km^2 and 9.6% of the EU-28 extent).

Major peatbogs habitats are concentrated mainly in four countries, Sweden, United Kingdom, Finland and Ireland, making 94.7% of the extent of peatbogs at EU-28 level. While, collectively, peatbogs represent 2% of the EU-28 land surface, within these four countries, peatbogs are a significant proportion of the total land cover (Table 3.4.5).

Table 3.4.5. Share of the EU-28 peatbogs extent (%) of the national surface area for the four countries where most European peatbogs is located

Country	**Share of the EU-28 peatbogs extent (%)**	**Share of the national surface extent (%)**
Sweden	33.7	6.5
United Kingdom	26.1	9.2
Finland	24	6.2
Ireland	11	13.5

Compared to other continents, Europe has historically suffered the greatest loss in mires (synonymous with any peat-accumulating wetland, hence including bogs and fens) (Parish et al., 2008). Approximately two thirds of European wetlands at the beginning of the 20th century have now been lost (CEC, 1995); peat formation has stopped in about 60% of the original mire area and possibly 10-20% is not even peatland anymore (Joosten, 1997).

The conversion of natural mire habitats to agriculture and productive forestry land uses can be considered the main drivers of habitats decline during recent and less recent times (e.g. Lindsay et al., 1988), and the decline

[69] Wetlands with accumulation of considerable amount of decomposed moss (mostly Sphagnum) and vegetation matter. Both natural and exploited peatbogs. (CORINE Land Cover inventory; https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/html/index-clc-411.html)

[70] Low-lying land usually flooded in winter, and with ground more or less saturated by freshwater all year round (CORINE Land Cover inventory; https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/html/index-clc-411.html)

is continuing (Janssen et al., 2016). Substantial transformations in their use and cover have converted these wetland areas into wastelands, reverting in most cases their condition from carbon sink to carbon source.

The loss of more than 70% of inland wetlands between 2000 and 2018 has been caused by land conversion; i.e. conversion of inland wetland areas to agricultural, forest and semi-natural areas (Figure 3.4.1). This loss of inland wetlands is driven by a decrease of ~0.5% in the extent of peatbogs (dominant in Europe) while inland marshes extent, smaller than peatbogs (Table 3.4.4), shows a slight increase over time. However, the slight decreasing trend in peatbogs loss after 2006 is influenced by the ongoing conservation and restoration efforts of peatlands across Europe.

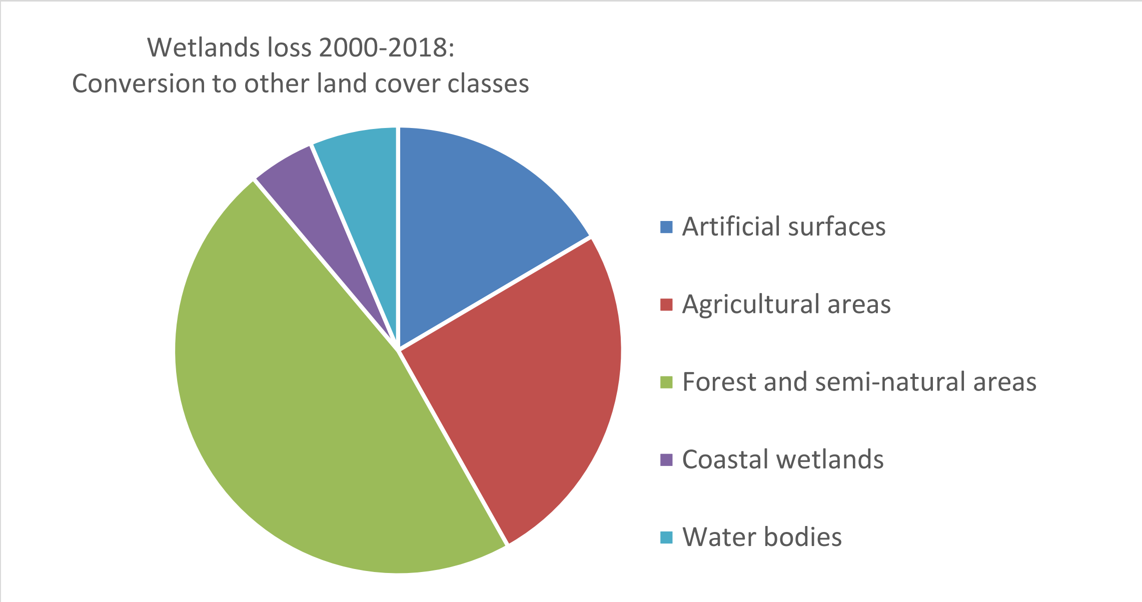

Figure 3.4.1. Conversion of inland marshes and peatbogs to other land cover classes between 2000 and 2018.

Box 3.4.2 showcases few examples on mires habitats restoration and conservation initiatives developed at local scale during the last thirty years which success has probably played a role in the trend observed concerning a decreasing inland wetland loss after 2006.

Box 3.4.2

Some examples of successful EU-LIFE projects carried out in the EU-28 countries where most peatbogs are found have been used here to showcase how local-scale projects can effectively contribute to reduce the loss of wetlands in Europe detected in the trend analysis developed in the frame of the EU MAES wetland assessment.

The "Restoration of Scottish raised bogs" project (2000-2003) focused on 45% of the lowland raised peatbogs area remaining in the UK. The project not only brought back 12.5 km^2 of raised peatbogs to a favourable condition but increased its area by 3.5 km^2 through the clearance of trees, scrub and heather (EU, 2007). In the same area, the project "Restoring active blanket bogs of European importance in North Scotland" (2001-2006) managed to recover 15.5 km^2 of blanket peatbogs, removing commercial forestry to restore the original habitat and improved the conditions of some additional 166 km^2 by blocking drainage.

In Sweden, the project "Life to Ad(d)mire" (2010-2015) improved the hydrological conditions of more than 400 km^2 of peatbogs land mainly in areas previously converted to agriculture and subsequently abandoned.

In Finland, within the "Boreal Peatland Life" Project (2010-2014), the hydrology of areas of bogs and mires was restored in 48 km^2 while additional 33 km^2 were recovered by means of trees removal.

These local-scale projects have also a long-term effect due to the dissemination work. Projects' newsletters and open days helped to raise awareness of the ecological importance of this ecosystem, countering their usually negative perception hence indirectly favouring their conservation (EU, 2007).

The change observed in the period 2000-2018 was driven by the loss of peatbogs mainly in the Atlantic biogeographical region, which accounts for 35% of the total inland wetlands' extent in EU-28 and suffered the biggest loss in absolute terms. As shown in the following section on the habitat conversion indicator, when looking at trends of habitat conversion and relative changes over the time period 2000-2018, the Black Sea and Mediterranean regions show the highest rates of relative wetland loss in Europe. Though these regions have a very low share of the European inland wetlands (between 0.6 and 1.3%), they have suffered the largest losses in relative terms (between 1.5 and 2%).

3.4.3.2 Data

The assessment of the condition of and pressures on inland wetlands, including inland marshes and peatbogs, is based on the guidelines set for the definition of inland wetlands (Maes et al., 2013) and the specific indicators selected for conditions and pressures (Maes et al., 2018). Data on pressure and condition indicators are presented respectively in Tables 3.4.6 and 3.4.7, which summarize the indicators data period and spatial resolutions used for the assessment (details on data sources can be found in the specific indicator fact sheets indicated in the table).

Table 3.4.6. Inland wetlands indicators of pressure selected for the MAES study, unit, data period, spatial resolution and scale. Dataset sources are reported in the fact sheets. All fact sheets are available as a supplement to this report.

<table>
<tr><th>Pressure class</th><th colspan="2">Indicator</th><th>Fact sheet number</th><th>Unit</th><th>Data period</th><th>Spatial resolution</th></tr>
<tr><td>Habitat conversion and degradation (Land conversion)</td><td colspan="2">Change of area due to conversion (SEBI004)</td><td>3.4.101</td><td>(% / 6 years)</td><td>2000-2018</td><td>100x100 m², EU-28</td></tr>
<tr><td rowspan="3">Climate change</td><td colspan="2">Drought events frequency (DRF)</td><td>4.1.101</td><td>Number of drought events / 5 years</td><td>1950-2018</td><td>0.25 degree (~25x25 km²), EU-28</td></tr>
<tr><td colspan="2">Extreme drought frequency (ExDRF)</td><td>4.1.101</td><td>Number of extreme drought events / 5 years</td><td>1950-2018</td><td>0.25 degree (~25x25 km²), EU-28</td></tr>
<tr><td colspan="2">Soil moisture (soil water deficit)</td><td>4.1.101</td><td>%</td><td>1951-2013</td><td>5x5 km², EU-28</td></tr>
<tr><td>Atmospheric pollution and nutrient enrichment</td><td colspan="2">Exposure to eutrophication</td><td>3.4.102</td><td>mol nitrogen eq / ha / year</td><td>2000-2016</td><td>0.25 degree (~25x25 km²), EU-28</td></tr>
<tr><td rowspan="2">Over-exploitation</td><td rowspan="2">Agriculture intensity pressure on wetlands</td><td>Non-atmospheric nitrogen inputs to soil</td><td>3.4.103</td><td>Kg / ha / year</td><td>2000-2012</td><td>Homogeneous Spatial Units (HSU), EU-27</td></tr>
<tr><td>Extent of agricultural area around inland marshes and peatbogs</td><td>3.4.103</td><td>%</td><td>2000-2018</td><td>100x100 m², EU-28</td></tr>
<tr><td>Other</td><td colspan="2">Soil sealing</td><td>3.4.104</td><td>km² / year</td><td>2006-2015</td><td>100x100 m², EU-28</td></tr>
</table>

Table 3.4.7. Inland wetlands indicators of condition selected for the MAES study, units, data period, spatial resolution and scale. Dataset sources are reported in the fact sheets. All fact sheets are available as a supplement to this report.

Condition class	Indicator	Fact sheet number	Unit	Data period	Spatial resolution
Structural ecosystem attributes (general)	Wetlands connectivity	3.4.201	km	2000-2018	100x100 m^2, EU-28
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Share of bogs, mire and fens habitats listed under Annex 1 of the Habitats Directive in favourable conservation status	3.5.203	Percentage	2013 - 2018	EU-28
	Trends in unfavourable conservation status of bogs, mires and fens habitats listed under Annex 1 of the Habitats Directive	3.5.203	Percentage	2013 - 2018	EU-28
	Percentage of wetlands area covered by Natura 2000	3.4.202	%	2000-2018	Biogeographical region, EU-28
	Percentage of wetlands area covered by Nationally Designated Areas	3.4.203	%	2000-2018	Biogeographical region, EU-28

3.4.3.3 Drivers and pressures: spatial heterogeneity and change over time

In this section pressure indicator values and trends are presented and discussed.

3.4.3.3.1 Assessment at the level of EU-28

For each indicator, the value of the percentage change over the last decades is reported for both short- and long-term trends in Table 3.4.8. Most of the indicators show that the short-term and long-term trends of pressures are stable in inland wetland habitats except for their exposure to eutrophication, which shows a significant reduction over the study period. On the other hand, the trends observed in the soil sealing indicator for inland wetland habitats show clear significant increasing pressure caused by artificialisation of areas within and around inland wetland habitats, increasing consequently the degradation and fragmentation of these habitats in both the short and long term. A short insight into the relevance of the reported pressure indicators for inland wetlands and into detected trends is provided in the following section. Climate change indicators are crosscutting indicators which are common to other ecosystem assessments. They are described in fact sheets 4.1.109 (Drought events frequency), 4.1.108 (Extreme drought events frequency) and 4.1.112 (Soil moisture). In table 3.4.6, the fact sheet for all climate change indicators is 4.1.101.

Table 3.4.8. EU aggregated pressure data for inland wetland ecosystems.

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation (Land conversion)	Change of area due to conversion (SEBI004)	(% / 6 years)	0.11%	-0.36	→	7	0.30%	→	7
Climate change	Drought events frequency (DRF)	Number of drought events / 5 years	1.25		unresolved		1.39	→	8
	Extreme drought frequency (ExDRF)	Number of extreme drought events / 5 years	0.2		unresolved		8.98	↓	8
	Soil moisture (soil water deficit)	%	13.5		unresolved		-0.35	→	6
Atmospheric pollution and nutrient enrichment	Exposure to eutrophication	mol nitrogen eq / ha /y	65.4	-20.7	↑	5	-34.2	↑	5
Over-exploitation	Agriculture intensity pressure on wetlands: Nitrogen inputs to soil	Kg / ha / year	31.3		unresolved		2.09	→	5
	Agriculture intensity pressure on wetlands: extent of agricultural area around inland marshes and peatbogs	%	8	-0.13	→	5	-2.26	→	6
Other	Soil sealing	km^2	28.2	6.48	↓	6	6.81	↓	7

↑: Significant improvement (significant downward trend of pressure indicator) - →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant upward trend of pressure indicator) - Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

3.4.3.3.2 In-depth assessment

Habitat conversion: The land accounts have been used to develop the habitat conversion indicator to assess the trends of changes in extent according to three time periods (2000-2006, 2006-2012 and 2012-2018). "Land accounts describe, in a consistent and systematic way, the amount of land stock and its changes over time" (EEA, 2019).

The indicator (Table 3.4.9) shows that, over the assessed time periods, there is a loss of inland wetland habitats through habitat conversion (conversion of wetland habitats to other habitats) between the year 2000 and 2006. A slight inland wetland gain (0.11% / 6 years) is perceived between 2006 and 2012 that seems to be lost again between 2012 and 2018.

Table 3.4.9. Change of inland wetland area due to habitat conversion (% / 6 years) for the three time periods for which CLC data are available

Indicator	**2000-2006**	**2006-2012**	**2012-2018**
% / 6 years	-0.46	0.11	-0.11

The *short-term* trend (2006-2012 to 2012-2018) and the *long-term* trend of the indicator (2000-2006 to 2012-2018) for EU-28 are computed as percentage change per decade and, in both cases, the pressure exerted on inland wetlands through habitat conversion is stable.

Within Europe though, spatial differences in the trends are detected between 2000 and 2018, where the highest trends in inland wetland habitat loss are found (in percentage terms relatively to the extent of inland wetlands) in the Mediterranean and Black Sea biogeographical regions. This result is in line with the outcomes depicted in the Mediterranean Wetlands Outlook 2 report (MWO2 report, 2018). On the other hand, the European Continental biogeographical region shows a slight gain in inland wetland habitats over time. More details are available in fact sheet 3.4.101.

Overexploitation: Overexploitation is expressed as the pressure on wetlands resulting from the intensification of agricultural activities undertaken in the surroundings of inland wetland habitats. Two indicators are developed to assess this pressure and its trends in inland wetland habitats over time. The first indicator assesses the nitrogen input into soil and the second indicator assesses the agricultural area extent around wetlands. For both indicators on agricultural intensification/overexploitation, the trends of these pressures have been assessed over time. More on the scope and description of both indicators is available in fact sheet 3.4.103.

Non-atmospheric nitrogen input to soil around inland wetlands: At European level, nitrogen input to soil around inland wetland habitats shows a stable trend over time of the assessed period. Nevertheless, the average nitrogen input rates (kg/ha) calculated in 2012 in the proximity area of inland wetland habitats show clear spatial differences (Figure 3.4.2). Inland marshes and peatbogs in the northern part of Central Europe undergo higher pressures than the rest of European inland wetlands with a wide hotspot in the Netherlands and high values also in Germany, South of Denmark and West of France. Values also peak in the southern half of Ireland. Inland marshes and peatbogs in Southern and Eastern Europe generally experience a lower pressure, but hotspots are visible in the Po valley in Italy, central Greece and eastern Hungary, with peaks in the Danube delta.

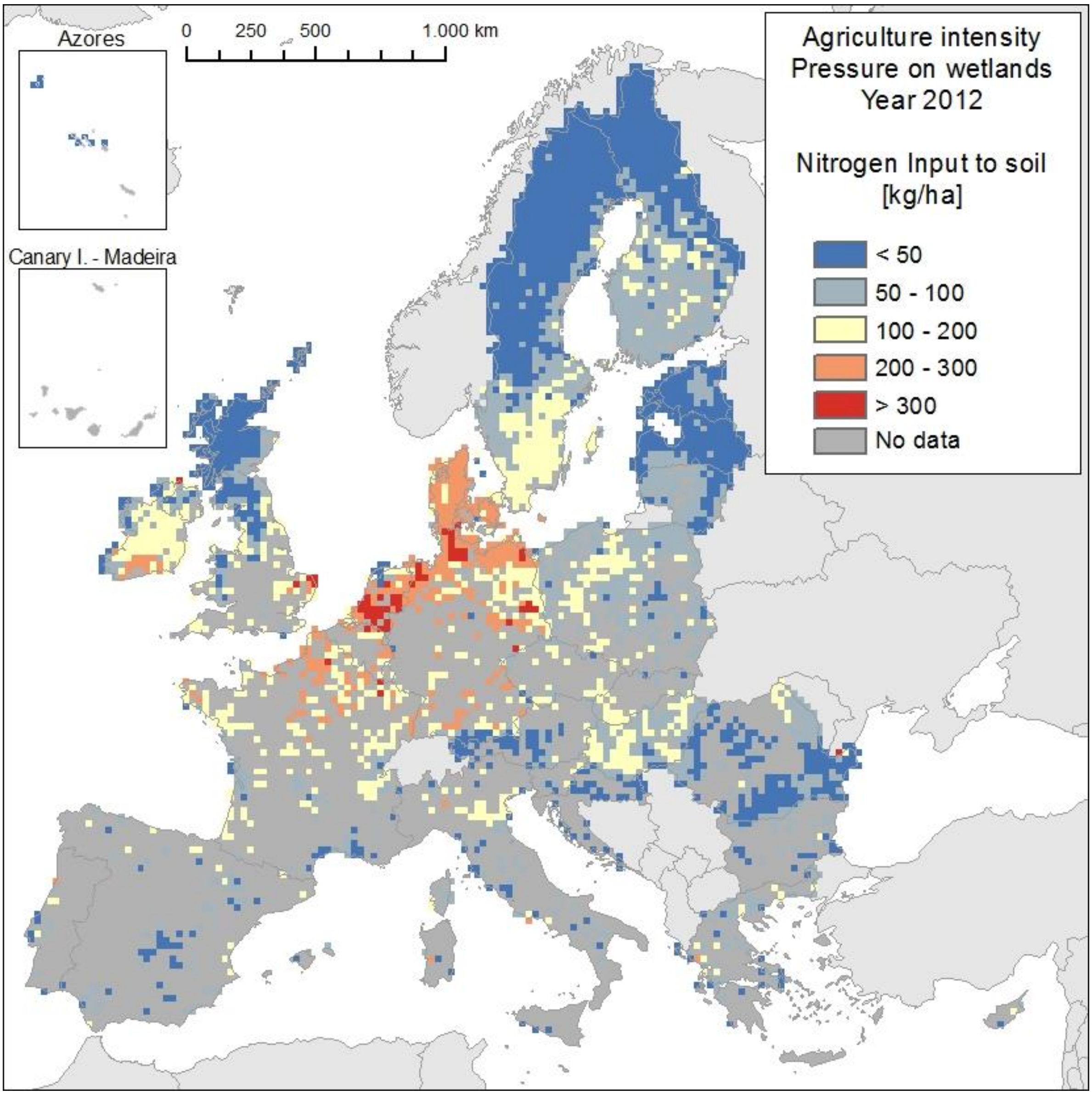

Figure 3.4.2. Pressure on inland marshes and peatbogs from nitrogen input to soil (latest available information from year 2012)

Agriculture area extent around inland wetlands: This indicator defines the percentage of agricultural area around inland marshes and peatbogs considered to have a potential impact on these habitats. This area has been defined through a buffer area of 10km radius around each inland wetland body. See fact sheet number 3.4.103 for more details.

Figure 3.4.3 shows no clear spatial pattern for the year 2012 at European level, with the exception of Scandinavia and most of the United Kingdom and Ireland where the pressure is very low. The general spatial pattern of the agriculture area extent around inland wetland habitats is not always coincident with the pattern of nutrient input pressure around these habitats. In particular, the percentage of surrounding area used for agriculture is very high in Romania and Spain while the pressure from nutrient load is lower. The opposite trend is visible, for instance, in Ireland.

At EU-28 level, both indicators are consistent in revealing that the pressure from overexploitation on inland wetlands is stable in both long- and short-term trends; the short-term trend for the first indicator has not been calculated due to lack of recent data.

More information on the spatial and temporal trends of overexploitation in Europe is reported in indicator fact sheet number 3.4.103.

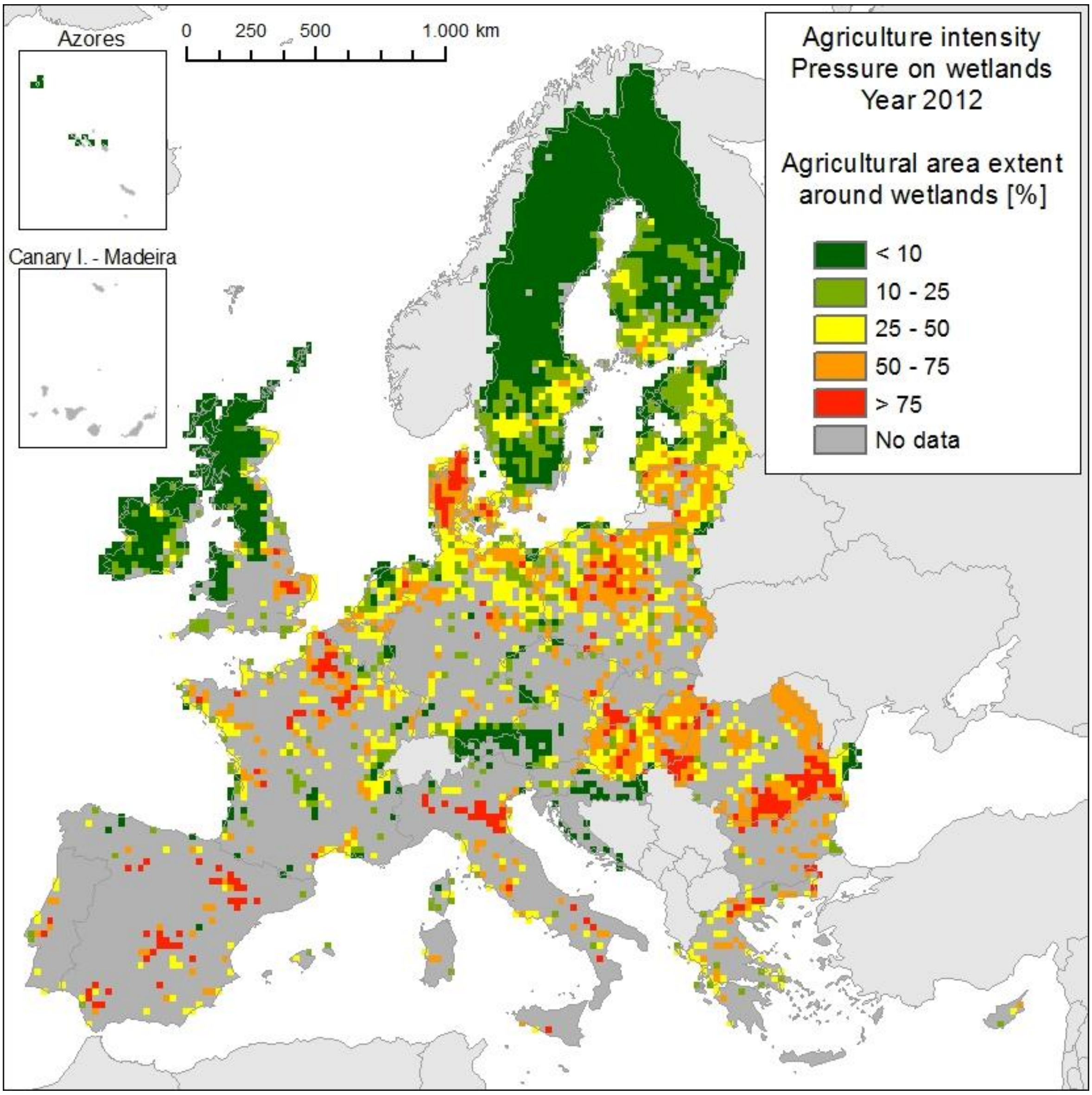

Figure 3.4.3. Pressure on wetlands from agricultural intensification: percentage of agricultural land use in the proximity of inland marshes and peatbogs (latest available information from year 2012)

Atmospheric pollution and nutrient enrichment: In addition to non-atmospheric nitrogen inputs, atmospheric pollution is also a considerable source of pressure on inland wetlands where exceedances in nutrients dumped in the environment are directly linked to hydrological alterations encompassing shifts in vegetation patterns and nutrient cycling, and so worsening the condition of wetlands. One of the effects of the over-enrichment of minerals and nutrients on inland wetlands is the significant increase of primary productivity in what are naturally low nutrients/production systems.

The indicator on atmospheric pollution and nutrient enrichment shows the exposure of inland wetland ecosystems to eutrophication through mean accumulated exceedance of critical loads for eutrophication by nitrogen (EMEP, 2018). More on the scope and description of the indicators is available in fact sheet 3.4.102.

The most recently reported critical load exceedances in Europe (year 2016, Figure 3.4.4) show that critical loads for eutrophication by nitrogen on inland marshes and peatbogs are exceeded everywhere with hotspots in Denmark, northern Germany, the Netherlands and northern Italy. The only exception to this trend is northern Scandinavia and northern UK that show critical load levels below the exceedance rate.

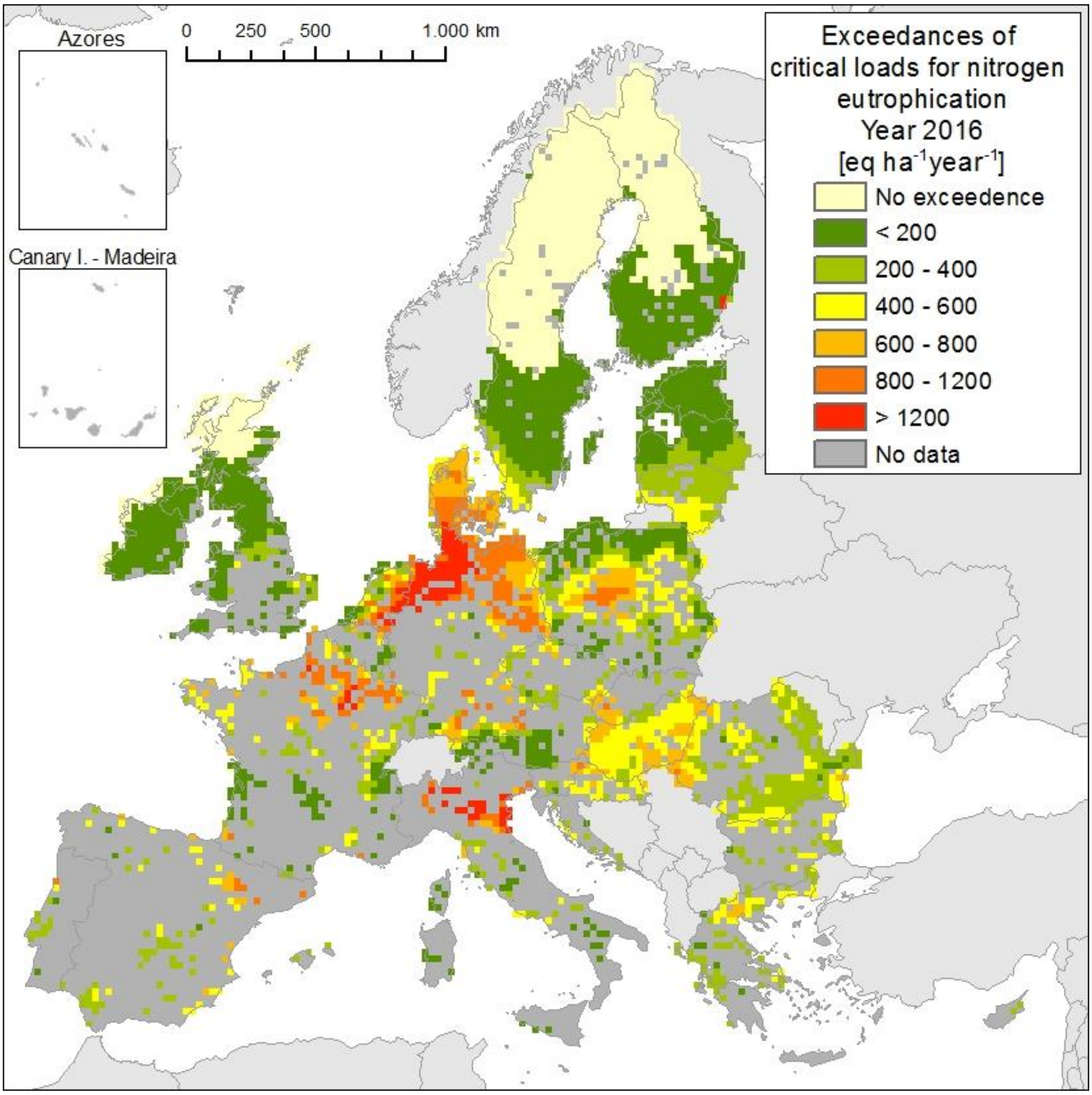

Figure 3.4.4. Exceedances of critical loads for eutrophication in inland wetlands calculated using the 2016 nitrogen depositions

At EU-28 level, the indicator shows a reduction in load values during the time period of the assessment, although the critical threshold is still exceeded. The assessment reveals that the pressure from eutrophication on inland marshes and peatbogs, although very high almost everywhere, is decreasing both in short- and long-term trends.

More information on the spatial and temporal short-term trends of atmospheric pollution and nutrient enrichment in Europe is available in the indicators' fact sheet number 3.4.102.

Soil sealing: Soil sealing, expressed as "the substitution of the original (semi) natural land cover or water surface with an artificial, often impervious cover" (Copernicus services, 2019), can be considered a quantifiable land use indicator closely correlating with impacts on water resources (Arnold et al., 1996). It has a direct impact on wetlands in terms of reducing their extent and altering their hydrological balance, and an indirect impact on water quality, supporting land uses which generate pollution.

The indicator on the pressure of soil sealing on inland wetlands builds on the work of Hicks (1995) who defined a direct relationship between wetland habitat quality and impervious surface area, with wetlands being impacted once the imperviousness of the local drainage basin exceeds 10%.

Both short- and long-term trends (2010-2015 and 2006-2015, respectively) show that the condition of inland marshes and peatbogs as measured by this indicator is degrading over time. The extent of inland marshes and peatbogs' soils being sealed is increasing at a rate of 6.5% and 6.8% per decade for short- and long-term respectively.

For more information on the assessment results of soil sealing on inland wetland ecosystems in Europe, please refer to the indicators' fact sheet number 3.4.104.

3.4.3.4 Ecosystem condition: spatial heterogeneity and change over time

In this section, condition indicator values and trends are presented and discussed.

3.4.3.4.1 Assessment at the level of EU-28

The overview presented in Table 3.4.10 provides a summary of the results achieved per indicator, where the value of percentage change over a decade is reported for both the short- and long-term trends. The trends in the condition of inland wetland ecosystems were assessed based on two sets of indicators linked to trends in wetland connectivity and trends in structural ecosystem attributes from data reported under the EU Nature directives.

Trends in the condition of inland wetlands show stable short-term and long-term trends for most indicators, except for the long-term wetland connectivity indicator. This reveals further degradation, i.e. less connectivity between inland wetlands in the long term.

Two indicators are directly derived from the Art.17 reporting on the conservation status of habitats under the Habitats Directive. The total area of bogs, mires and fens that is covered under Annex 1 of the Habitats Directive is 137,738 km2 (see chapter 2, Table 2.2). This area is in fact more than the inland wetland area reported in Table 3.4.3. This discrepancy is related to the lack of a clear definition of wetland habitats and emphasizes again the need for an appropriate classification of wetlands and crosswalks between the different ecosystem typologies. The EU level assessment of the conservation status of 13 bogs, mires and fens habitats (Annex I of this chapter) concluded that only 10.7% are in good (or favourable) conservation status. The remaining habitats are in poor (35.7%), bad (51.8%) or unknown status (1.8%) (State of Nature report for the period 2013-2018, forthcoming). Only 4% of the bogs, mires and fens habitats that is in an unfavourable status is showing improving trends while 64% of is showing deteriorating trends.

A short insight into the relevance of the reported condition indicators for inland wetlands and into detected trends is provided in the following section.

3.4.3.4.2 In-depth assessment

Wetlands connectivity: A well-connected network of wetland habitats is crucial for the ecological functioning of this ecosystem since its deterioration can have a significant impact, among others, on flood regulation and on water bird populations (Merken et al., 2015). The spatial distribution of wetlands is a key aspect in determining their connectivity (Amezaga et al., 2002) as well as addressing management and planning efforts to restore and maintain connectivity patterns (UN Environment, 2017).

Wetland connectivity can be assessed by means of articulated and complex metrics (Wang et al., 2014). In this case, given the continental scale of our analysis, the simplest measure for structural connectivity is calculated as the distance from one wetland to its nearest neighbouring wetland (Calabrese and Fagan, 2004).

Looking at the latest information available (year 2018, Figure 3.4.5), the spatial pattern of the inland wetlands' connectivity indicator shows better connected inland wetlands in northern European countries, with increasing disconnection between wetlands following a southward gradient. This result is related to a higher density of inland marshes and peatbogs, more present in northern European countries.

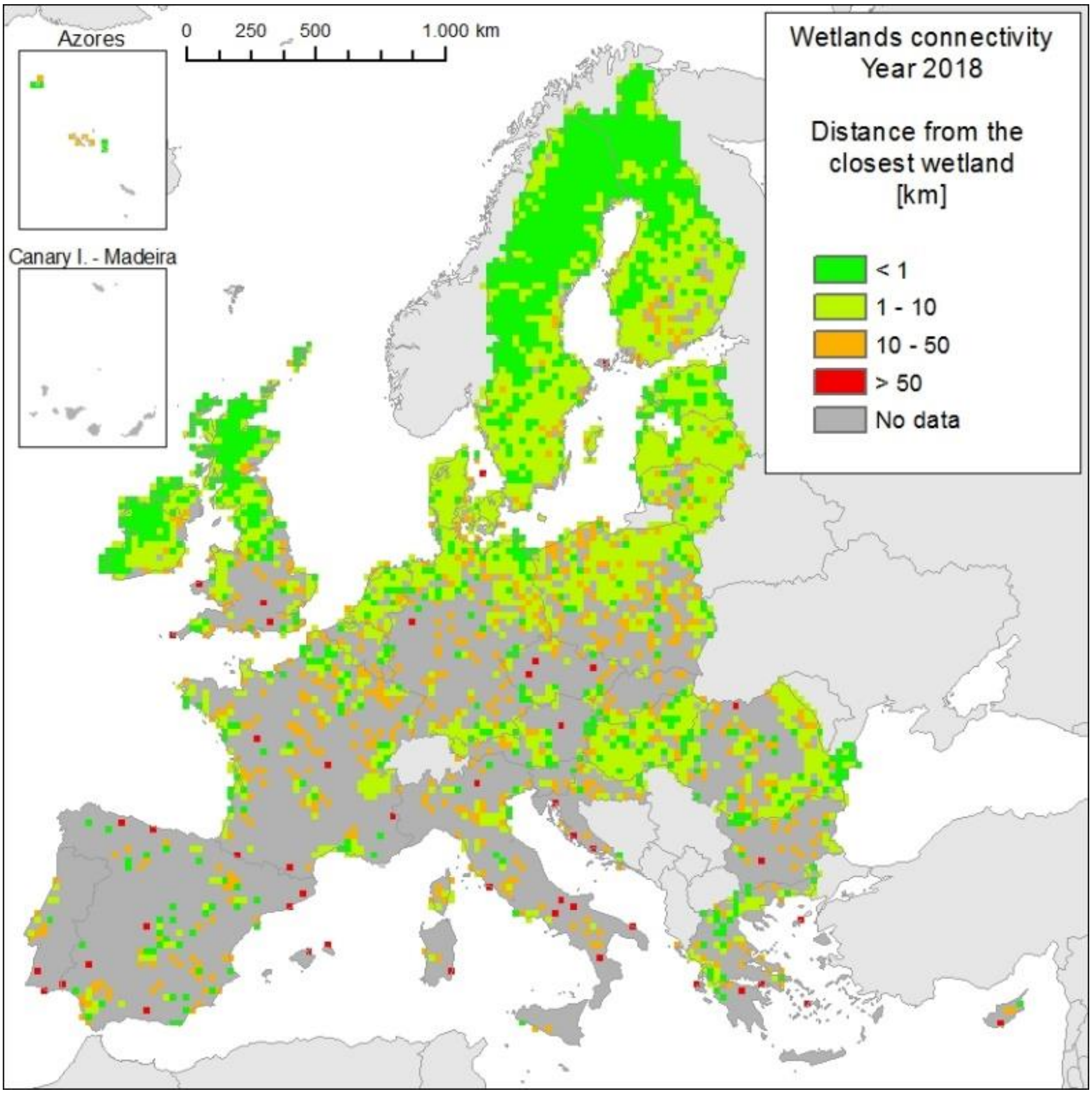

Figure 3.4.5. Inland marshes and peatbogs connectivity for year 2018

Table 3.4.10. EU aggregated condition data and trends in the conservation status of habitats in inland wetland ecosystems.

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Structural ecosystem attributes (general)	Wetland connectivity	km	1294	0,91	→	7	1,52	↓	8
Structural ecosystem attributes monitored under the EU Nature directives and national legislation	Share of bogs, mire and fens habitats extent listed under Annex 1 of the Habitats Directive in favourable conservation status*	%	10.7						
	Trends in unfavourable conservation status of bogs, mires and fens habitats listed under Annex 1 of the Habitats Directive*	% improving		4.0	↑				
		% stable		22.0	→				
		% deteriorating		64.0	↓				
		% unknown		10.0	unresolved				
	Percentage of wetlands covered by Natura 2000	%	38,6	-2,05	→	7	-1,43	→	8
	Percentage of wetlands covered by Nationally Designated Areas	%	33,9	0,09	→	7	0,31	→	8

↑: Significant improvement (significant upward trend of condition indicator) - →: No change (the change is not significantly different from 0% per decade)
↓: Significant degradation (significant downward trend of condition indicator) - Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

* The indicators on bogs, mires and fens habitat conservation status have been treated differently than the other indicators with a different baseline year and different time period (2013–2018); so the percent change is expressed for a period of 6 years instead of 10 as for the other indicators. The trends in conservation status are only available for bogs, mires and fens habitats in an unfavourable conservation status. Please check chapter 2 for details.

Looking at the trends at EU-28 level, while the condition is stable in the most recent timeframe (2012-2018), the long-term trend condition (2000-2018) indicates a statistically significant decrease in connectivity and a degrading condition of the ecosystem. This should be placed in the context of restoration efforts developed in Europe in recent years: as the loss of habitat is mainly happening in the first reporting period (2000-2006), also the connectivity values have become more stable in the following years.

For more information on the methodology used to develop the European inland wetland connectivity indicator and the spatial and temporal trends, please refer to the indicators' fact sheet number 3.4.201.

Percentage of wetlands area covered by Natura 2000 and Nationally Designated Areas: The indicators developed using the Natura 2000 network database for Europe and the EEA's Common Database on Designated Areas (CDDA), which cover "nationally designated protected areas", areas designated as protected by a national designation instrument, based on national legislation, show the coverage of inland wetlands monitored under the EU Nature Directives (Figure 3.4.6). More information about the development of this indicator can be found in the indicator fact sheet number 3.4.202 and 3.4.203.

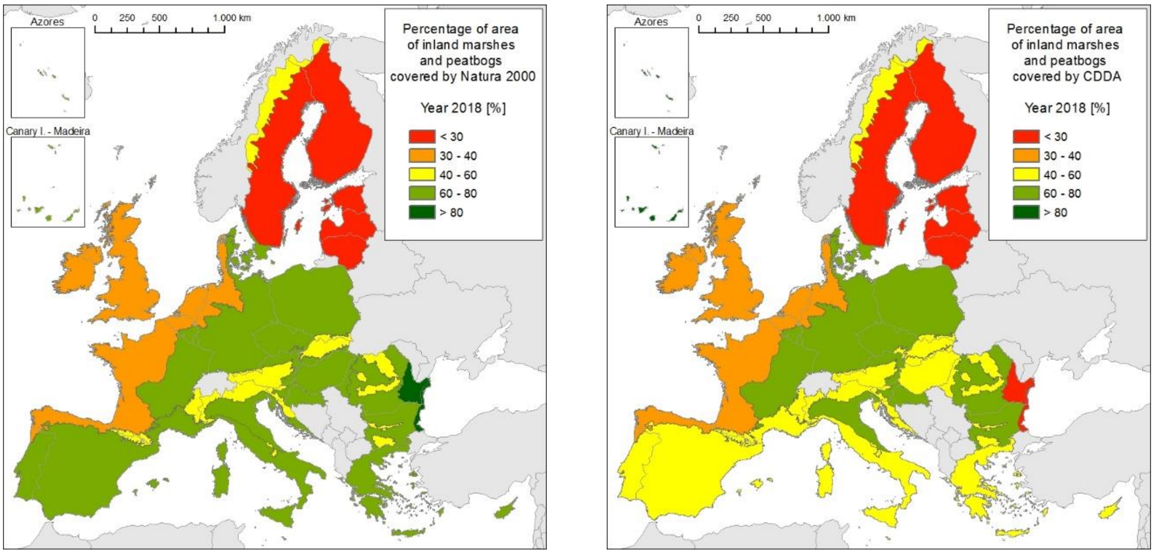

Figure 3.4.6. Percentage of protected inland marshes and peatbogs area by biogeographical region in the year 2018, under Natura 2000 (left) and CDDA (right)

The spatial trends in percentage of inland marshes and peatbogs covered under both Natura 2000 and CDDA show lower values in the north of Europe, where the extent of inland wetland habitats is very high compared to the southern region. Clear differences are visible between the two instruments; a relatively small share of inland wetlands in the Mediterranean, Black Sea and Steppic biogeographical regions are covered by the national designation. At the same time, the European designation, although specifically targeting only one particular type of habitat (habitats of Community interest) seems to help filling this gap. As it could be expected in regions where the extent of the wetland ecosystem is very limited, Natura 2000 sites cover almost 80% of the inland wetlands' extent in the Mediterranean region and more than 90% in the Steppic and Black Sea regions.

According to this analysis, at European level 5% of the whole Natura 2000 network is made up of inland marshes and peatbogs habitats; 37% of the whole inland wetland ecosystem is listed under this scheme. As for the trends analysis at EU-28 level, there are no significant changes in the extent of covered inland wetland habitats under Natura 2000 or CDDA, neither in the short nor in the long term, suggesting that, despite the poor condition of these habitats, there has been no significant increase in the protection coverage of inland wetland habitats in the last two decades.

3.4.3.5 Convergence of evidence

3.4.3.5.1 Summary of the trends in pressure and condition

Table 3.4.11 summarizes the short- and long-term trends of pressures and condition indicators. The table does not include the indicators on habitat conservation status as they do not result in a single trend (but rather a proportion for each trend).

Trends of pressures on inland wetlands were calculated using 8 indicators with available data. The assessment reveals that in the short-term trend, one indicator shows negative change resulting in degradation, two no change, one a positive change resulting in improvement, and four are unresolved. In the long-term trend, two indicators show negative change resulting in degradation, five no change and one a positive change resulting in improvement.

Trends of inland wetlands condition were calculated using 3 indicators with available data. In the long-term trend no indicator show improvement, two show no change, and one degradation.

Table 3.4.11. Summary of trends in pressure and condition of the inland wetland ecosystems in the EU-28.

	Indicator	**Short-term trend - Since 2010**	**Long-term trend**
Pressures	Change of area due to conversion	→	→
	Drought events frequency	unresolved	→
	Extreme drought events frequency	unresolved	↓
	Soil moisture	unresolved	→
	Exposure to eutrophication	↑	↑
	Nitrogen inputs to soil	unresolved	→
	Extent of agricultural area around inland marshes and peatbogs	→	→
	Soil sealing	↓	↓
Condition	Wetland connectivity indicator	→	↓
	Percentage of wetlands covered by Natura 2000	→	→
	Percentage of wetlands covered by Nationally Designated Areas	→	→

↑: Significant improvement (significant downward trend of pressure indicator; significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade)
↓: Significant degradation (significant upward trend of pressure indicator; significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment
Indicators of conservation status of habitats, species and birds are excluded.

The main conclusions of the assessment of the condition of inland wetland ecosystems (long-term trends) indicates that, despite being already very poor (section 1.1.3.4.1), the condition of inland wetlands shows no improvement; on the contrary, a significant share of the indicators is showing signs of further degradation.

It is to note though, that a shortfall of this assessment is the limited number of indicators used due to data unavailability. In addition, two of the indicators used[71] are partially redundant, since they refer to the extent of the ecosystem covered by national or international protection schemes. Nevertheless, the results are in line with the trends highlighted in the pressure assessment: most of the pressure indicators show increasing or stable pressure on the ecosystem during the timeline of the assessment, suggesting a likely cause-effect relationship between pressures and condition.

[71] The two indicators being the “Percentage of wetlands covered by Natura 2000” and the “Percentage of wetlands covered by Nationally Designated Areas”.

3.4.3.5.2 Mapping convergence of evidence

The indicators used for the assessment of the inland wetland ecosystem have been computed for each wetland body, where possible. Whenever the information was available at high resolution, trends assessed at this scale were attributed to the dependent wetland polygons. When the input data was not spatially explicit, no trend was computed.

A spatially explicit trend was computed for eight of the indicators[72] used to calculate short- and long-term trends of pressures and condition (Table 3.4.11). Based on this spatially explicit information, it was possible to assess the level of degradation, improvement or no change in the condition of each of the wetland bodies. Figure 3.4.7 shows the total extent of the ecosystem estimated to be under degradation, according to the number of indicators showing this trend.

More than 40% of the area of peatlands and marshes shows degradation signs based on one or more indicators. While the convergence of evidence has been mapped for each wetland feature, the maps in Figure 3.4.8 are shown at a lower resolution (25 km pixel size) for ease of visualization.

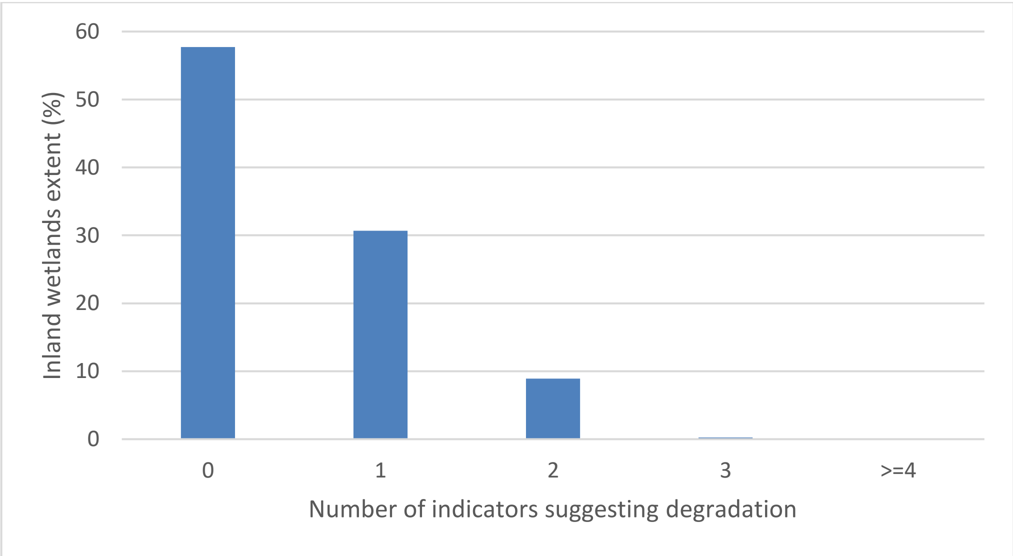

Figure 3.4.7. Percentage extent of the inland wetlands' ecosystem in relation to the number of indicators suggesting degradation

[72] The eight indicators being Drought events frequency; Extreme drought events frequency; Soil moisture; Exposure to eutrophication; Nitrogen inputs to soil; Extent of agricultural area around inland wetlands; Soil sealing; Connectivity.

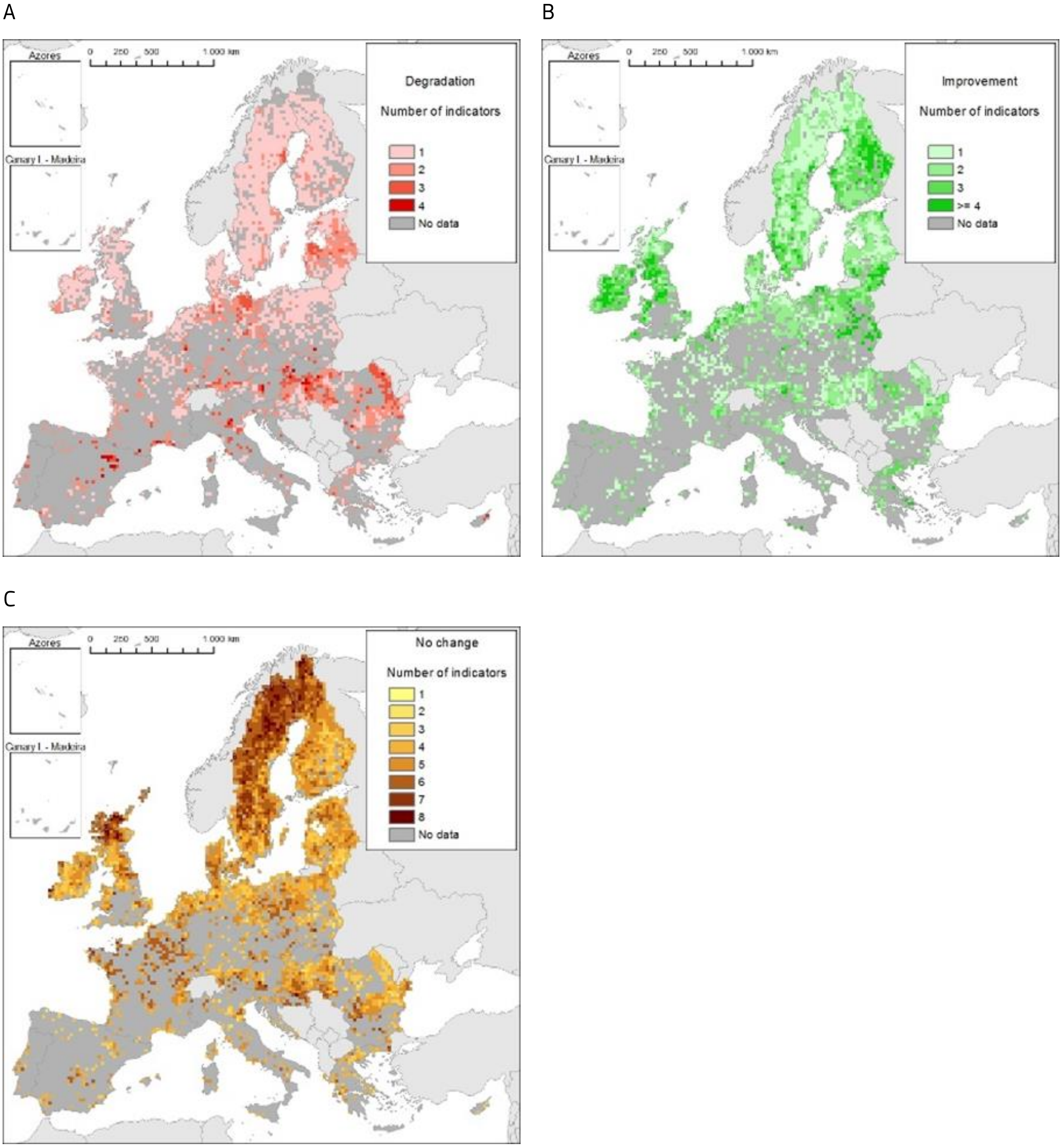

Figure 3.4.8. Convergence of evidence mapping: Summary of indicators. A) Degradation; B) Improvement and C) No change. The numbers in the legends indicate the number of indicators where significant trends were found.

While the signal of no change in inland wetlands condition is supported by a high number of indicators all across Europe, in particular in Sweden, Scotland and France, degradation trends are suggested by a higher number of indicators in the Mediterranean region and in Eastern Balkans and hotspots are also visible in eastern Germany and western Latvia. On another note, the strongest indication of improvement in the condition of inland wetlands are visible in northern UK, Ireland and south of Finland, possibly as a response to the local restoration actions implemented for the last decades in these areas (Box 3.4.2).

3.4.4 Coastal wetlands: description of the ecosystem

Coastal wetland habitats are defined in the MAES framework as “Marine” (level 1) and “Marine inlets and transitional waters” ecosystem types (level 2). The Marine inlets and transitional waters ecosystem types are defined in the first MAES report, page 24 (Maes et al, 2013), as “ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5 ‰” which, beside coastal wetlands, also include “lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments”.

Coastal wetlands remain a major knowledge gap to address in MAES as there are very little core indicators in place to assess them. Efforts need to prioritize future assessment of coastal wetland habitats using an ecosystem-based definition which includes the diversity of wetland habitats as well as their interconnected hydro-ecological nature which overlaps with other ecosystems as well. This assessment provides some fragmented information as a baseline to build a first understanding of the limited knowledge available at present. Such a baseline needs to be considered as a basis of a more comprehensive future assessment.

3.4.4.1 Coastal wetland ecosystem extent and change

The coastal wetland ecosystem covers only 0.6% of the whole ecosystem extent at EU-28 level. It is made up of five classes (Table 3.4.12) constituting by far the smallest MAES ecosystem (the second smallest is the Sparsely Vegetated Land ecosystem that is almost three times as big). The definition of the five classes according to the CORINE land cover inventory is given in Table 3.4.13.

Table 3.4.12. Ecosystem extent of coastal wetlands (km^2) for the period 2000-2018

Coastal wetlands	**2000**	**2006**	**2012**	**2018**
Salt marshes	3,830	3,851	3,860	3,865
Salines	532	533	533	539
Intertidal flats	10,923	10,944	10,936	10,936
Coastal lagoons	5,768	5,773	5,766	5,765
Estuaries	3,674	3,672	3,672	3,671
Total	24,727	24,773	24,767	24,776

The extent of this ecosystem in the EU-28 remains substantially stable over the 2000 to 2018 period, with a slight increase of 0.2% (49 km^2).

Table 3.4.13. Definition of the five classes included in the coastal wetland ecosystem (Source: https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/html/index.html)

Coastal wetland class	CORINE Land Cover inventory definition
Coastal salt marshes	Vegetated low-lying areas in the coastal zone, above the high-tide line, susceptible to flooding by seawater. Often in the process of being filled in by coastal mud and sand sediments, gradually being colonized by halophilic plants
Salines	Salt-pans for extraction of salt from salt water by evaporation, active or in process of abandonment. Sections of salt marsh exploited for the production of salt, clearly distinguishable from the rest of the marsh by their parcellation and embankment systems
Intertidal flats	Coastal zone under tidal influence between open sea and land, which is flooded by sea water regularly twice a day in a ca. 12 hours cycle. Area between the average lowest and highest sea water level at low tide and high tide. Generally non-vegetated expanses of mud, sand or rock lying between high and low water marks
Coastal lagoons	Stretches of salt or brackish water in coastal areas which are separated from the sea by a tongue of land or other similar topography. These water bodies can be connected to the sea at limited points, either permanently or for parts of the year only
Estuaries	The mouth of a river under tidal influence within which the tide ebbs and flows

In 2018, 44.1% of the ecosystem is made up of intertidal flats while the biggest change in extent between 2000 and 2018 (+1.3%) is reported for the smallest class (Salines). Salt marshes, a very important ecosystem for biodiversity, have the second biggest change in extent (+0.9%). More than half of the surface of coastal salt marshes in Europe is shared between three countries: France (20.3%), Spain (18.3%) and United Kingdom (12.3%).

3.4.4.2 Status and trends of Habitat Conservation Status (2013 – 2018)

As introduced in section 1.1.3.4.1, Article 17 reported data from Member States for the period 2013-2018 have been used to produce two indicators expressing the conservation status of coastal wetland habitats which are protected under the Habitats Directive: the share of coastal wetlands habitats in a favourable conservation status and the trends in conservation status of coastal habitats that are in an unfavourable status (poor and bad).

The eight habitats of the Annex 1 of the Habitats Directive associated to coastal wetlands in Europe entirely cover the coastal wetlands ecosystem. The list of these eight habitats is given in the Annex II of this chapter. Across the EU, coastal wetland habitats are reported by this Directive to have the worst status among all MAES ecosystem types. As shown in Table 3.4.14, 91% of these habitats are in an unfavourable status while only less than 3% are in good (or favourable) conservation status (State of Nature report for the period 2013-2018, forthcoming). Of the habitats that is in an unfavourable status, only 15% is showing improving trends while more than 24% is showing deteriorating trends. It has to be noticed that there is a major degree of lack of knowledge (Unknown) about the trends of the condition of coastal wetlands in Europe, since a big share of the coastal wetland related habitats in unfavourable condition has an unknown trend (24%). The analysis of the fragmented knowledge available on coastal wetland habitats confirms that, despite the huge efforts in research and conservation of these areas, there is currently little available knowledge at EU-28 level about their trends.

Table 3.4.14. Conservation status of coastal wetland habitats which are protected under the Habitats Directive: number of habitats in a favourable, unfavourable (poor and bad) and unknown status and trends of the habitats that are in an unfavourable status

Coastal wetlands Conservation Status	**Good**	**Poor**	**Bad**	**Unknown**
Estuaries		2	2	
Mudflats and sandflats not covered by seawater at low tide		2	2	1
Coastal lagoons		1	5	
Large shallow inlets and bays		1	3	1
Salicornia and other annuals colonizing mud and sand	1	4	1	
Spartina swards (Spartinion maritimae)		1	3	
Atlantic salt meadows (Glauco-Puccinellietalia maritimae)		1	3	
Boreal Baltic narrow inlets			1	
Percentage	**2.9%**	**34.3%**	**57.1%**	**5.7%**
Coastal Wetlands Conservation Status Trends for habitats in Unfavourable status	Deteriorating	Improving	Stable	Unknown
Percentage	**24.2%**	**15.2%**	**33.3%**	**24.2%**

3.4.5 Extended wetland layer: description of the ecosystem

The *extended wetland* ecosystem is defined according to the Ramsar Convention, signed by all EU-28 parties, which states that wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six meters". Furthermore, wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".

In addition to the explicit inclusion of coastal wetlands under the wetland assessment in MAES, as mentioned earlier in this document, there is a need to properly assess wetland ecosystems in Europe using an ecosystem-based approach: the ecosystem must be delimitated based on the identification of the hydro-ecological boundaries of wetlands.

A great diversity of wetlands exists making the definition of a wetland ecosystem both challenging and controversial. As stated in Fitoka et al., (2017), the most widely accepted definition of wetlands is the one by the Convention on Wetlands (Ramsar, Iran, 1971).

Building on an ecosystem-based justification of an inclusive definition, delimitation and delineation of wetlands, the development of an extended wetland ecosystem layer using the "hydro-ecological" boundaries of this ecosystem (including their wetness and flow characteristics) is an important factor for their full recognition and governance in Europe. Wetlands can otherwise be overlooked, for example when in a complex of other ecosystem types or in a degraded condition.

Based on the approach developed by the Horizon 2020 Satellite-based Wetland Observation Service (SWOS) (Abdul Malak et al., 2016), an ecosystem-based delimitation of wetlands in line with the Ramsar classification has been implemented. The ecosystem-based delimitation includes inland wetlands as defined by MAES classification, in addition to coastal wetlands and transitional ecosystems corresponding to wetlands such as riparian forests, wet grasslands, estuaries, or rice fields. This reclassification integrates wetland habitats classified under other ecosystems which depend at the hydro-ecological level on wetlands for their proper use and management.

Based on the above, a spatial layer for the year 2012 was produced reflecting the complexity of this ecosystem and providing a baseline on which to start building a more comprehensive assessment of the wetland ecosystems in Europe. The new wetland ecosystem classes proposed to be integrated in the MAES nomenclature[73], moved from other MAES ecosystems to the newly defined wetland one, imply class shifts for rice fields (moved from croplands), wet grasslands (moved from grasslands), wet heathlands (moved from heathland and scrub) and Riparian forests (moved from forests). The reader is referred to Annex IV for more details about the crosswalk scheme between the proposed modified MAES classes and the reference CLC classification scheme.

Results of the 2012 extended wetland ecosystem layer developed show a wetland coverage of about 370,000 km^2 at EU-28 level (Figure 3.4.9) of which 26% corresponds to the share of wetlands covered by MAES wetland assessment (inland marshes and peatbogs), 7% to the share of coastal wetlands while 67% are newly added classes matching the hydro-ecological wetlands dimension.

[73] https://biodiversity.europa.eu/maes/typology-of-ecosystems

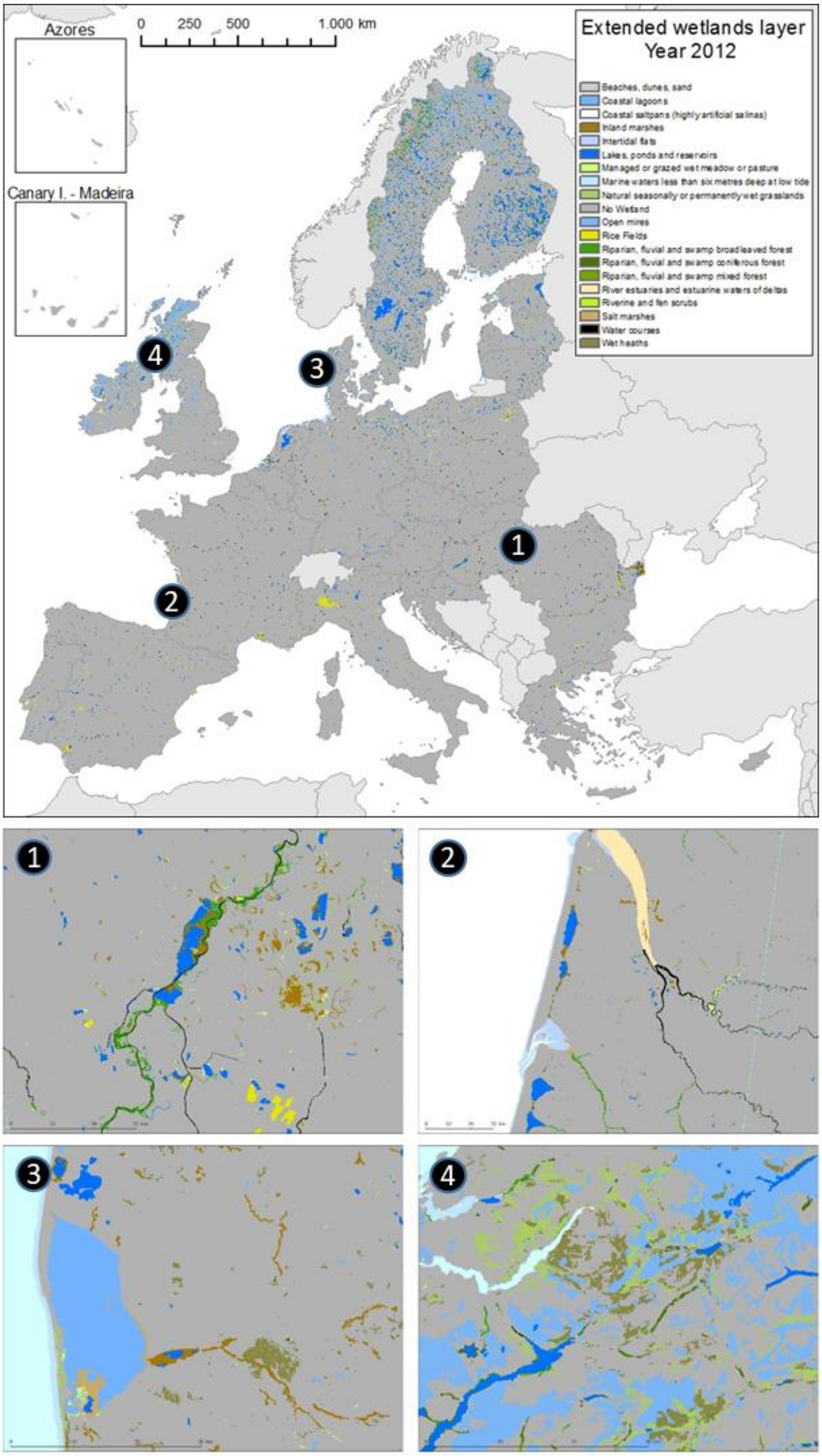

Figure 3.4.9. Delineation of the extended wetland layer for 2012 covering 370,000 km^2 of wetland habitats in EU-28.

Excepting the Urban MAES class, extended wetland habitats connect with all the other MAES ecosystems. 29% of its extent is covered by the "Rivers and lakes" assessment but most of the other classes are not specifically (separately) addressed within the MAES assessment (Figure 3.4.10).

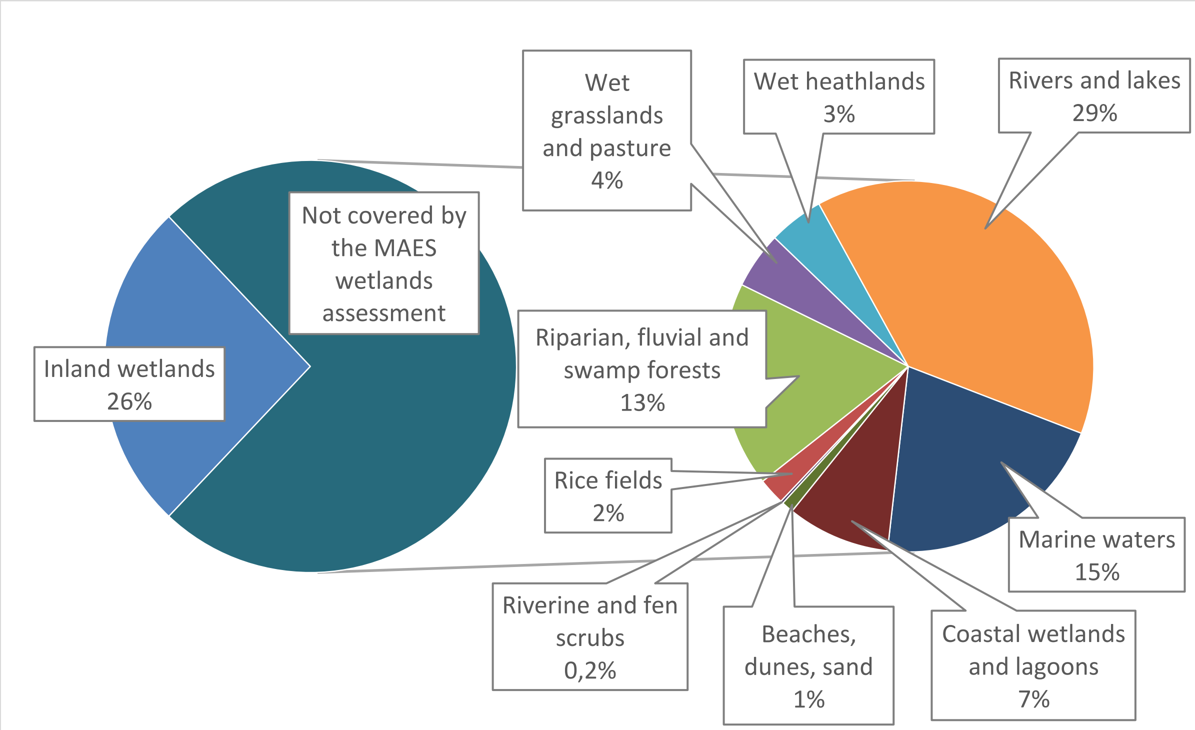

Figure 3.4.10. Extended wetland ecosystem layer at the EU-28 level: classes covered by the MAES Wetlands assessment (inland wetlands) and newly added ones are specified

3.4.5.1 Wetland habitat representativeness in EU policies

Due to the cross-cutting nature of wetlands, their habitats are the subject of different legislative instruments at European level, overlapping and complementing each other in some cases but also leaving some clear gaps in effectively managing certain wetland related habitats that lack proper legislative coverage. As shown in Figure 3.4.11, several EU pieces of legislation are relevant to certain wetland habitats (i.e. coastal lagoons, coastal saltpans, lakes, ponds and reservoirs, marine waters less than 6 meters at low tide, river estuaries and estuarine waters of deltas). However, other important wetland habitats (beaches, sand, inland marshes, intertidal flats, open mires, rice fields, riparian fluvial habitats, managed or grazed wet meadow or pasture, wet grasslands among others) are not given the same consideration. This partial coverage of the wetland habitats is perceived as a major gap in terms of their adequate management and governance.

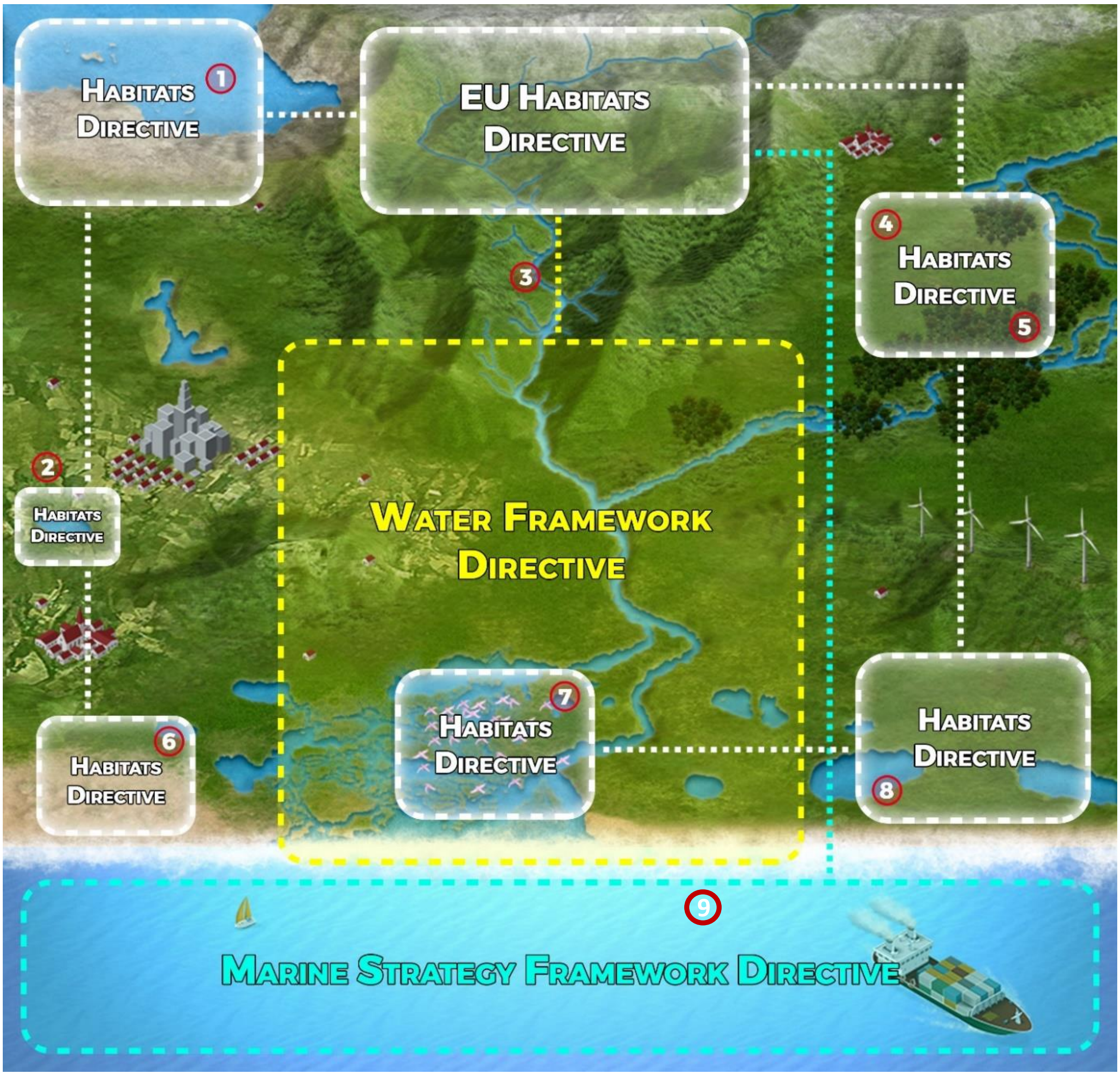

Figure 3.4.11. Wetlands and policies in the EU: examples of European habitat types belonging ecologically to wetland ecosystems and the patchy treatment of most relevant EU environmental policies in covering them: 1. Tidal mudflats, 2. Urban wetland, 3. Alluvial meadows, 4. Grasslands, wet meadows, 5. Riparian forest, 6. Dunes, 7. Deltaic areas and 8. Salt meadows and marshes, 9. Marine waters less than six meters deep at low tide

The habitats of Community interest covered by **the network of Natura 2000** constitute 41% of EU-28 extended wetlands area. Marine waters (19.5%), open mires (18.74%) and lakes, ponds and reservoirs (19.8%) make up almost 60% of the wetland areas listed under this network (Figure 3.4.12). Less than 10% of the wetland area within Natura 2000 is covered by riparian, fluvial and swamp forest.

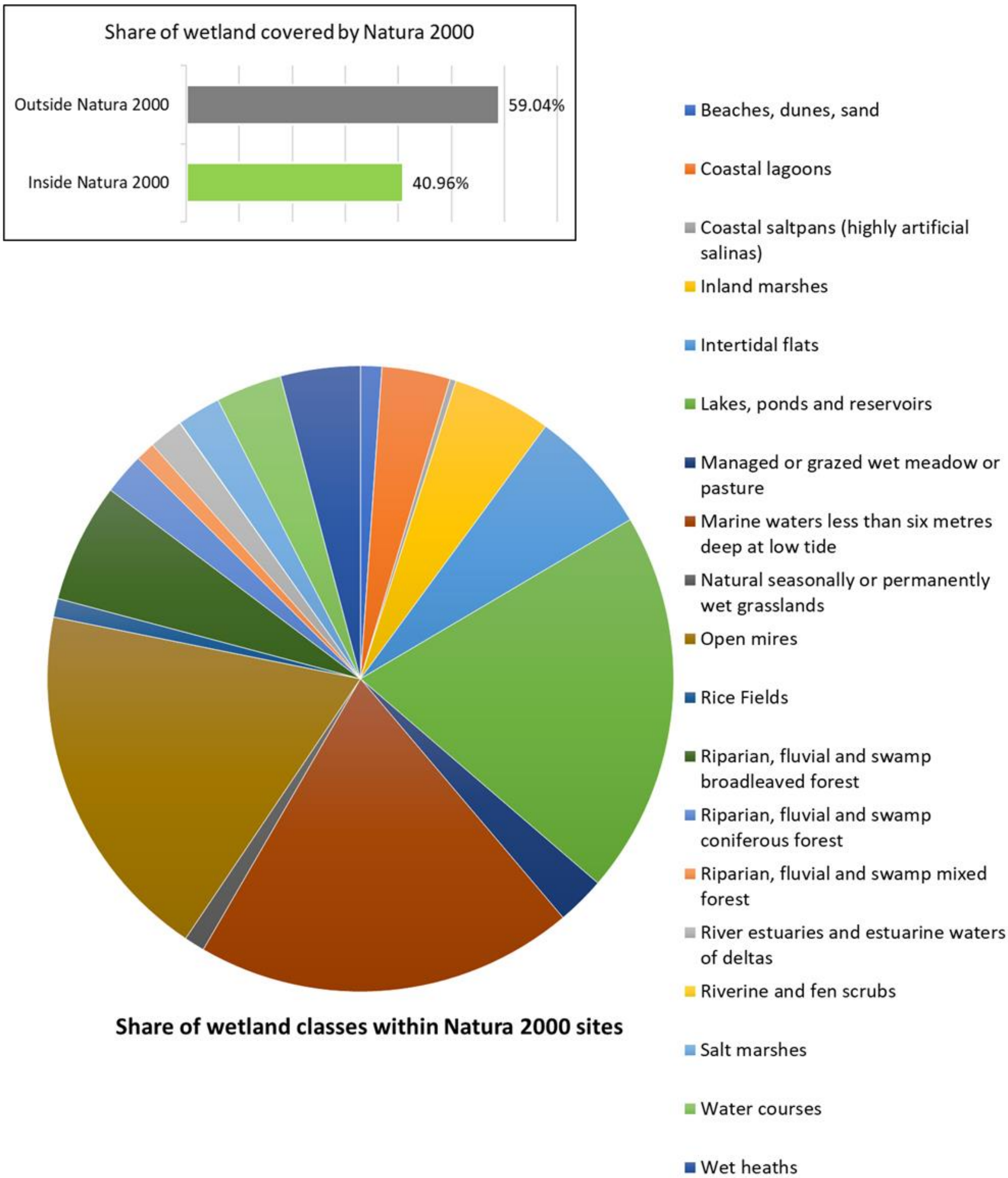

Figure 3.4.12. Percentage of wetland area covered by the Natura 2000 network and share of classes within the Natura 2000 network

When it comes to understanding which wetland habitats are protected, there seems to be a high heterogeneity in the protection rates (Figure 3.4.13). Although around 90% of the coastal ecosystems area (saltpans, lagoons, intertidal flats and marshes) belong to areas designated as Natura 2000, less than 20% of wetlands linked to riparian, fluvial and swamp coniferous and mixed forests are represented in this network. While traditional wetland habitats of cultural interest, such as rice fields, are totally lacking representativeness in the Natura 2000 network as they are not listed as (semi-natural) habitats of Community interest.

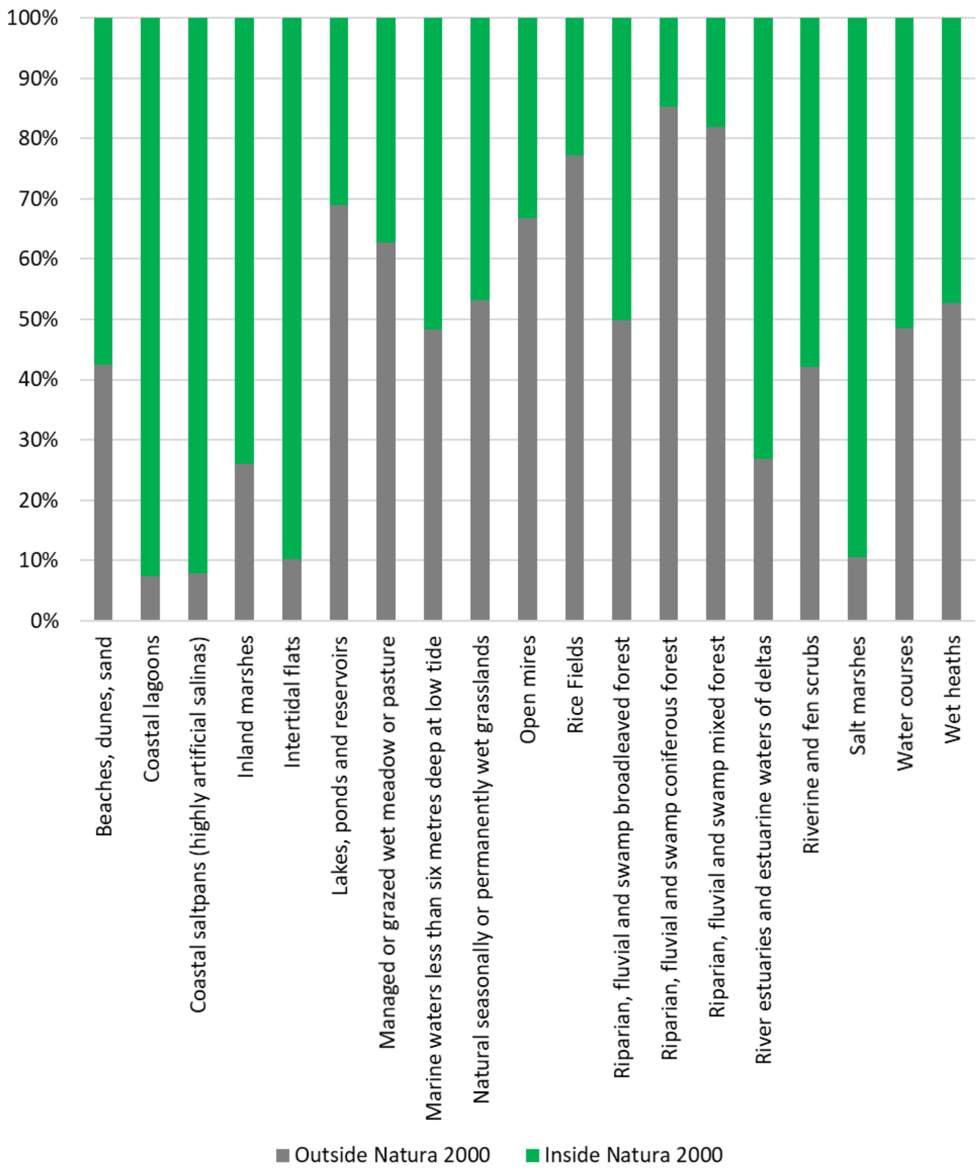

Figure 3.4.13. Percentage of wetland classes covered by the Natura 2000 network

The ***EU Water Framework Directive***[74], adopted in 2000, commits all EU Member States to achieve a good qualitative and quantitative status of all ground and surface waters.

Article 2.10 of the Directive provides the following definition of a body of surface water: "Body of surface water" means a discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water. This definition includes artificial or heavily modified water bodies, estuaries and saline water up to a nautical mile from the marine shore.

Though all wetland habitats are identified by the WFD as important components of the assessment of ecological status of associated water bodies and important as buffer habitats to be taken into consideration for restoration and management plans, the wetland classes listed in the reporting obligations cover a limited amount of these wetland habitats. Wetland habitats that are considered water bodies, according to the Directive, and for which Member States have the obligation to report are shown in Table 3.4.15. This table shows that only 44% of the extended wetlands in Europe are currently reported under the WFD and therefore

[74] https://ec.europa.eu/environment/water/water-framework/index_en.html

building an understanding of the condition of all wetlands based on the WFD information would be misleading because of the partial availability of information.

Table 3.4.15. Surface extent of the wetland ecosystems covered by the Water Framework Directive and percentage of the total extended wetlands area

Wetland habitat	km2	%
Coastal lagoons	5,903	1.6
Coastal saltpans (highly artificial salinas)	534	0.1
Lakes, ponds and reservoirs	98,784	26.1
Marine waters less than six metres deep at low tide	48,492	12.8
River estuaries and estuarine waters of deltas	3,750	1.0
Water courses	10,260	2.7
Total wetlands area covered by EU Water Framework Directive	167,723	44.3

The EU ***Marine Strategy Framework Directive***, adopted in 2008 to “protect more effectively the marine environment across Europe”[75], is the first EU legislative tool dealing with the protection of marine biodiversity and, more concretely, designed with the aim to achieve a good environmental status by 2020. The Directive covers the whole wetland marine habitat (“Marine waters less than six meters deep at low tide”), hence the 15.5% of the extended wetlands ecosystem.

The ***EU Habitats Directive*** introduced in 1992 aims at achieving a favourable conservation status for different habitats of Community interest, of which 61 are related to wetlands (see Annex III).

The EU Member States report every six years on the conservation status of these habitats (through the Habitat Directive) which, in spatial terms, cover more than 95% of the extended wetland ecosystem surface. Due to the coverage of the geo-spatial information on the distribution of the habitats currently available, this statistic is valid at EU-28 level (but Croatia is excluded). Furthermore, being the resolution of the layer (10 km pixel resolution) much lower than the wetland ecosystem one (100 m pixel resolution), the percentage values can only be considered as indicative.

In Table 3.4.16, the extent of each habitat covered by the three directives analysed is expressed in percentage terms showing the overlap for some specific habitats.

At the ecosystem level, less than 44% of wetlands are covered by both the HD and the WFD while around 16% of the wetland habitats present within the marine ecosystem (marine waters less than 6 meters of depth at low tide) are covered by both the HD and the MSFD (Table 3.4.16).

As highlighted by the assessment results of the Rivers and lakes ecosystem, (Chapter 3.6), if strengthened, the synergies between strategies linked to the Nature and the Water Framework Directives, (for instance, by stimulating investments in the recovery of riparian habitats), could generate positive spin-off benefits which would help improving certain wetland habitats and ensure the delivery of regulatory ecosystem services such as flood control and water purification.

In that sense, policy should also consider the role of healthy wetlands as important carbon sinks in mitigating climate change effects. Such a consideration would boost the efforts in pressure reduction and ecosystem restoration.

The same applies to the need of consolidating European legislation and policy initiatives that better link Nature with the Marine Strategy Framework Directive, especially focusing on the issues of the Land-Sea interface. Such initiatives could increase the knowledge on coastal wetland ecosystems and ensure a more effective assessment of their condition and trends.

[75] https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm

Table 3.4.16. Percentage coverage of the extent of wetland ecosystems by the EU directives considered

Wetland habitat	**Percentage of habitat covered**		
	Habitats Directive[76]	**Water Framework Directive**	**Marine Strategy Framework Directive**
Beaches, dunes, sand	89.9		
Coastal lagoons	91.9	100.0	
Coastal saltpans (highly artificial salinas)	99.8	100.0	
Inland marshes	87.4		
Intertidal flats	99.9		
Lakes, ponds and reservoirs	93.3	100.0	
Managed or grazed wet meadow or pasture	94.8		
Marine waters less than six meters deep at low tide	95.1	82.6	100.0
Natural seasonally or permanently wet grasslands	94.7		
Open mires	98.7		
Rice Fields	84.1		
Riparian, fluvial and mixed forest	98.6		
Riparian, fluvial and swamp broadleaved forest	94.1		
Riparian, fluvial and swamp coniferous forest	99.3		
River estuaries and estuarine waters of deltas	99.8	100.0	
Riverine and fen scrubs	96.6		
Salt marshes	99.0		
Water courses	88.9	100.0	
Wet heaths	98.6		
Total	95.5	44.3	15.5

3.4.5.2 Status and trends of Habitat Conservation Status (2013 – 2018)

A total of 61 habitat types in Annex 1 of the Habitats Directive are associated to the extended definition of the wetland ecosystem (Annex III). These habitats are part of mires, bogs and fens but also coastal wetlands, rivers and lakes and their vegetation, wet grasslands, and riverine forests.

Though no core indicators of MAES have been calculated so far for the extended wetland habitat layer for Europe, two indicators (one on condition and one on trends) derived from the Habitats Directive reported data for the period 2013-2018 have been used to help set an understanding on the knowledge available concerning the status & trends of the Annex 1 habitats related to the extended delimitation of wetlands.

The two indicators express the share of extended wetlands habitats in a favourable conservation status and the trends in conservation status of extended habitats that are in an unfavourable status (poor and bad).

Across the EU, most of the area of the extended wetland ecosystem (84%) has an unfavourable status while only 12% of the wetlands area is considered in favourable status (Table 3.4.17) while knowledge gaps seem to be reduced to 4% only.

According to the trends of Annex I habitats associated with wetlands in bad conservation status, 47% of these habitats is reported to has a downward trend, 28% of the area shows a stable trend, and only 7% is improving. The situation is unknown for 19% of the area.

[76] Croatia not included

Table 3.4.17. Conservation status of extended wetland habitats which are protected under the Habitats Directive: share of habitats in a favourable, unfavourable (poor and bad) and unknown status and trends of the habitats that are in an unfavourable status

Extended Wetlands Conservation Status	**Good**	**Poor**	**Bad**	**Unknown**
Percentage	12.0%	37.7%	46.0%	4.3%
Extended Wetlands Conservation Status Trends for Unfavourable	Deteriorating	Improving	Stable	Unknown
Percentage	46.7%	7.1%	27.5%	18.8%

3.4.6 Options for policy

Historically, European wetlands have suffered great declines, continued degradation and habitat loss that are still taking place due to different persisting drivers. The results of the MAES wetland assessment overwhelmingly confirms that, though efforts are ongoing to better conserve and more effectively manage and restore wetlands in Europe, the ecological character of wetland habitats is still dire (see also separate assessments by Ramsar Convention, 2018 and Davidson et al., 2019). Evidence extracted from the MAES assessment shows that compared to all terrestrial, freshwater and marine ecosystems, wetlands represent the ecosystem in the worst condition in Europe. To add to the specific pressures affecting wetlands, the climate change crisis including changes in precipitation and rising temperatures are contributing to worsening wetlands condition and affecting their function and its capacity to provide key ecosystem services, namely carbon sequestration and flood regulation, among others.

The degraded condition of wetlands in Europe is influenced by several factors related mainly to the lack of a European policy that considers wetland ecosystems, wetlands definition and their change in use and socio-cultural values in a comprehensive way.

This patchy treatment of wetland habitats and their underlying biodiversity by legislative and regulatory tools is reflected by a heterogeneous condition reported for different wetland habitats. Whereas rivers and lakes, fully covered by the WFD but also by other ones (Nitrates, Bathing Water, Urban Waste Water treatment Directives) show a better condition status or somehow certain signs of improvement (Chapter 3.6), habitats such as intertidal flats, open mires, rice fields, riparian forests and wet grasslands, which, beside the Habitats Directive, are not specific targets of European policies, show a much worse status that is also deteriorating in time.

In this respect, we recall that, according to the Art.17 assessment (section 3.4.3.4.1), 64% of the number of bogs, mires and fens in unfavourable condition status show a negative trend as compared to 35% of the number of freshwater habitats that are in an unfavourable status. Despite these worrying signs over time stressing the poor condition of these habitats, the assessment shows that there has been no significant increase in the protection coverage of inland wetland habitats in the last two decades.

The lack of coordinated conservation and restoration policies is also likely to have increased the physical fragmentation and isolation of wetland habitats which strongly linked to their further degradation also in terms of their capacity to provide ecosystem services while the lack of specific monitoring obligations hampers the possibility to properly assess the consequences.

The evidence provided by this assessment opens some questions regarding the level of implementation of the identified relevant policies in these habitats, or the effectiveness of wide restoration measures implemented so far in these ecosystems.

A fundamental change is essential in the way of treating wetland ecosystems to change the historical trends. This is only possible by better integrating the broad extent of wetland ecosystems in existing EU and upcoming targeted restoration policies in addition to improving the implementation of the ongoing policies and would ensure more effective conservation of these habitats.

Forward-looking policies need to find a more comprehensive approach to promote European wetland conservation and their wise-use (in the sense of the Ramsar Convention), respecting their hydro-ecological characteristics and ensuring their integrity in management (sectoral and environmental policies), conservation and protection (environmental policies). Such a change in the paradigm would benefit the inclusion of a properly defined wetland ecosystem in European post-2020 strategies and guarantee more effective protection, conservation and restoration agendas.

A transformative change towards better understanding and managing wetland ecosystems is challenging and requires innovative approaches to establish clear links between the EU Birds and Habitats Directives, the Water Framework Directive, the Floods Directive, the Marine Strategy Framework Directive as well as global frameworks such as the Ramsar Convention and the UN Sustainable Development Goals.

Possible options to be up taken by European policies include reaching vital agreements among scientists, practitioners and policy makers on widely used and ecologically sound definitions of wetland habitats that ensure proper delimitations, delineations and nomenclatures. This would guarantee a proper assessment and monitoring of wetlands that is coherent at all levels –*aligning the wide-variety of current definitions set under the Biodiversity Strategy, WFD, MSFD, LULUCF* and other European and global frameworks.

In brief, setting such agreements under a general policy framework that addresses the wide array of wetland ecosystems would influence an enhanced governance system of these habitats in the future, namely an ecosystem-based management and proper use of its underpinning habitats by any sectoral activity. *Such a general policy framework that explicitly addresses wetlands in Europe will better integrate policies ensuring that the ecological characteristics of this ecosystem are fully integrated* in the decision-making processes.

3.4.7 Knowledge gaps and future research challenges

Despite the critical role of wetlands providing a foundation for human well-being and as hotspots of biodiversity, threats against them continue to mount and their condition is still declining in Europe. The MAES condition assessment shows that both inland and coastal wetlands have the worst condition among all marine, freshwater and terrestrial ecosystems in Europe.

The main evidence, crucial to properly tackle this problem but currently missing in this study, is the assessment of pressures and condition of a wetland ecosystem delimitated based on its hydro-ecological functioning. This assessment suggests the approach to enable such a comprehensive assessment and tests it (section 3.4.5) as an ecosystem-based solution to overcome the heterogeneity of approaches in Europe to classify and assess these habitats. Furthermore, information on the location of wetlands, their delimitation, delineation, their condition, their hydro-ecological character, and the services they provide to people is in fact often sparse and difficult to find or access.

For these reasons, the in-depth assessment has mainly focused on inland wetlands (inland marshes and peatbogs) as suggested within the MAES framework. Nevertheless, there are limitations in terms of data availability, also for this specific ecosystem: from the core list of 25 indicators proposed in the fifth MAES report (Maes et al., 2018) for the assessment of the inland wetlands' ecosystem, only one third was practically implemented for this work. This was due to limitations in the availability or reliability of ancillary data needed to produce European wide indicators and to the lack of background information to assess trends and changes over time.

In particular, it has to be remarked that out of the eight soil related indicators, only soil sealing could be included in the final assessment, as a result of insufficient resources to include a full soil assessment.

One of the main targets for Horizon Europe regarding the wetland ecosystem, could be to overcome these bottlenecks and gaps in knowledge around wetland ecosystems that result in a limited effectiveness in the implementation of existing wetlands-related policies.

On the other hand, Horizon Europe needs to ensure a streamlining of the use of the broad definition of wetlands within European policies to make conservation and management efforts more effective vis-á-vis this ecosystem, enabling an all-inclusive management of this rich ecosystem based on its hydro-ecological characteristics.

Furthermore, research is needed to provide knowledge on carbon fluxes in wetlands and on targeted restoration efforts that would co-benefit biodiversity and climate change adaptation and mitigation. As shown in Box 3.4.2, targeted restoration of wetlands such as rewetting peatbogs, would allow the reestablishment of the hydrological conditions of these habitats and a decrease in the annual runoff.

Similarly, the limited awareness among the general public about the real extent and the social, economic, ecological and cultural values of wetlands is an important constraint that needs to be overcome by addressing societal behaviour and by fostering public support for wetland restoration (Scholte et al., 2016).

This could be achieved by providing more visibility to wetland ecosystem restoration benefits among all sectors in society and increasing public information about their values to human wellbeing.

3.4.8 Conclusions

This wetland ecosystem assessment reveals that the condition of extended wetlands in Europe over the last two decades is poor or degraded. Inland wetland ecosystems and their habitats continue to suffer from multiple pressures that are stable or even increasing over time except for nutrient enrichment that shows a significant decrease during the last decades linked to effective regulation.

Despite significant wetland restoration efforts in Europe over the last decades, which have already proved, at local scale, to effectively decrease wetland extent loss, the assessment demonstrates that tangible improvements in the condition of wetlands and the reestablishment of their functions are far from being met.

This critical situation dominating wetlands requires transformative changes at all levels enabling the implementation of long-term mechanisms and governance models at multiple scales that are implemented based on ecosystem-based conservation and adaptive monitoring programmes that respect the hydro-ecological boundaries of this ecosystem.

Fortunately, the upcoming strategies being set for Europe are carefully considering the inclusion of targeted strategic plans for wetland conservation and restoration. Such a strategic approach to wetland governance, supported by on-going European policies, aims at laying out a foundation for a very much needed different future for wetlands in its broadest sense, where full/integrated management, enhanced conservation and targeted restoration can halt and reverse degradation and ensure that European wetlands play a key role in European Green Deal and the EU Biodiversity Strategy to 2030.

Acknowledgements

The authors would like to thank Eleni Tryfon (EEA) for carefully reading and reviewing a first version of this chapter and for providing critical comments which greatly improved it.

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Annex I. List Annex 1 habitats of the Habitats Directive associated to inland wetlands

Code	Description
2170	Dunes with Salix repens ssp. argentea (Salicion arenariae)
2190	Humid dune slacks
7110	Active raised bogs
7120	Degraded raised bogs still capable of natural regeneration
7130	Blanket bogs (* if active bog)
7140	Transition mires and quaking bogs
7150	Depressions on peat substrates of the Rhynchosporion
7160	Fennoscandian mineral-rich springs and springfens
7210	Calcareous fens with Cladium mariscus and species of the Caricion davallianae
7220	Petrifying springs with tufa formation (Cratoneurion)
7230	Alkaline fens
7240	Alpine pioneer formations of Caricion bicoloris-atrofuscae
7310	Aapa mires
7320	Palsa mires

Annex II. List of habitats in Annex 1 of the Habitats Directive associated to the coastal wetlands ecosystem

Code	Description
1130	Estuaries
1140	Mudflats and sandflats not covered by seawater at low tide
1150	Coastal lagoons
1160	Large shallow inlets and bays
1310	Salicornia and other annuals colonizing mud and sand
1320	Spartina swards (Spartinion maritimae)
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
1650	Boreal Baltic narrow inlets

Annex III. List of habitats in Annex 1 of the Habitats Directive associated to the extended wetland ecosystem

Code	Description
1110	Sandbanks which are slightly covered by sea water all the time
1120	Posidonia beds (Posidonion oceanicae)
1130	Estuaries
1140	Mudflats and sandflats not covered by seawater at low tide
1150	Coastal lagoons
1160	Large shallow inlets and bays
1170	Reefs
1310	Salicornia and other annuals colonizing mud and sand
1320	Spartina swards (Spartinion maritimae)
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
1340	Inland salt meadows
1410	Mediterranean salt meadows (Juncetalia maritimi)
1510	Mediterranean salt steppes (Limonietalia)
1530	Pannonic salt steppes and salt marshes
1630	Boreal Baltic coastal meadows

1650	Boreal Baltic narrow inlets
2170	Dunes with Salix repens ssp. argentea (Salicion arenariae)
2190	Humid dune slacks
3110	Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae)
3120	Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with Isoetes spp.
3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea
3140	Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation
3160	Natural dystrophic lakes and ponds
3170	Mediterranean temporary ponds
3180	Turloughs
3190	Lakes of gypsum karst
31A0	Transylvanian hot-spring lotus beds
3210	Fennoscandian natural rivers
3220	Alpine rivers and the herbaceous vegetation along their banks
3230	Alpine rivers and their ligneous vegetation with Myricaria germanica
3240	Alpine rivers and their ligneous vegetation with Salix elaeagnos
3250	Constantly flowing Mediterranean rivers with Glaucium flavum
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
3270	Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation
3280	Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of Salix and Populus alba
3290	Intermittently flowing Mediterranean rivers of the Paspalo-Agrostidion
4010	Northern Atlantic wet heaths with Erica tetralix
4020	Temperate Atlantic wet heaths with Erica ciliaris and Erica tetralix
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)
6420	Mediterranean tall humid grasslands of the Molinio-Holoschoenion
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6440	Alluvial meadows of river valleys of the Cnidion dubii
6450	Northern boreal alluvial meadows
6460	Peat grasslands of Troodos
7110	Active raised bogs
7120	Degraded raised bogs still capable of natural regeneration
7130	Blanket bogs (* if active bog)
7140	Transition mires and quaking bogs
7150	Depressions on peat substrates of the Rhynchosporion
7160	Fennoscandian mineral-rich springs and springfens
7210	Calcareous fens with Cladium mariscus and species of the Caricion davallianae
7220	Petrifying springs with tufa formation (Cratoneurion)
7230	Alkaline fens
7240	Alpine pioneer formations of Caricion bicoloris-atrofuscae
7310	Aapa mires
7320	Palsa mires
91D0	Bog woodland
91E0	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)
91F0	Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris)
92B0	Riparian formations on intermittent Mediterranean water courses with Rhododendron ponticum, Salix and others

Annex IV. Crosswalk scheme between the proposed modified MAES classes and the CLC reference classification scheme

The crosswalk scheme between the newly proposed or modified MAES wetland classes and the CLC reference classification scheme used is presented in Figure 3.4.14. The classification is developed with very high thematic level of detail, up to level 3 or 4 in the MAES hierarchical typology. The possibility to effectively map each single class depends on data availability: the class that can be represented at the moment in the extended wetland layer is the one in the column “Mapped MAES classes”. These classes partially overlap with the Ramsar definition; a crosswalk scheme of these modified MAES classes with Ramsar wetland types can be found in Fitoka et al., 2017.

Mapped MAES Hierarchical Level	Mapped MAES Classes	Sub-classes		Corresponding CLC class	Mapping method
4	2.1.3.1 Rice fields			2.1.3	CLC
3	3.1.1 Riparian, fluvial and swamp broadleaved forest			3.1.1	Combination of CLC 3.1 with RZP, GSWE and WaW for all the study-area
3	3.2.1 Riparian, fluvial and swamp coniferous forest			3.1.2	
3	3.3.1 Riparian, fluvial and swamp mixed forest			3.1.3	
3	4.3.1 Managed or grazed wet meadow or pasture			2.3.1	Combination of CLC 2.3.1, GSWE and WaW
3	4.3.2 Natural seasonally or permanently wet grasslands			3.2.1	Combination of CLC 3.2.1, GSWE and WaW
4	5.1.1.3 Wet heaths			3.2.2	Combination of CLC 3.2.2, GSWE and WaW
4	5.1.1.4 Riverine and fen scrubs (EUNIS F9)			3.2.2	Ecosystem Type Map v3.1, class F9
3	6.2.1 Beaches, Dunes, Sand	6.2.1.1 Beaches		3.3.1	CLC
		6.2.1.2 Coastal and fluvial dunes without vegetation			
		6.2.1.3 River banks			
2	7.1 Inland marshes (small ponds below 8 ha might be included)	7.1.1 Inland freshwater marshes (small ponds below 8 ha might be included)	7.1.1.1 Inland freshwater marshes without reeds (small ponds below 8 ha might be included)	4.1.1	CLC
			7.1.1.2 Inland freshwater marshes with reeds (small ponds below 8 ha might be included)		
		7.1.2 Inland saline or brackish marshes (small ponds below 8 ha might be included)	7.1.2.1 Inland saline or brackish marshes		
			7.1.2.2 Inland saline or brackish marshes with reeds (small ponds below 8 ha might be included)		
2	7.2 Open mires	7.2.1 Bogs	7.2.1.1 Raised bogs	4.1.2	CLC
			7.2.1.2 Blanket bogs		
		7.2.2 Fens	7.2.2.1 Poor fens		
			7.2.2.2 Rich fens		
		7.2.3 Mixed mires (mixture of ombrotrophic & minerotrophic)	7.2.3.1 Palsa mires		
			7.2.3.2 Aapa mires		
			7.2.3.3 Polygon mires		
		7.2.4 Other mires	7.2.4.1 Transition mires and quaking bogs		
			7.2.4.2 Valley mires		
		7.2.5 Peat extraction, hydrological modifications			
2	8.1 Salt marshes	8.1.1 Salt marshes without reeds		4.2.1	CLC
		8.1.2 Salt marshes with reeds			
3	8.2.1 Coastal lagoons			5.2.1	CLC
3	8.2.2 River estuaries and estuarine waters of deltas			5.2.2	CLC
2	8.3 Coastal saltpans (highly artificial salinas)			4.2.2	CLC
2	8.4 Intertidal flats			4.2.3	CLC
2	9.1 Water courses	9.1.1 Interconnected running water courses	9.1.1.1 Permanent Interconnected running water courses	5.1.1	CLC
			9.1.1.2 Seasonal/intermittent interconnected running water courses		
			9.1.1.3 Highly modified natural water courses and canals		
		9.1.2 Separated water bodies belonging to the river system (dead side-arms, flood ponds below 8 ha)	9.1.2.1 Permanent separated water bodies belonging to the river system (dead side-arms, flood ponds below 8 ha)		
			9.1.2.2 Seasonal/intermittent separated water bodies belonging to the river system (dead side-arms, flood ponds below 8 ha)		
2	9.2 Lakes, ponds and reservoirs	9.2.1 Natural water bodies	9.2.1.1 Natural permanent water bodies (over 8 ha)	5.1.2	CLC
			9.2.1.2 Natural seasonal/intermittent water bodies (over 8 ha)		
		9.2.2 Man made water bodies	9.2.2.1 Ponds and lakes with completely man-made structure (generally below 8 ha)		
			9.2.2.2 Artificial fish ponds		
			9.2.2.3 Standing water bodies of extractive mineral sites		
			9.2.2.4 Other		
4	9.2.2.5 Inland saltpans			1.3	Not possible to extract it from CLC 1.3
4	10.1.1 Marine waters less than six metres deep at low tide			5.2.3	CLC combined with a bathimetry layer (depth <= 6 metres)

Figure 3.4.14. Crosswalk scheme between the newly proposed or modified MAES wetland classes and the CLC reference classification scheme. CLC: Corine Land Cover; GSWE: Global Surface Water Explorer; RZP: Riparian Zones Copernicus product; WaW: Water & Wetness Copernicus High Resolution Layer product.

3.5 Heathlands, shrubs and sparsely vegetated lands

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Summary: Since 1800's, the historical area of heathlands and shrubs has been reduced by 95% and 90% and nowadays, heathlands and shrubs cover 4% of the total EU land area. Since 2000, heathlands decreased by 1.2% which is the biggest decrease in proportion compared to other ecosystems.

In the last two decades, the pressure from land take affecting heathlands and shrubs has decreased. Land take affecting heathlands and shrubs decreased by 36% since 2000 and by 68% since 2010. The origin of the land take change from construction and sprawl of quarrying areas in the 2000's period to extension of industrial and commercial sites since 2012.

Atmospheric nitrogen deposition also decreased by 22% which is positive for heathlands, an ecosystem very sensitive to eutrophication. But, although the pressure is decreasing, even a low and chronic input might affect some of their ecological functions.

The surface area of heathlands and shrubs affected by fire increased by 44% since 2000. Burning is a traditional management practice that has positive and negative impacts on heathlands and shrubs depending on the regions.

Currently sparsely vegetated lands cover 1.5% of EU terrestrial area. Land take decreased by 82% since 2000 and by 45% since 2010. The origin of the land take changed from construction and sprawl of quarrying areas in the 2000's period to extension of industrial and commercial sites since 2012.

Even if there is no measurement at EU level, the pressures on sparsely vegetated lands as cliffs, screes or dune can suffer by over frequentation due to tourism or climbing activities. Even if there is no specific measurement at EU level, the pressures the most reported through the Habitats directive on sparsely vegetated lands as cliffs, screes or dune are linked to sport, tourism and leisure activities as over frequentation due to tourism or climbing activities.

The conservation status of heathlands and shrubs, and sparsely vegetated ecosystems is in general poor. Only 14.3% of heath and scrub habitats and 21.2% of sclerophyllous scrubs is in favourable conservation status. Rocky habitats do slightly better: 25.4% are in favourable conservation status.

Both heathlands and shrubs, and sparsely vegetated lands are well covered by European legislation with respectively 40% and 53% of their total area included in the Natura 2000 network.

3.5.1 Introduction and description of headlands and shrubs and sparsely vegetated lands

Heathlands and shrubs are dominated by small woody plants often in combination with herbs, and sometimes with a large contingent of mosses, liverworts and lichens. They are distributed across all the biogeographic regions of Europe from Mediterranean to boreal regions and lowlands to high altitudes. Most of these habitats are strongly dependent on human interventions, particularly grazing, fire and mowing. Due to an historical relation with traditional pastoral systems, they mainly occupy an intermediate position between more intensively managed grassland types and mature woodlands (Janssen et al., 2016). They also include bushy sclerophyllous vegetation.

According to the habitat types of heathlands and shrubs, they can provide diverse environmental, social and cultural ecosystem services as carbon storage, biodiversity, water provision, flood protection, aesthetic/recreational value, and economic value from tourism, and grazing (Hampton, 2008, Olmeda et al., forthcoming).

Sparsely vegetated lands include bare or sparsely vegetated rock, lava, ice and snow of cliffs, screes, caves, volcanoes, glaciers and snow-fields, dunes, beaches and sand plains. They occur throughout Europe and they are shaped by geological or climatological processes (Janssen et al., 2016). These two types of ecosystems can be associated or interlinked in some mountain or coastal areas (Zaghi, 2008, Hampton, 2008). All these landscapes and habitats are very important for biodiversity and provide many services, also appreciated for leisure and tourism, which can be also a risk if this is not regulated.

The EU Nature legislation aims to promote the conservation of a large number of habitats characteristic of heathlands and shrubs, and sparsely vegetated lands. Several action plans aim at providing guidance to maintain at and restore towards a favourable conservation status for specific habitats inside or outside Natura 2000 network. They can be used for developing instruments at EU and national level and to establish, promote and implement actions as projects financed by the LIFE programme, and in the context of the agricultural policy (e.g. agri-environmental schemes) and of other environmental policies and actions (e.g. to combat eutrophication, nitrogen deposition, etc.).

In line with the overall objective of this report, the aim of this chapter is to determine and report the trends in the pressures and condition of heathlands and shrubs, and of sparsely vegetated lands relative to the baseline year 2010. This chapter can thus be used to evaluate the targets of the EU Biodiversity Strategy to 2020. It is important to stress that this assessment is primarily based on indicators for which European wide, harmonized datasets have been collected. Where needed more context is provided by citing to relevant literature. However, this chapter did not make a systematic review of the literature on pressures on biodiversity and ecosystems.

This chapter delivers the baseline data to establish a (legally binding) methodology for mapping and assessment of ecosystems and their capacity to deliver services and to determine the minimum criteria for good ecosystem condition of heathlands and shrubs, and of sparsely vegetated lands, as required by the new EU Biodiversity Strategy to 2030. Determining these criteria of heathlands and shrubs, and of sparsely vegetated lands ecosystems requires also agreeing on a reference condition against which the past or present condition can be evaluated. More work will be needed to determine the target and reference levels of pressure and condition indicators in agreement with stakeholders, scientists and policymakers.

3.5.2 Ecosystem extent and change

The extent of heathlands and shrubs as reported in Corine Land Cover as Moors and heathlands (322) and sclerophyllous vegetation (323) and sparsely vegetated lands as Beaches, dunes, sands (331), Bare rocks (332), Sparsely vegetated areas (333), Burnt areas (334), Glaciers and perpetual snow (335) (MAES, 2013)

Heathlands and shrubs cover about 4% and **sparsely vegetated lands** 1.5% of the EU land area. Between 2000 and 2018, the extent of heathlands and shrubs decreased by 1.2% which is the highest relative decrease among all ecosystems in relation to its overall area. This reduction is mainly due to afforestation (35%), fires (22%) and urban sprawl (15%) (LEAC, 2019)

Sparsely vegetated lands extent increased by 1.5% which is due to the increase of burnt areas (Table 3.51).

Table 3.5.1. Surface area based on Corine Land Cover accounting layers for 2000, 2006, 2012 and 2018

Area (km2)	2000	2006	2012	2018
Heathland and shrub	184,071	183,225	182,727	181,814
Sparsely vegetated land	66,979	66,584	66,471	67,986

3.5.3 Data

Data on pressures indicators (Table 3.5.2 and Table 3.5.3) and ecosystem condition indicators (Table 3.5.4 and Table 3.5.5) related to heathlands and shrubs were identified in the earlier phase of the MAES project. The tables summarize indicators data period and spatial resolutions used for the assessment (details on data sources can be found in the fact sheets available online). It can be noted that there often exists a trade-off between spatial and temporal resolutions. The longest time-series are generally available at very coarse spatial scale, whereas detailed spatial patterns are generally available as a point in time assessment.

Table 3.5.2. Heathlands and shrubs indicators of pressures that were selected for MAES study, with data period and spatial resolution scale. * = for this indicator no temporal trend could be evaluated. NA = data not available. Dataset sources are reported in the fact sheets.

Class	Indicator	Unit	Data period	Spatial Resolution	Indicator fact sheets code
Habitat conversion and degradation (land conversion)	Land Take	km^2	2000-2018	MS	3.5.101
	Change in forest extent	NA	NA	NA	NA
	Fire	km^2	2000-2018	MS	3.5.102
Pollution and nutrient enrichment	Critical load exceedance (source: EMEP)	mol nitrogen eq/ha/y	2000-2016	EU-28	3.5.103

Table 3.5.3. Sparsely vegetated lands indicators of pressures that were selected for MAES study, with data period and spatial resolution scale. * = for this indicator no temporal trend could be evaluated. NA = data not available. Dataset sources are reported in the fact sheets.

Class	Indicator	Unit	Data period	Spatial Resolution	Indicator fact sheets code
Habitat conversion and degradation (land conversion)	Land Take	km^2	2000-2018	MS	3.5.101

Table 3.5.4. Heathlands and shrubs indicators of ecosystem conditions that were selected for MAES study, with data period and spatial resolution scale. * = for this indicator no temporal trend could be evaluated. NA = data not available. Dataset sources are reported in the fact sheets (supplement to this report).

Class	Indicator	Unit	Data period	Spatial Resolution	Indicator fact sheets code
Structural ecosystem attributes (general)	Landscape fragmentation	NA	NA	NA	
Structural ecosystem attributes monitored under the EU Nature directives and national legislation	Share of heath and scrub habitats listed under Annex 1 of the Habitats Directive in favourable conservation status	%	2013 - 2018	EU-28	3.5.203
	Trends in unfavourable conservation status of heath and scrub habitats listed under Annex 1 of the Habitats Directive (3.5.203)	%	2013 - 2018	EU-28	3.5.203
	Share of sclerophyllous scrubs habitats listed under Annex 1 of the Habitats Directive in favourable conservation status (3.5.203)	%	2013 - 2018	EU-28	3.5.203
	Trends in unfavourable conservation status of sclerophyllous scrubs habitats listed under Annex 1 of the Habitats Directive (3.5.203)	%	2013 - 2018	EU-28	3.5.203
	Proportion of heathlands and shrubs covered by Natura 2000	%	2000-2018	Biogeoregions EU-28	3.5.201
	Proportion of heathlands and shrubs covered by nationally designated areas	%	2000-2018	Biogeoregions EU-28	3.5.201

Table 3.5.5. Sparsely vegetated lands indicators of ecosystem conditions that were selected for MAES study, with data period and spatial resolution scale. * = for this indicator no temporal trend could be evaluated. NA = data not available. Dataset sources are reported in the fact sheets (supplement to this report).

Class	Indicator	Unit	Data period	Spatial Resolution	Indicator fact sheets code
Structural ecosystem attributes (general)	Landscape fragmentation	NA	NA	NA	
Structural ecosystem attributes monitored under the EU Nature directives and national legislation	Share of rocky habitats listed under Annex 1 of the Habitats Directive in favourable conservation status	%	2013 - 2018	EU-28	3.5.203
	Trends in unfavourable conservation status of rocky habitats listed under Annex 1 of the Habitats Directive (3.5.203)	%	2013 - 2018	EU-28	3.5.203
	Proportion of sparsely vegetated lands covered by Natura 2000	%	2000-2018	Biogeoregions EU-28	3.5.201 and 3.5.202
	Proportion of sparsely vegetated lands covered by nationally designated areas	%	2000-2018	Biogeoregions EU-28	3.5.201 and 3.5.202

3.5.4 Drivers and pressures: spatial heterogeneity and change over time

The most important pressures influencing the condition of **heathlands and shrubs** are the reduction of their surface extent due to conversion, fires (mainly in the Mediterranean region) and eutrophication. Abandonment or decrease of traditional management is also a pressure leading to scrub encroachment (Olmeda et al., forthcoming).

Due to their characteristics, **sparsely vegetated lands** can suffer from reduction of area due to land take, or to climate change in the case of glaciers and snow-fields, and related sea level rise and storms affecting dunes and beaches (EEA, 2017). Leisure and tourism have also an impact on screes, cliffs and coastal dunes and beaches.

3.5.4.1 Assessment at the level of EU-28

Even if the trends of some pressures go in the right direction, their impacts still remain as the artificial land take impacts the ecosystems almost permanently and can be hardly reversed. The eutrophication impact can remain beyond the reduction period.

For **heathlands and shrubs, land take** due to the development of urban and other artificial land use decreased by 35.8% since 2000 and by 68.5% compared to the 2010 baseline (table 3.5.6). In the period 2000-2012, construction and sprawl of mines and quarrying areas are the most impacting factors. From 2012, land take is mainly due to conversion of heathlands and shrubs into industrial and commercial sites.

This reduction of pressures related to land take since 2000 can be interpreted as a positive signal but we should remind that only between 5 and 10% of heathland areas still exist in Western Europe compared to 1800 (Bensettiti et al., 2005).

The pressure from **eutrophication** is decreasing with a percentage of change per decade of -22%. For heathlands, atmospheric nitrogen (N) deposition is a major driver of change, altering the structure/function of nutrient-poor heathlands over Europe (see 3.5 103 Critical loads fact sheet). These effects may vary across the ecosystem's distribution, as heathlands are highly vulnerable to land-use changes combined with climate change effects (Taboeda, 2018). In 2016, the exposure was nearly 205 mol N eq/ha/year equivalent to about 3 kg N/ha/year. This is below the critical nitrogen loads for this ecosystem (10-20 kg N/ha/year) but some ecosystem function might negatively respond to low but chronic N inputs already below 10kgN/ha/yr (Bähring et al., 2017). And local deposition due to agriculture fertilization is another source of nitrogen increasing deposition in the nearby heathland areas which causes reduction in plant richness (Olmeda et al., forthcoming).

Controlled **burning** is commonly used to reduce development of pioneer trees preventing woodland encroachment in northern countries, but there is little understanding of their effects towards the southern edge of the range of European heathlands and shrubs. Based on land cover flow analysis, along the period 2000-2018, there is an increase of burnt heathlands with more than 40% of areas affected by fire (the distinction between controlled fires and uncontrolled fires cannot be done). Looking at the details, this happens mainly in the Mediterranean region impacting in the species composition, which might lead to a reduction in biodiversity.

Sparsely vegetated lands are mainly threatened by habitat conversion. **Land take,** due to the development of urban and other artificial land use, shows a significant downward long-term trend with a negative change rate of -45.6% per decade (Table 3.5.7). In the period 2000-2012, sprawl of mines and quarrying areas and construction are the most impacting factors. From 2012 onwards, sprawl due to industrial and commercial sites increased reaching an equivalent level in land take compared to mines and quarrying areas. Other types of pressure, which are not included in this assessment, are expected to have a significant impact on this ecosystem. Screes and cliffs can suffer from leisure activities such as climbing or infrastructure supporting tourism. Eutrophication can impact some plant species linked to this ecosystem. Dunes and beaches also suffer from coastal erosion due to climatic events such as storm surges and seasonal over frequentation for leisure. From a species protection perspective, most species present in the vegetation of sparsely vegetated lands are endemic or have a slow growth and reproduction rate. They are particularly vulnerable, as any reduction of these populations pushes them towards the limits of extinction and makes them very difficult to be restored (Bensettiti et al., 2005) as the Pyrenean ragwort (*Senecio pyrenaicus*) or the bearded vulture (*Gypaetus barbatus*).Even if there is no specific measurement at EU level, the pressures the most reported through the Habitats directive related cliffs, screes or dune are linked to sport, tourism and leisure activities as over frequentation due to tourism or climbing activities.

Table 3.5.6. EU aggregated pressure indicators for heathlands and shrub

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation (land conversion)	Land take	km^2	191	-68.53%	↑	8	-35.82%	↑	8
	Change in forest extent				unresolved			unresolved	
	Fire	km^2	418	20.75%	↓	8	43.81%	↓	8
Other pressures (including soil erosion)	Critical load exceedance	$eq\ ha^{-1}\ yr^{-1}$	230.30	-18.39%	↑	5	-22.07%	↑	5

Table 3.5.7. EU aggregated pressure indicators for sparsely vegetated lands

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation (land conversion)	Land take	km^2	30	-82.43%	↑	8	-45.62%	↑	8

↑: Significant improvement (significant downward trend of pressure indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment.

3.5.4.2 In-depth assessment

3.5.4.2.1 Heathlands and shrubs

Compared to the period 2006-2018, Belgium, Croatia, Cyprus, France and Portugal had also a significant land take for the period 2000-2006 due to construction. The importance of land take for the two periods 2000-2006 and 2006-2012 is mainly due to changes in Spain with respective land take of 15 089 ha (62% of the total EU-28 land take) and then 8 834 ha (53% of the total EU-28 land take). For the period 2012-2018, the land take for Spain is only 15% of the total EU-28. This land take is mainly due to sprawl of construction and mine & quarrying sites.

Burning practices are used in several regions of Europe. But an increased threat of wildfires due to warming and droughts led to a shift in the species composition of Mediterranean shrublands, which might lead to a reduction in their biodiversity. The details of the land cover flow assessment for the period 2000-2018 show that these practices mainly affect the Mediterranean region. Uncontrolled burning also disturbs some Alpine and Boreal heathlands (Wessel, et al, 2004, Zaghi, 2008).

3.5.4.2.2 Sparsely vegetated lands

Land take in Spain is causing most of the losses with 65% of the total EU-28 for the period 2000-2006, mainly caused by mining and quarrying activities. Germany has a stable rate of land take across the three periods and it is the most impacted by loss of sparsely vegetated lands with 31% for the period 2006-2012 and 26% for the period 2012-2018, compared to the total EU land take for this period.

3.5.5 Ecosystem condition: spatial heterogeneity and change over time

Only two indicators are currently available to assess the trends of conditions of heathlands and shrubs and sparsely vegetated lands. The share of these ecosystems under EU or national legislations can give an indication that the related areas are less exposed to pressures or under more sustainable management practices. Additional information on the conditions of the relevant sites and on the implementation of management plans (better practices, restoration, protection) could be helpful but extremely difficult to collect at EU scale.

An improved support to monitoring on species diversity (richness and trends in abundance) will help to get a better picture on the condition of these ecosystems.

3.5.5.1 Assessment at the level of EU-28

Our knowledge of the condition of heathlands and shrub and of sparsely vegetated lands is based on structural ecosystem attributes monitored under the EU nature directives (Tables 3.5.8 and 3.5.9).

The MAES ecosystem type heathland and shrub overlaps with two broad Annex 1 habitat groups: heath and scrub and sclerophyllous scrubs. EU level art.17 assessment data is available for 12 heath and scrub habitats and for 13 sclerophyllous scrubs habitats. The total area of heath and scrub covered under Annex 1 of the Habitats Directive is 88,335 km^2 whereas for sclerophyllous scrubs the total area is 35,132 km^2 (See chapter 2, Table 2.2).

The EU level assessment of the conservation status of 12 heath and scrub habitats concluded that only 14.3% are in good (or favourable) conservation status. The remaining habitats are in poor status (47.6%), a bad status (26.2%) or unknown (11.9%) (State of Nature report for the period 2013-2018, forthcoming). Only 11.1% of the heath and scrub habitats that are in an unfavourable status is showing improving trends.

The EU level assessment of the conservation status of 13 sclerophyllous scrubs habitats concluded that 21.2% respectively, are in good (or favourable) conservation status; 48.5% is in poor status, 27.3% is in bad status and the remainder is unknown (3%) (State of Nature report for the period 2013-2018, forthcoming). None of sclerophyllous scrubs habitats that are in an unfavourable status is showing improving trends.

As for sparsely vegetated land, we included art.17 information for rocky habitats of which the total area covered under Annex 1 of the Habitats Directive is 67,744.km^2 (excluding Romania) (see chapter 2, Table 2.2)

The EU level assessment of the conservation status of 14 rocky habitats concluded that 25.4% are in good (or favourable) conservation status. The remaining rocky habitats are in poor status (56.3%), a bad status (7%)

or unknown (11.3%) (State of Nature report for the period 2013-2018, forthcoming). Only 5.7% of the rocky habitats that is in an unfavourable status is showing improving trends.

The percentages of heathlands and shrubs, and of sparsely vegetated lands covered by the Natura 2000 network and the network of Nationally Designated areas (CDDA) have been calculated to evaluate the change since 2000. As based on the designation of the Natura2000 network and the nationally designated areas networks at a given time (the year 2018), this indicator focuses only on the trend due to the change in the ecosystem extent not including the changes in Natura 2000 and CDDA areas. The values of the indicator are the result of the statistical analysis by combining CORINE Land cover 2000, 2006, 2012 and 2018 with the Natura 2000 network reported by MS end of 2018 and the nationally designated areas -CDDA- reported by MS in 2018. The trends show a stable situation in terms of coverage for both short and long-term analysis (Table 4)

From 2000 up to 2018, the share of **heathlands and shrubs** under Natura 2000 designation remains stable with around 40% and around 32% under national designations.

The share of **sparsely vegetated lands** under Natura 2000 designation remains stable with around 53% and around 44% under national designations.

Table 3.5.8. EU aggregated condition indicators for heathlands and shrubs

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Structural ecosystem attributes (general)	Landscape fragmentation				unresolved			unresolved	
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Share of heath and scrub habitats listed under Annex 1 of the Habitats Directive in favourable conservation status*	%	14.3						
	Trends in unfavourable conservation status of heath and scrub habitats listed under Annex 1 of the Habitats Directive*	% improving		11.1	↑				
		% stable		30.6	→				
		% deteriorating		25.0	↓				
		% unknown		33.3	unresolved				
	Share of sclerophyllous scrubs habitats listed under Annex 1 of the Habitats Directive in favourable conservation status*	%	21.2						
	Trends in unfavourable conservation status of sclerophyllous scrubs habitats listed under Annex 1 of the Habitats Directive*	% improving		0.0	↑				
		% stable		46.2	→				
		% deteriorating		30.8	↓				
		% unknown		23.1	unresolved				
	Share of heathlands and shrubs covered by Natura 2000	%	40.58%	0.10%	→	8	0.09%	→	8
	Share of heathlands and shrubs covered by Nationally Designated Areas	%	32.09%	0.14%	→	8	0.14%	→	8

Table 3.5.9. EU aggregated condition indicators for sparsely vegetated lands

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Structural ecosystem attributes (general)	Landscape fragmentation				unresolved				unresolved
Structural ecosystem attributes monitored under the EU Nature Directives and national legislation	Share of rocky habitats listed under Annex 1 of the Habitats Directive in favourable conservation status*	%	25.4						
	Trends in unfavourable conservation status of rocky habitats listed under Annex 1 of the Habitats Directive*	% improving		5.7	↑				
		% stable		56.6	→				
		% deteriorating		15.1	↓				
		% unknown		22.6	unresolved				
	Share of sparsely vegetated land covered by Natura 2000	%	53.15%	-0.68%	→	8	-0.21%	→	8
	Share of sparsely vegetated land covered by Nationally Designated Areas	%	43.99%	-0.74%	→	8	-0.28%	→	8

↑: Significant improvement (significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

* The indicators on habitat conservation status have been treated differently than the other indicators with a different baseline year and different time period (2013–2018); so the percent change is expressed for a period of 6 years instead of 10 as for the other indicators. The trends in conservation status are only available for habitats in an unfavourable conservation status. Please check chapter 2 for details.

3.5.5.2 In-depth assessment

The share of ecosystems under EU or national legislations is also stable at biogeographic level since 2000.

In 2018, the share of **heathlands and shrubs** under Natura 2000 designation are above 74% in the Pannonian and Boreal regions. Between 45 and 55% in Alpine and Continental regions (Figure 3.5.1). The share under national designations is about 75% in the Boreal region and between 45 and 56% in the Macaronesian, Continental, Alpine and Atlantic regions. In the Macaronesian region, bushy sclerophyllous shrubs are predominant.

These proportions are not due to the ecosystem extent in each region. Indeed, the Mediterranean, Alpine, Atlantic and Continental regions share the most ~~important~~ extensive part of the total extend of Heathlands and shrub (EEA, 2016).

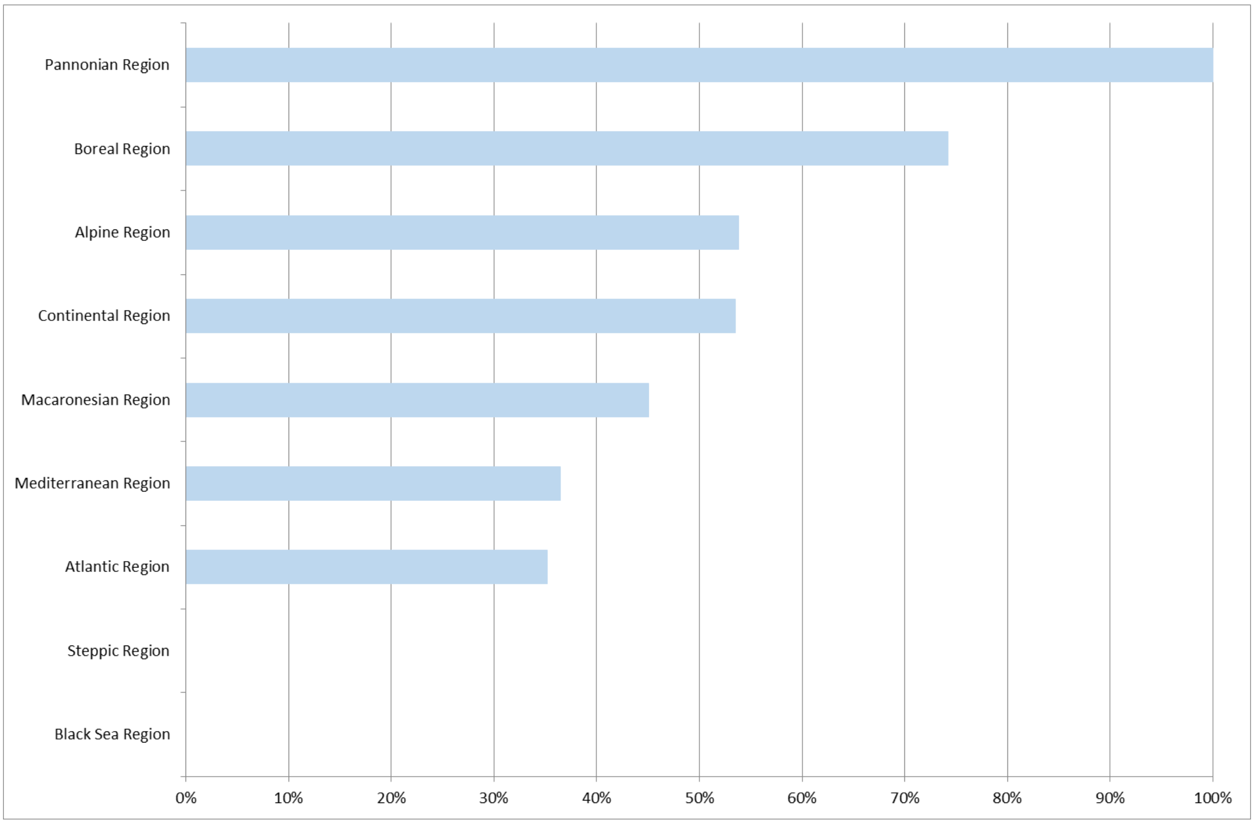

Figure 3.5.1. Share of heathlands and shrubs covered by Natura2000 per biogeographic region - 2018

The share of **sparsely vegetated lands** under Natura 2000 designation are around and more of 90% in the Pannonian, Steppic and Black Sea regions. Between 48 and 60% for the other regions (Figure 3.5.2).

The share under national designations is between 50 and 70% in the Pannonian, Atlantic and Boreal regions. Between 28 and 48% for the other regions.

These proportions are not due to the ecosystem extent in each region. Indeed, the, Alpine, Mediterranean and Atlantic regions share the most important part of the total extend of sparsely vegetated lands (EEA, 2016).

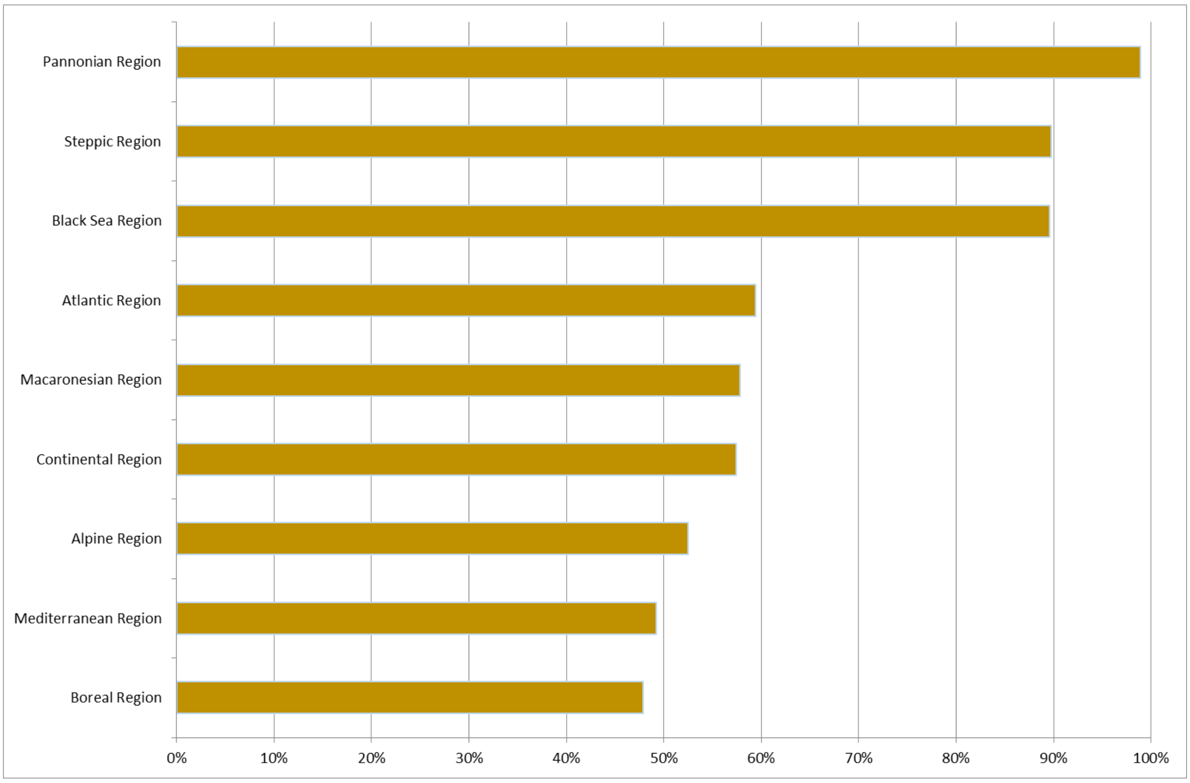

Figure 3.5.2. Share of sparsely vegetated lands covered by Natura2000 per biogeographic region

3.5.6 Convergence of evidence: Assessment conclusions based on the pressure and condition indicators

Tables 3.5.10 and 3.5.11 summarize the short and long term trends of pressures and condition indicators of heathlands and shrub, and sparsely vegetated land, respectively. The table does not include the indicators on habitat conservation status as they do not result in a single trend (but rather a proportion for each trend).

Table 3.5.10. Summary of trends in pressure and condition of heathlands and shrub in the EU-28.

	Indicator	**Short-term trend - Since 2010**	**Long-term trend**
Pressures	Land take	🡡	🡡
	Change in forest extent	unresolved	unresolved
	Fire	🡣	🡣
	Critical load exceedance for nitrogen	🡡	🡡
Condition	Landscape fragmentation	unresolved	unresolved
	Share of heathlands and shrubs covered by Natura 2000	🡢	🡢
	Share of heathlands and shrubs covered by Nationally Designated Areas	🡢	🡢

🡡: Significant improvement (significant downward trend of pressure indicator; significant upward trend of condition indicator); 🡢: No change (the change is not significantly different from 0% per decade); 🡣: Significant degradation (significant upward trend of pressure indicator; significant downward trend of condition indicator)
Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment; Indicators of conservation status of habitats, species and birds are excluded.

Table 3.5.11. Summary of trends in pressure and condition of sparsely vegetated lands in the EU-28.

	Indicator	Short-term trend - Since 2010	Long-term trend
Pressures	Land take	↑	↑
Condition	Landscape fragmentation	unresolved	unresolved
	Share of sparsely vegetated lands covered by Natura 2000	→	→
	Share of sparsely vegetated lands covered by Nationally Designated Areas	→	→

↑: Significant improvement (significant downward trend of pressure indicator; significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator; significant downward trend of condition indicator)

Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment; Indicators of conservation status of habitats, species and birds are excluded.

3.5.7 Options for policy

Since 2000, important pressures such as habitat conversion and eutrophication affecting the condition of heathlands and shrubs have been significantly reduced. But a more detailed interpretation of the current results is limited due to weak availability of data related to abandonment or decrease of traditional management practices, which are some of the most impacting pressures. Likewise, missing data on tourism and leisure related to sparsely vegetated lands also limit the condition assessment.

These two ecosystem types with their associated habitats benefit from a certain level of protection due to the implementation of the Habitats Directive, the Natura 2000 network and national network of designated areas. But it is also essential to concentrate efforts on restoration by improving the condition of these degraded ecosystems. The development and support of extensive agro-ecological farming systems should further increase the positive effect of the protection schemes on habitat and species condition in the respective ecosystems as suggested in the action plans described below.

Conservation and management of **heathlands and shrubs** are implemented through EU action plans already in place for two heathland habitats (Northern Atlantic wet heaths with *Erica tetralix*, and Alpine and Boreal heaths), a third one (European dry heaths) being in preparation (Hampton, 2008, Zaggi, 2008, Olmeda et al., forthcoming). Several of suggested measures can be supported by the European Agricultural Fund for Rural Development, as agri-environment measures. Training for implementation of measures, and investments in restoration are supported by the LIFE programme. Beyond these specific action plans for conservation, an extensive farming system integrating necessary measures must be supported by the Common Agricultural Policy in order to proceed with an integrated management approach considering the relations between habitat condition and the socio-ecological system which allows for their sustainable management (Hampton, 2008, Olmeda et al., forthcoming).

For **sparsely vegetated lands**, pressures induced by tourism and leisure management should be considered at regional and local scales for sustainable use and management.

3.5.8 Knowledge gaps and future research challenges

For **heathlands and shrubs,** beyond atmospheric nitrogen information, data on nitrogen deposition and eutrophication due to local pressures are missing. Information on abandonment and extensive rural practices is also crucial but still difficult to collect at European scale. For **sparsely vegetated lands**, tourism and leisure information as number of visitors or climbers are important even if these numbers may show a very high variation on local level and is therefore difficult to collect at European scale and relate it to the specific ecosystem. As these ecosystems are well covered by the Nature directives, information collected in the framework of the LIFE projects can be an important source of information but hardly generalized beyond biogeographical level.

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3.6 Rivers and lakes

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Summary: Rivers and lakes ecosystems form a network that links land to the sea, transporting water, materials and biota across systems. Specifically, rivers ecosystems are characterised by running water (lotic habitats) while lakes ecosystems by standing waters (lentic habitats). The interfaces between water bodies and their catchment, including riparian zones, floodplains, and lakeshores are also an important part of the freshwater ecosystem. Since 2000, the EU has put in place an ambitious and comprehensive water legislation to protect aquatic ecosystems and ensure the sustainable use of water resources, the Water Framework Directive (WFD 2000/60/EC). The Directive establishes a clear target that is to achieve good ecological and chemical status for all water bodies in the EU, including rivers, lakes, coastal and transitional waters as well as groundwater. The EU-28 extent of river and lake ecosystems was assessed to comprise about 1.3 million km of total river length, 84,000 km^2 of lake surface area, 297,000 km^2 of riparian land, and 367,000 km^2 of potentially flooded areas, for an estimated extent of the whole ecosystem of about 407,000 km^2.

Pressure and ecosystem condition indicators were assembled and mapped for Europe through several sources, including datasets available up to September 2019. There often existed a trade-off between spatial and temporal data resolutions. Generally, the longest time-series were available at very coarse spatial scale, whereas detailed spatial patterns were available as a point in time assessment.

Overall, human pressures on freshwaters due to water abstractions and nutrient pollution have declined in the EU-28 since 2000, however in most recent years the improvement rate has slowed down, so that pressure trends in the 2010s remained mostly stable. Concerning pollution and nutrient enrichment, improvements are seen mostly in relation to domestic emissions or atmospheric nitrogen deposition. Conversely, average diffuse nutrient emissions from agricultural land are still high, especially in some European agricultural regions. In addition, the legacy of nitrogen pollution in groundwater is not represented in the pressure indicators. Land take in potentially flooded areas has continued in the last two decades. This is worrying for the critical role of natural riparian areas for pollution retention, flood attenuation, erosion control, habitat provision, and surface and ground water connectivity. Pressure due to presence of invasive alien species of Union concern is widespread, and affects particularly the Continental and Atlantic biogeographical regions. Important knowledge gaps regarded the impacts of climate change, hydromorphology alteration, fishery exploitation, and emissions of pesticides, emerging pollutants and nanoplastics to freshwater. All these pressures could not be quantified in this assessment due to a lack of data at the European scale.

The foremost piece of information on freshwater ecosystem conditions is the water bodies ecological status, reported by Member States under the WFD implementation. According to the information reported in the second River Basin Management Plans (RBMPs), covering to the period 2010-2015, 39% of EU rivers and lakes are in good or high ecological status, 38% are in moderate status and 17% are in poor or bad status. No information is available for 5% of rivers and lakes. Trends of major pollutants and nutrients of WISE monitoring stations with sufficient monitoring period indicate improvements in water quality at the EU-28 scale. Similarly, Europe's bathing water quality has improved markedly over the last 40 years, following the introduction of the EU Bathing Water Directive. The latest data (2014-2018) indicate that the share of excellent inland bathing waters is around 80%. According to the second round of RBMPs reporting under the Water Framework Directive, about 34% of river water bodies and 22% of lakes are affected by hydromorphological pressures. About hydrological alteration, 61% of stream network experience lower than 'natural' low flow occurrences and 8% of EU-28 land is suffering severe over-exploitation of water resources (Water Exploitation Index > 0.2). Trends could not be assessed, but scenario analysis indicates that flow regime alterations are likely to worsen in the future. Barriers disrupt the longitudinal connectivity of rivers and lakes: at the EU-28 scale around 60% of streamflow is estimated to be intercepted by dams and the accessibility of the stream network between barriers is on average reduced to only 4% of the network that would be available in the absence of barriers. Expansion of artificial land in riparian areas in 2000-2018 has occurred at a rate of 7% per decade, especially at the expense of agricultural land. Conversely, no improvement has been seen in terms of expansion of natural land cover. Similar considerations can be given

for amount of land protected by EU Nature Directives: the proportion of rivers and lakes protected by Natura 2000 or Nationally Designated areas has remained largely stable.

The EU level assessment of the conservation status of 20 freshwater habitats concluded that 18.4% are in good (or favourable) conservation status. The remaining habitats are in poor status (41.8%), a bad status (32.7%) or unknown (7.1%).

The summary statistics, based on pressure and condition indicator long-term trends, showed a prevalence of the pressure indicators toward improvement (declining pressures), but an important share of pressures had unresolved trends. It is likely that these unknowns hide degrading conditions, such as adverse impacts of climate change, invasive alien species and chemicals/litter to name a few. Similarly, ecosystem condition is improving according to most of the indicators, but sizable shares of indicators are not changing or exhibited unresolved trends. Degrading conditions were mostly ascribed to increased share of artificial land cover in riparian land. The apparent lag of response between the reduction of pressures and improvement in condition could be related to different aspects, among which: (i) the level of pressure reductions might not be sufficient to produce significant improvements in the condition of aquatic ecosystems; (ii) the restoration of ecological processes might require longer times; (iii) not all the significant pressures could be included in the convergence of evidence; and (iv) not all the pressures act proportionally, with some pressures (or combination of pressures) having higher detrimental effects on aquatic ecosystems.

Mapping of freshwater indicators at NUTS2 (Nomenclature of Territorial Units for Statistic level 2) scale could include only nine indicators with enough spatial detail (six on pressures and three on condition). Maps show that degrading and improving trends for pressure and condition indicators coexist in the same region. This suggests that while some measures with positive effects have been taken, they may not be sufficient to address the wide range of degrading drivers acting on aquatic ecosystems. The maps highlight that changes of pressure and condition indicators vary spatially thus average continental values might mask opposed local trends. About 20% of NUTS2 units showed clear improvement (no degrading indicator and one or more improving indicators), whereas 23% of units showed at least three degrading conditions, indicating a likely worsening of freshwater ecosystem trajectory.

As most pressures on aquatic ecosystems derive from human activities, the sustainable use of water resources and the protection of freshwater ecosystems require trade-offs between different uses of water, and coordination between objectives of economic development and environmental protections. The WFD is a pioneering legislation as it includes ecological targets, addresses the complexity of pressures affecting the status of aquatic ecosystems, and provides the framework for developing and maintaining the monitoring of pressures and ecosystems condition. Long-term monitoring has proven crucial to understand the effectiveness of measures and the recovery of conditions, as well as to detect new forms of pressure. Indeed, the analysis shows that some pressures are attenuating, such as pollution from wastewater treatment plants. On the other hand, the current level of pressures might still be too high for the recovery of ecosystem condition. There is a clear indication that the share of artificial land cover has increased in riparian areas, with a consequent degradation of riparian habitats. Strengthening synergies between habitat and biodiversity legislation and strategies with the WFD, e.g. by investing in recovery of riparian habitats, could generate positive spin-off benefits for improving freshwater habitats and improving delivery of regulatory ecosystem services, such as flood control and water purification. Finally, policy should consider the effect of future climate change, which could override the efforts in pressure reduction and ecosystem restoration.

Water is a key resource for society, necessary for multiple uses. However, land-based human activities produce pressures that affect natural water availability and quality, modify riparian habitats, and alter the abundance and composition of plants, fish and micro-organisms living in the aquatic environment. In the river basin, water is at the end of the pollution cascade. Overall, the assessment of rivers and lakes indicated that these ecosystems are still in poor condition. Major knowledge gaps remain in assessing current status in space and changes in time of pressures linked to climate change, chemicals and biodiversity issues, and on the response of ecosystems to multiple pressures.

3.6.1 Introduction and description of freshwater ecosystems

Inland freshwater resources include rivers, lakes, glaciers and groundwater. Freshwater ecosystems form a network that links land to the sea, transporting water, materials and biota across systems. In specific, river ecosystems are characterized by running water (lotic habitats) while lake ecosystems by standing waters (lentic habitats). The interfaces between the water bodies and their catchments, including the riparian zones, the floodplains, and the lakeshores, are also an important part of the freshwater ecosystems.

Since 2000, the EU has put in place an ambitious and comprehensive water legislation to protects aquatic ecosystems and ensure the sustainable use of water resources, the Water Framework Directive (WFD 2000/60/EC). The Directive establishes a clear target that is to achieve good ecological and chemical status for all water bodies in the EU, including rivers, lakes, coastal, and transitional waters. In addition, groundwater bodies need to achieve good quantitative and chemical status. The WFD demands the establishment of monitoring networks, the analysis of significant pressures acting on the aquatic ecosystems, the evaluation of the Status, and the development of River Basin Management Plans, in which Programme of Measures are in place to address the pressures preventing the achievement of the good status. For water bodies where the target is not achieved, the plans indicate the measures to be deployed for reaching the target. Also, the legislation provides that measures required under several other Directives, such as the Nitrates Directive or the Urban Waste Water Directive, are included in the Programme of Measures. In addition to the WFD, the Groundwater Directive (2006/118/EC) protects groundwater resources, aiming at achieving good chemical status for all groundwater bodies in the EU; the Floods Directive (2007/60/EC) aims at assessing and managing the risks of flooding for all watercourses and coastal lines. The Directive on Environmental Quality Standards (Directive 2008/105/EC) set environmental quality standards (EQS) for the substances in surface waters, designating priority substances of concern.

In line with the overall objective of this report, the aim of this chapter is to assess and report the trends in the pressures and condition of rivers and lakes relative to the baseline year 2010. This chapter can thus be used to evaluate the targets of the EU Biodiversity Strategy to 2020. It is important to stress that the assessment is primarily based on indicators for which European wide, harmonized datasets were available in September 2019. Data that became available after September could not be included in the current assessment. Where possible, data were aggregated and presented using as spatial units the Nomenclature of Territorial Units for Statistics level 2 (NUTS2). Details on data sources and documents supporting the chapter can be found in the dedicated fact sheets (available online), and are not repeated herein. Where needed, more context is provided by citing relevant literature. However, this chapter did not make a systematic review of the literature on pressures on biodiversity and ecosystems.

This chapter delivers the baseline data to establish a (legally binding) methodology for mapping and assessing ecosystems and their capacity to deliver services and to determine the minimum criteria for good ecosystem condition of rivers and lakes as required by the new EU Biodiversity Strategy to 2030. Determining these criteria of rivers and lakes ecosystems requires also agreeing on a reference condition against which the past or present condition can be evaluated. More work will be needed to determine the target and reference levels of pressure and condition indicators in agreement with stakeholders, scientists and policymakers.

3.6.2 Ecosystem extent and change

Freshwater ecosystems comprise aquatic habitats of rivers and lakes, but their functionality depends on the exchanges with surrounding land. Riparian areas and floodplains can be seen as complementary to rivers and lakes as part of freshwater ecosystems, and provide many of their linked ecosystem services. While freshwater ecosystems are quite dynamic, and extent or locations may change depending on hydrological conditions, mapping river and lake ecosystems is difficult as available satellite images have insufficient resolution to acquire smaller rivers. Therefore, a number of datasets were employed to define ecosystem extent (see Fact sheet 3.6.001).

In the EU-28, the extent of freshwater ecosystem was assessed to comprise about 1.3 million km of total river length, 84,000 km^2 of lake surface, 297,000 km^2 of riparian land, and 367,000 km^2 of potentially flooded areas. Notably, this includes only consideration of main rivers, whereas small streams are missed. Figure 3.6.1 shows the density of freshwater ecosystems at NUTS2 level, and highlights the abundance of lakes in the Scandinavia region, and of rivers in the Mediterranean region. Despite seasonal changes, the extent of rivers and lakes in Europe has been stable since the 1980s (Pekel et al., 2016); this is confirmed by CLC accounting layers that report about 108,000 km^2 of rivers and lakes for the period 2000, 2006 and 2012.

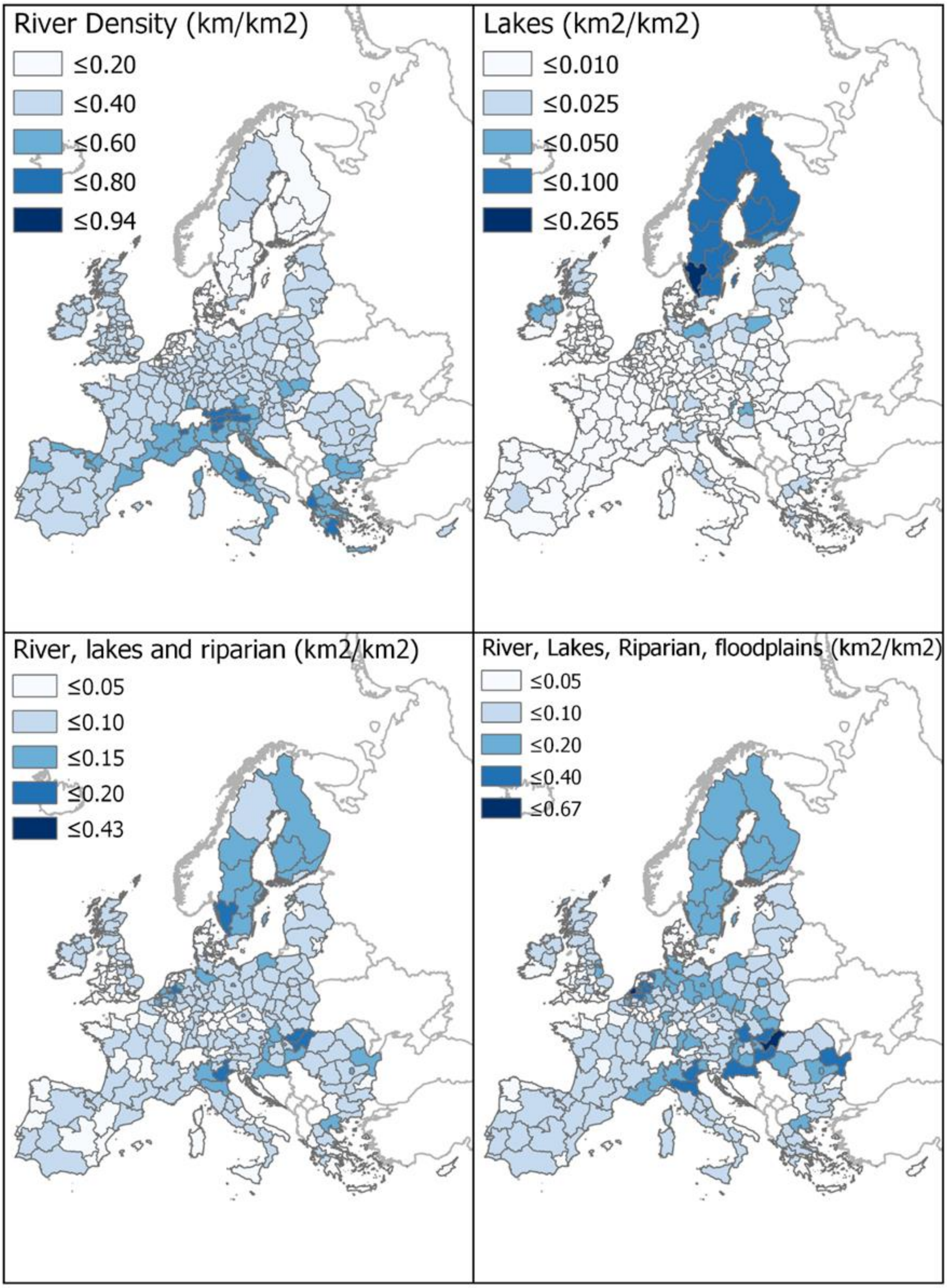

Figure 3.6.1. Density of freshwater ecosystems at NUTS2 level: total river length (km/km^2); total lake surface area (km^2/km^2); rivers, lakes, plus riparian land (km^2/km^2); and plus potential flooded area (km^2/km^2).

3.6.3 Data

Data on pressure indicators (Table 3.6.1) and ecosystem condition indicators (Table 3.6.2) in freshwaters were identified in the earlier phase of the MAES project. The tables summarize indicators data period and spatial resolution (extent and grain) used for the assessment (details on data sources can be found in the relative fact sheets available online). It can be noted that there often exists a trade-off between spatial and temporal resolutions. The longest time-series are generally available at very coarse spatial scale, whereas detailed spatial patterns are generally available as a point in time assessment.

Table 3.6.1. Freshwater indicators of pressures that were selected for the MAES study, with data period and spatial extent and grain. * = for this indicator no temporal trend could be evaluated. NA = data not available. Dataset sources are reported in the fact sheets (All fact sheets are included in the supplement of this report).

Class	Indicator	Unit	Data period	Spatial extent	Spatial grain	Fact sheet number
Habitat conversion and degradation (land conversion)	Land take in rivers and lakes	km^2/y	2000-2018	EU-28	NUTS0	3.6.101
	Land take in potentially flooded areas	km^2/y	2000-2018	EU-28	NUTS0	3.6.101
Climate change	Change in water temperature	NA				
Pollution and nutrient enrichment	Atmospheric nitrogen deposition	kg/ha	2000-2016	EU-28	NUTS2	3.6.102
	Gross nutrient balance (nitrogen and phosphorus)	kgN/ha UUA kgP/ha UUA	2004-2015	EU-28	NUTS2	3.2.10X, 3.2.10Y
	Consumption of pesticides	NA				
	Waste water collection treatment rate: % population treated at least at secondary level	fraction	2007-2015	EU-27 (no SK)	NUTS0	3.6.103a
	* Domestic emissions of nitrogen, phosphorus and BOD	t/y	2010	EU-28	NUTS2	3.6.103b
Over-exploitation	Gross Water abstractions	M m^3/y	2000-2015		NUTS0	3.6.104
	Fish catches (t/y) (in freshwater)	NA				
Introduction of Alien species	Number of annual introductions (number/y)	NA				
	* Pressure by invasive alien species of Union concern on rivers and lakes	number	2017	EU-28	Grid 10 x 10 km^2	4.2.102

Table 3.6.2. Freshwater indicators of ecosystem conditions that were selected for the MAES study, with data period considered and spatial resolution (extent and grain). * = for this indicator no temporal trend could be evaluated. NA = data not available. Dataset sources are reported in the fact sheets (Supplement to this report).

Class	Indicator		Unit	Data period	Spatial Extent	Spatial grain	Fact sheet number
Environmental quality (physical and chemical quality)	* Chemical status		classes	Before 2009; 2010-2016	EU-25 (no EL, LT, SI)	River Basin District	3.6.201
	Water quality in rivers	Monitored concentration of pollutants	mg/L	2000-2017	EU-28	EU-28	3.6.202a
		* % of river reaches with mean TN< 4 mg N/l, TP<0.1 mg P/l, and BOD < 5 mg O_2/l	%	2010	EU-28	NUTS2	3.6.202b
	Organic pollutants, metals, pesticides		NA				
	Bathing water quality		classes	2014-2018	EU-28	NUTS0	3.6.203
	* Flow alteration: frequency of days with flow below natural 10th percentile (Q10)		frequency	2010	EU-28	Grid 5x5 km^2	3.6.204
	* Water exploitation index (WEIC)		ratio	2010	EU-28	River Basin District	3.6.205
	Land cover in riparian land	Share of artificial land	fraction	2000-2018	EU-28	NUTS2	3.6.205a
		Share of agricultural land					
		Share of natural land					
		* Density of infrastructures	km/km^2	2015	EU-28	NUTS2	3.6.205b
	Hydro-morphological alteration by barriers	* Fraction of streamflow interception	fraction	2015	EU-28	NUTS2	3.6.207
		* Fraction of accessible stream network	fraction	2015	EU-28	NUTS2	3.6.207
Structural ecosystem attributes (general)	* Ecological status		classes	Before 2009; 2010-2016	EU-26 (no EL, LT)	River Basin District	3.6.208
Structural ecosystem attributes based on species diversity and abundance	Biological quality elements		NA				

Class	Indicator	Unit	Data period	Spatial Extent	Spatial grain	Fact sheet number
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Share of freshwater habitats listed under Annex 1 of the Habitats Directive in favourable conservation status	Percentage	2013 - 2018	EU-28	EU-28	3.5.203
	Trends in unfavourable conservation status of freshwater habitats listed under Annex 1 of the Habitats Directive	Percentage	2013 - 2018	EU-28	EU-28	3.5.203
	Proportion of rivers and lakes covered by Natura 2000	fraction	2000-2018	EU-28	Biogeoregions	3.5.203
	Proportion of rivers and lakes covered by nationally designated areas	fraction	2000-2018	EU-28	Biogeoregions	3.5.203

3.6.4 Drivers and pressures: spatial heterogeneity and change over time

3.6.4.1 Assessment at the level of EU-28

Assessment of pressures in freshwaters was conducted for the short term (2010-most recent year; Table 3.6.1) and for the longer period (long-term) starting in 2000 where data was available. Generally, human pressures on freshwaters due to over-exploitation (e.g. water abstractions) and nutrient pollution are still very high. For example, agricultural gross nutrient balances are still important, especially in some European agricultural regions, such as in the Netherlands, Belgium, United Kingdom and Denmark.

Most pressures acting on freshwaters are due to processes that are moderately to highly stable, and changes in response to policies take time to become apparent. Several pressures have declined in the EU-28 since 2000, however in most recent years the improvement rate has slowed down, so that pressure trends in the 2010s remained mostly stable (Table 3.6.3). Land take in potentially flooded areas has continued in the last two decades. This is worrying for the critical role of natural riparian areas for pollution retention, flood attenuation, erosion control, habitat provision, and surface and ground water connectivity. With regards to pollution and nutrient enrichment, improvements are seen mostly with regards to domestic emissions and atmospheric nitrogen deposition. This is only in part due to limited amount of information for the most recent years, as stabilization is confirmed also for pressures for which data of 2017-2018 are available, like for example atmospheric nitrogen deposition. Conversely, improvements in diffuse sources of pollution, like agricultural emissions of nutrients, are not yet visible. In addition, the legacy of nitrogen pollution in groundwater is not represented in the pressure indicators. Distribution baselines of invasive alien species (IAS) listed as of Union concern (Commission Implementing Reg. 1141/ 2016 and 1163/ 2017) have only been recently established (Tsiamis et al. 2017, 2019). About 37% of freshwater is impacted by presence of IAS of Union concern; areas of high pressure due to IAS are found across the entire EU-28, particularly in the Atlantic and Continental biogeoregions. Trends in pressure by IAS of Union concern could not be computed yet.

There are important knowledge gaps regarding the impacts of climate change on water temperature and water flow alteration, fishery exploitation, pressure due to invasive alien species, and regarding emissions of pesticides, emerging pollutants and nanoplastics to freshwater. All these pressures could not be quantified in this assessment due to a lack of data at the European scale.

Table 3.6.3. EU aggregated pressure data in relation to freshwater. Decadal change is always indicated, but sometimes it is not significant. The trend change (arrow) takes this into account.

Pressure class	Indicator		Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation	Land take in rivers and lakes		km^2/y	9.7	-4.8%	→	7	-1%	→	8
	Land take in potentially flooded areas		km^2/y	73.6	0.15%	→	7	0.2%	→	8
Climate change	Change in water temperature					unresolved			unresolved	
Pollution and nutrient enrichment	Atmospheric nitrogen deposition		kg/ha/y	9.6	-12%	→	5	-18%	↑	6
	Gross nutrient balance	Nitrogen	kg N/ha/y	49	+2%	→	4	-12%	→	6
		Phosphorus	kg P/ha/y	2	-77%	→	4	-118%	↑	6
	Consumption of pesticides					unresolved			unresolved	
	Waste water collection treatment rate: % population treated at least at secondary level		%	78.7	7.5%	↑	6	10.6%	↑	7
	Domestic emissions of nitrogen, phosphorus and BOD		10^3 t/y	BOD: 1,451 TN: 690 TP: 118		unresolved			unresolved	
Over-exploitation	Gross Water abstractions		M m^3/y	204,489	-2%	→	6	-7%	↑	7
	Fish catches (t/y) (in freshwater)					unresolved			unresolved	
Introduction of alien species	Number of annual introductions (number/y)					unresolved			unresolved	
	Presence of invasive alien species of Union concern under EU regulation		%	37		unresolved			unresolved	

↑: Significant improvement (significant downward trend of pressure indicator); →: No change (the change is not significantly different from 0% per decade);
↓: Significant degradation (significant upward trend of pressure indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

3.6.4.2 *In-depth assessment*

Land take by urban areas and infrastructure generally means irreversible habitat loss. Land take in potential flood-prone areas in 2000-2018 amounted to about 1325 km^2 (0.4% of the land considered). The largest land take was recorded in the Netherlands and France. Mostly, land take occurred at the expenses of agricultural land. Transition from cropland or grassland into artificial areas accounted for 93% of land take, whereas 5% was from conversion of woodlands. Even if land take occurred mostly at the expenses of agricultural land, this pressure is still important as conversion reduces space for habitats and ecosystems that provide important services such as the regulation of the water balance and protection against floods, particularly if soil is highly sealed. Land occupied by man-made surfaces and dense infrastructure connects human settlements and fragments landscapes. It is also a significant source of water, soil and air pollution that is quickly discharged into the river networks.

Concerning nutrient enrichment and pollution, improvements since 2000 have been seen especially for reductions in air pollution (mean atmospheric nitrogen deposition) and in domestic emissions. Air pollution impacts peaked in the 1980s (for acidification) and through 1990s (for eutrophication). International legislation, particularly the EU National Emission Directive (EC, 2001; 2016), prompted pollution reduction investments that triggered a general improvement of environmental conditions. During the 17 years of analyzed data (2000-2016), atmospheric nitrogen deposition has reduced steadily at a rate of change of -0.17 kg/ha (-18%) over a decade. Large reductions of deposition have been attained in the most polluted areas of Europe, such as Benelux, Germany, France, the United Kingdom, and Italy. Concurrently, the Urban Waste Water Directive has imposed increased levels of domestic waste treatment that reduced discharge of pollutants in receiving fresh water bodies. Upgrading from primary to at least secondary treatment type reduces nutrient emissions by 40-50%, and is even more efficient for removal of organic pollution (Vigiak et al., 2018). Trends of domestic waste emissions were thus estimated in terms of the share of population that is connected to at least secondary treatment level. According to data from the EU-27 (excluding Slovakia, for which no statistics was available) the population that accessed at least secondary treatment level increased from about 373 M people in 2007 to almost 412 M in 2015. The improvement has been steady, at a rate of about 1% of population per year (from 76 to 82%). In particular, access to secondary or higher treatment in 2010-2015 has been larger in several Eastern European countries.

Conversely, diffuse nitrogen pollution due to agricultural nutrient excess remains of concern, with little improvements in the last decade of available data. Gross nitrogen balance continued to be high, at around 50 kg N/UUA ha land at the EU-28 scale. Improvements are recorded in some Member States, notably The Netherlands, Denmark, Sweden, Croatia, Greece, and Malta, more recently also in Estonia and Lithuania, whereas an upward trend is reported for Cyprus and Latvia. Gross phosphorus balance is instead closer to neutrality, and generally phosphorus excess has reduced in the EU-28 from about 4 kg P/UUA ha in 2004 to 1 in 2015. Significant reductions of phosphorus balance are reported for Bulgaria, the Benelux area, Croatia, Finland, France, Greece, Lithuania, Malta, Poland, Slovenia, and the United Kingdom.

Water abstractions pose heavy pressure on freshwater ecosystems, especially where water availability is limited. In 2010 around 204,490 million m^3 of water (roughly equivalent to 46.8 mm) was abstracted in the EU-28 zone as off-stream. About 39% of these gross abstractions was used and 61% was returned back to the environment with a certain level of physical or chemical deterioration. The highest share of gross abstraction was from cooling sector (42%), followed by agriculture (26%), manufacturing and mining (16%), and public water supply (16%). In general, water for hydropower is abstracted in-stream and regarded as non-consumptive. However, it is not impact free. Hydropower generation leads to changes in natural water cycles in rivers and lakes, deteriorates erosion and sedimentation patterns in river beds, and causes substantial changes in riparian ecosystems. Cooling installations return water back to the environment at increased temperature that may favor invasive alien species and act as a barrier to native species moving upstream. Water consumption in the agricultural sector is mostly for crop irrigation, to meet crop requirements. Around 7-8% of total agricultural areas are irrigated in Europe with this value reaching 15% in southern Europe. Various industries, such as the pulp and paper, iron and steel, textiles, food and beverages, and chemicals sectors, use water in production processes. Some industries, such as the food industry, also incorporate water into products. The mining industry carries out off-stream water abstraction but also discharges water as part of the dewatering process, resulting in substantial levels of water-borne emission of pollutants. Water abstraction for mining usually lowers the groundwater table and deteriorates water quality because of the high levels of emissions released from the dust depression and dewatering processes. The public water supply industry uses relatively large amounts of water of good (i.e. drinking) quality from the environment. Around 64% of the total public water supply, on average, goes to households, while the remainder is allocated to other connected services. Despite the importance of water abstractions for aquatic habitats, datasets are sparse and incomplete, with the most important data gaps concerning water for agriculture and for mining.

Water abstraction decadal change was -7% for 2000-2015, but no significant change occurred between 2010 and 2015. The use of cooling water by the energy sector has increased in Europe, particularly in the south and in the west between 1990 and 2015, but has been stable in 2000-2015. In agriculture, there has been a decline in utilised irrigated areas and water use for irrigation. However, in the coming years, a slight increase in the water requirement for irrigation associated with a decrease in precipitation in southern Europe together with the lengthening of the thermal growing season, may be expected (EEA, 2018). Changing production processes, technological improvements, and recycling and reusing water all lead to gains in efficiency and, in turn, reduced water use by the manufacturing and mining industry, with an estimated decline of 13% between 2000 and 2015. Improvements in water conveyance systems have resulted in substantial water savings by domestic supply, particularly in Western Europe where water supply to households has declined from 230 litres per capita in 1990 to 134 litres per capita in 2015. Despite the improvements, the important reductions in water abstractions from 1990 to 2010 may not continue in the foreseeable horizon. In the light of these considerations, abstractions until 2020 are considered to remain stable and similar to 2010.

3.6.5 Ecosystem condition: spatial heterogeneity and change over time

3.6.5.1 Assessment at the level of EU-28

Freshwater ecosystem condition for the EU-28 was assessed considering a number of selected indicators (Table 3.6.2). Values in 2010, together with short and long-term trends, are reported in Table 3.6.4.

The foremost piece of information on freshwater ecosystem conditions is the waterbodies ecological status, reported by Member States under the Water Framework Directive implementation. The ecological status is an integrative measure of the condition of the aquatic ecosystem. It is defined in five categories: high, good, moderate, poor and bad. The classification of ecological status includes information on: 1) biological elements (composition and abundance of phytoplankton, aquatic flora, benthic invertebrate fauna, fish fauna); 2) hydromorphological elements supporting the biological elements (hydrological regime and morphological conditions); and 3) chemical and physico-chemical elements supporting the biological elements. The ecological status is established for each water body at the local scale by the regional water authorities. According to the information reported in the second River Basin Management Plans (RBMPs), covering to the period 2010-2015, in EU 39% of rivers and lakes are in good or high ecological status, 38% are in moderate status and 17% are in poor or bad status. No information is available for 5% of rivers and lakes.

In addition to ecological status, other indicators were selected to cover specific aspects of rivers and lakes condition. Several indicators focused on ecosystem environmental quality (physical and chemical). Trends of major pollutants (Biochemical Oxygen Demand – BOD; ammonium) and nutrients (including nitrates, orthophosphate and total phosphorus) were derived from the WISE monitoring station network (EEA, 2019), but this was limited to stations with sufficient stability of monitoring, which do not cover all European regions homogeneously. Trends were computed at the EU-28 scale, but not at higher spatial granularity as the monitoring network was too heterogeneous across River Basin Districts to assess changes consistently. Eco-hydrological modelling at continental scale, calibrated with data from the European monitoring network, offered a complementary information, providing an estimation of the fraction of river network where mean annual concentrations are below critical thresholds set based on literature of quality standards. This source of information provides a spatially consistent picture of current levels of organic (BOD) and nutrient pollution (nitrogen and phosphorus) in Europe. However, since hydrologic variability affects inter-annual modelled concentrations, trends in river fractions in time could not be assessed. For the same reason, short-term trends in monitored water quality were not assessed.

Freshwater conditions depend as well on the degree of encroachment of riparian and floodplain areas, as urbanization often interferes with delivery of important ecosystem services like nutrient uptake or flood attenuation. Strikingly, artificial areas have expanded in riparian land. CORINE CLC data confirms that urbanization in riparian land has occurred in 2000-2018 at a rate of 7%/decade, especially at the expense of agricultural land. After 2010 however, land cover in riparian land appears to be stable.

On the other hand, no improvement has been seen in terms of expansion of natural land cover. Similar considerations apply to the amount of land protected by EU Nature Directives: the proportion of freshwater ecosystems protected by Natura2000 or Nationally Designated areas has remained largely stable, and 63% of freshwater habitats continue to be uncovered by regulation.

Water regime alteration and availability compared to demands was assessed in terms of low flow alteration and the Water Exploitation Index (WEIC). Indicators of flow regime must be averaged on at least one decade. Therefore trends for the MAES period (2000-today) were not assessed. However, scenario analysis (Bisselink et al., 2018) indicates that flow regime alteration conditions are likely to degrade in the future.

According to the second round of RBMPs reporting under the Water Framework Directive, about 34% of river water bodies and 22% of lakes are affected by hydromorphological pressures. Altered hydromorphology, together with chemical and nutrient pollution, were among the most reported impacts affecting the ecological status of water bodies. Hydromorphological alterations remain difficult to assess at the continental scale. Two indicators were selected as proxies of barrier impacts on the stream network: the percentage of streamflow mass intercepted by dams at any reach, which is an index of alteration of material fluxes; and the fraction of stream network length that is accessible between barriers in relation to the length potentially accessible in their absence, which is an index of potential habitat continuity. Both indices reveal the importance of barriers and interrupted longitudinal connectivity in Europe, with 60% of streamflow estimated to be intercepted by dams and 4% of stream network estimated to be accessible between barriers. Yet these estimates are likely underestimating the impact of barriers, as only major dams could be mapped. On the other hand, the presence of by-passes was not considered either. Hydromorphological alterations due to flood-control or channelization was not addressed. Indicators of hydro morphological alterations represent thus a partial approximation of freshwater conditions.

Europe's bathing water quality has improved markedly over the last 40 years, following the introduction of the EU Bathing Water Directive (EEA, 2016). Effective monitoring and management has led to a drastic reduction in pollutants released through untreated or partially treated urban wastewaters. As a result, more and more bathing sites have reached 'excellent' quality. However, revision of the Directive has led to changes in data reporting, and data collected before 2014 cannot be compared to the current system. Thus, the long-term decadal change, while positive, could not be quantified. In the short term, bathing water quality could be assessed consistently only for 2014-2018. During this five-year period the share of excellent inland bathing waters increased from 78.2% to 80.8%. The share of poor quality bathing waters decreased from 2.4% in 2014 to 1.9% in 2018. Thus, in the short term the trend indicates basically stable conditions.

Overall, 39% of rivers and lakes are reported in good ecological status. Other environmental quality indicators, except for some water quality parameters (including nutrients and BOD) that show improvements, suggest that ecosystem condition has been stable since 2000, and in some areas have degraded for the loss of riparian land due to urbanization. In addition, we lack spatial and temporal data on biological quality elements, invasive alien species and other pollutants, such as organic compounds, metals and pesticides covering the EU-28 with sufficient homogeneity to have a complete picture of the recent trends.

Two indicators are directly derived from the Art.17 reporting on the conservation status of habitats under the Habitats Directive: the share of freshwater habitats in a favourable conservation status and the trends in conservation status of freshwater habitats that are in an unfavourable status (poor and bad). The total area of freshwater habitats covered under Annex 1 of the Habitats Directive is estimated at 68,050 km2 (excluding Romania) (See chapter 2, Table 2.2). This corresponds to 64% of the total extent of river and lakes ecosystems in the EU-28, and 22% of freshwater ecosystems when including the extent of riparian land. The EU level assessment of the conservation status of 20 freshwater habitats concluded that 18.4% are in good (or favourable) conservation status. The remaining habitats are in poor status (41.8%), a bad status (32.7%) or unknown (7.1%) (State of Nature report for the period 2013-2018, forthcoming). Only 3.8% of the freshwater habitats that is in an unfavourable status is showing improving trends. 35% of the freshwater habitats that is in an unfavourable status is showing deteriorating trends.

Table 3.6.4. EU aggregated freshwater aggregated condition data. Empty short term cells indicate that short term trend was not evaluated due to lack of sufficient data, or because the period was too short to allow meaningful analysis indicators

Condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Environmental quality (physical and chemical quality)	Share of rivers and lakes achieving good chemical status	%	36	0	→		NA	unresolved	
	Water quality BOD	mg/l	2.09		unresolved		-26%	↑	7
	Water quality N-NH4	mg/l	0.131		unresolved		-74%	↑	7
	Water quality N-NO3	mg/l	1.87		unresolved		-8%	↑	7
	Water quality P-PO4	mg/l	0.070		unresolved		-28%	↑	7
	Water quality TP	mg/l	0.103		unresolved		-43%	↑	7
	River fraction with mean TN < 4 mg N/l	%	76		unresolved			unresolved	
	River fraction with mean TP < 0.1 mg P/l	%	56		unresolved			unresolved	
	River fraction with mean BOD < 5 mg O_2/l	%	86		unresolved			unresolved	
	Poor bathing water quality	%	2.5	-1.25%	→	8	NA[1]	↑	5
	Low flow alteration	%	61		unresolved	3		unresolved	3
	Water exploitation index > 0.20	%	8		unresolved	3		unresolved	3
	Share of artificial areas in riparian land	%	7		unresolved		7%	↓	8
	Share of agricultural areas in riparian land	%	47		unresolved		-2%	→	
	Share of natural areas in riparian land	%	21		unresolved		1%	→	
	Infrastructure density riparian land	km/km^2	2.03		unresolved			unresolved	
	Dam interception of streamflow	%	60.3		unresolved	3		unresolved	3
	Fraction of accessible network	%	3.8		unresolved			unresolved	

Structural ecosystem attributes (general)	Share of rivers and lakes achieving good ecological status	%	39	0	➔	5		unresolved	
Structural ecosystem attributes based on species diversity and abundance	Biological quality elements				unresolved			unresolved	
Structural ecosystem attributes monitored under the EU Nature directives and national legislation	Share of freshwater habitats listed under Annex 1 of the Habitats Directive in favourable conservation status*	%	18.4						
	Trends in unfavourable conservation status of freshwater habitats listed under Annex 1 of the Habitats Directive*	% improving	3.8		↑				
		% stable	37.5		➔				
		% deteriorating	35.0		↓				
		% unknown	23.8		unresolved				
	Proportion of rivers and lakes covered by Natura 2000	%	32		unresolved			➔	7
	Proportion of rivers and lakes covered by nationally designated areas	%	20		unresolved			➔	7
	Proportion of rivers and lakes not covered by nature regulation	%	63		unresolved			➔	

↑: Significant improvement (significant upward trend of condition indicator); ➔: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant downward trend of condition indicator): Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

* The indicators on freshwater habitat conservation status have been treated differently than the other indicators with a different baseline year and different time period (2013–2018); so the percent change is expressed for a period of 6 years instead of 10 as for the other indicators. The trends in conservation status are only available for freshwater habitats in an unfavourable conservation status. Please check chapter 2 for details.

[1]: data for bathing water quality showed marked improvement in the long term, however data collected before 2014 cannot be compared to current data, so decadal change for long term could not be computed

3.6.5.2 In-depth assessment

The scientific knowledge underpinning the WFD ecological status classification has largely improved from the first (2009) to the second (2010-2015) RBMPs reporting round. There was a marked reduction in water bodies of unknown status, accompanied by a large improvement in confidence in classification thanks to more widespread application of inter-calibrated biological assessment methods. However, this hampers comparison of status between the first and second RBMPs. Overall, the second RBMPs show limited change in ecological status compared with the first RBMPs; for most water bodies the ecological status remained similar in both sets of RBMPs (Figure 3.6.2). A closer look at the change in quality elements shows some improvement (EEA, 2018). The improvements are seen in all the most commonly used biological quality elements in rivers, but they are less clear in phytoplankton in lakes. Based on the second RBMPs reporting round, which use data from 26 Member States (excluding Lithuania and Greece[77]), 39% (Figure 3.6.3) of river and lake water bodies have achieved good ecological status. Lakes generally have a better status than rivers, partly due to many of the lakes located in relative sparsely populated regions (Sweden and Finland).

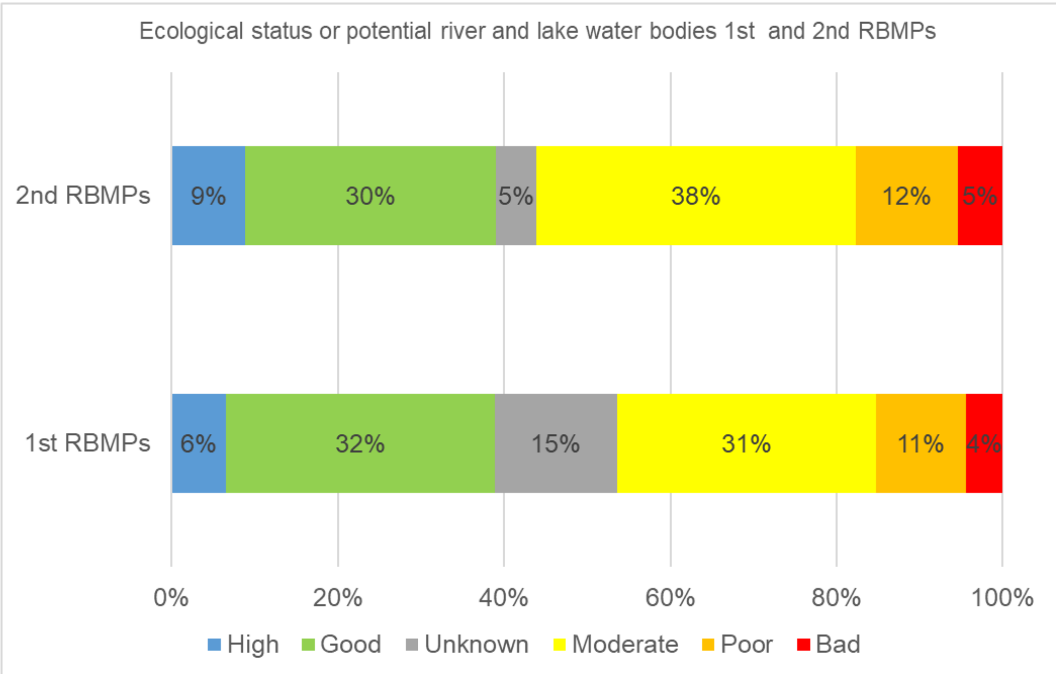

Figure 3.6.2. Ecological status reported in the second RBMPs reporting round (2010-2015) and the first one (2009). Source: WISE-SoW database including data from 26 Member States (EU-28 except Greece and Lithuania). The quality of scientific knowledge on which ecological classes are defined has improved from the first to the second reporting round, hampering direct comparison. Nevertheless, the two reporting rounds indicate stability of ecological status in the MAES assessment period.

[77] Data for Lithuania and Greece were not available in September 2019. They are now available and can be accessed at European Environment Agency (EEA, 2020) WISE WFD dataviewer: https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd

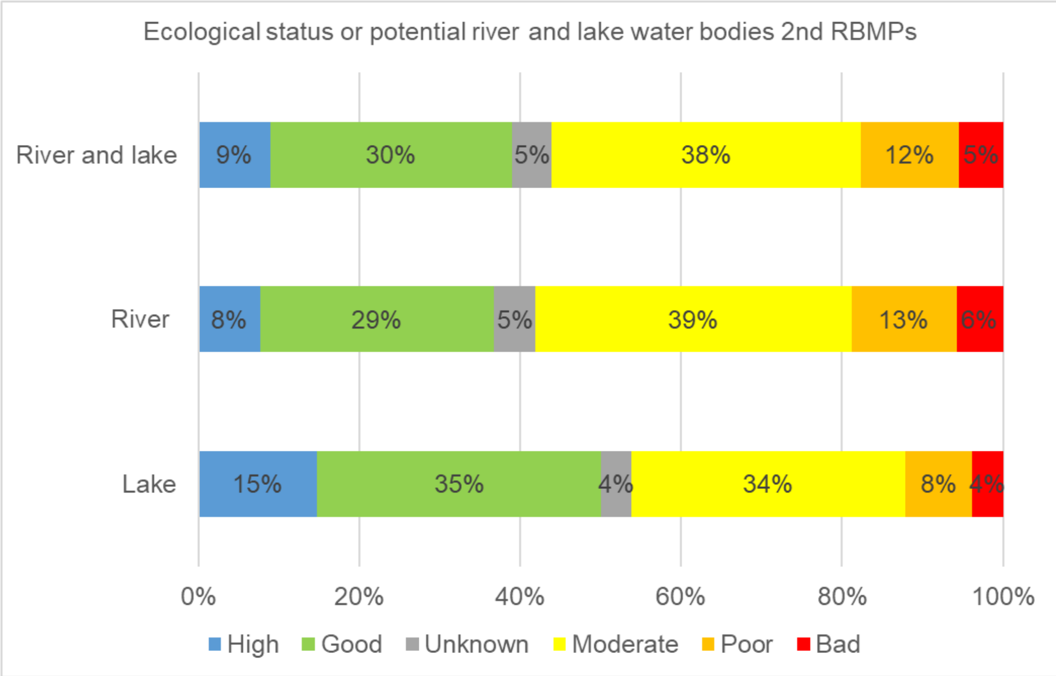

Figure 3.6.3. Ecological status or potential of rivers and lakes water bodies in the EU (second River Basin Management Plans reporting round). Source: WISE-SoW database including data from 26 Member States (EU-28 except Greece and Lithuania[78]).

3.6.6 Convergence of evidence

3.6.6.1 Summary of the trends in pressure and condition

Table 3.6.5 summarizes the short and long term trends of pressures and condition indicators. The table does not include the indicators on habitat conservation status as they do not result in a single trend (but rather a proportion for each trend).

Trends of pressures on rivers and lakes were calculated using 13 indicators. The assessment reveals that in the short-term trend, no indicator shows negative change resulting in degradation, six no change, one a positive change resulting in improvement, and six are not available or unresolved. In the long-term trend, no indicator shows negative change resulting in degradation, three no change, four a positive change resulting in improvement, and six indicators remain unresolved or have no data.

Trends of condition of rivers and lakes were calculated using 23 indicators. In the short-term trend, no indicator shows further degradation or improvement, three show change, and 20 indicators remain unresolved. In the long-term trend six indicators indicate improvement, five show no change, and one degradation. 11 remain unknown (unresolved or no data).

[78] Data for Lithuania and Greece were not available in September 2019. They are now available and can be accessed at European Environment Agency (EEA, 2020) WISE WFD dataviewer: https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd

Table 3.6.5. Summary of trends in pressure and condition of rivers and lakes in the EU-28

	Indicator	Short-term trend (change)	Long-term trend (change)
Pressures	Land take in rivers and lakes	→	→
	Land take in potentially flooded areas	→	→
	Change in water temperature	unresolved	unresolved
	Atmospheric nitrogen deposition	→	↑
	Gross nutrient balance (nitrogen)	→	→
	Gross nutrient balance (phosphorus)	→	↑
	Consumption of pesticides	unresolved	unresolved
	Waste water - population treated at least at secondary level	↑	↑
	Domestic emissions of nitrogen, phosphorus and BOD	unresolved	unresolved
	Gross Water abstractions	→	↑
	Fish catches (t/y) (in freshwater)	unresolved	unresolved
	Number of annual introductions (number/y)	unresolved	unresolved
	Pressure by invasive alien species of Union concern on rivers and lakes	unresolved	unresolved
Condition	Share of rivers and lakes achieving good chemical status	→	unresolved
	Water quality BOD	unresolved	↑
	Water quality N-NH4	unresolved	↑
	Water quality N-NO3	unresolved	↑
	Water quality P-PO4	unresolved	↑
	Water quality TP	unresolved	↑
	River fraction with mean TN < 4 mg N/l	unresolved	unresolved
	River fraction with mean TP < 0.1 mg P/l	unresolved	unresolved
	River fraction with mean BOD < 5 mg O_2/l	unresolved	unresolved
	Poor bathing water quality	→	↑
	Low flow alteration	unresolved	unresolved
	Water exploitation index > 0.20	unresolved	unresolved
	Share of artificial areas in riparian land	unresolved	↓
	Share of agricultural areas in riparian land	unresolved	→
	Share of natural areas in riparian land	unresolved	→
	Infrastructure density riparian land	unresolved	unresolved
	Dam interception of streamflow	unresolved	unresolved
	Fraction of accessible network	unresolved	unresolved
	Share of rivers and lakes achieving good ecological status	→	unresolved
	Biological quality elements	unresolved	unresolved
	Proportion of rivers and lakes covered by Natura 2000	unresolved	→
	Proportion of rivers and lakes covered by nationally designated areas	unresolved	→
	Proportion of rivers and lakes not covered by nature regulation	unresolved	→

↑: Significant improvement (significant downward trend of pressure indicator; significant upward trend of condition indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator; significant downward trend of condition indicator); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment; Indicators of conservation status of habitats, species and birds are excluded.

Considering the long-term trends, most pressures acting on rivers and lakes that could be accounted for were estimated to be reducing, especially nutrient pollution, and no pressure was estimated to be increasing (degrading situation). Yet, an important share of pressures remained unresolved; it is likely that these knowledge gaps hide a number of degrading pressures that could not be quantified, such as the impact of climate change on aquatic habitats, the spread of invasive alien species of Union concern, or the impact of emerging pollutants and chemicals (pesticides, chemicals, litter) to name a few. Section 7 on knowledge gaps elaborates more on these issues. In addition, despite nutrient emissions having decreased, justifying improving trends, their values remain high in many regions.

The dominance of improving trends in ecosystem pressures is not fully reflected in the long term trends of ecosystem conditions; the share of improving indicators, while dominating, is balanced by indicators that are not changing or unresolved. Degrading conditions were limited to urbanization in riparian land.

The apparent lag of response between the reduction of pressures and improvement in condition could be due to different aspects. Firstly, the level of pressures reduction might be insufficient to produce significant improvements in the conditions of aquatic ecosystems. Secondly, the restoration of ecological processes might require longer times (e.g. Jeppesen et al., 2005). Third, not all the significant pressures have been considered, as for several pressures status and trends could not be assessed. Finally, not all the pressures act proportionally, with some pressures (or combination of pressures) having higher detrimental effects on aquatic ecosystems.

3.6.6.2 Mapping convergence of evidence

Where possible, MAES indicators were assessed at NUTS2 scale (Tables 3.6.1 and 3.6.2). This was considered a balanced compromise between original data resolution and policy relevance. In some cases, only coarser resolution was available. When information was available at NUTS0 scale, indicator trends assessed at this scale were applied to all dependent NUTS2 units, respecting the hierarchical nesting of administrative units. Some indicators were assessed at River Basin District level or in grids (Table 3.6.2). However, trends for these datasets were not available, so these indicators could not be considered in the mapping. Finally, some condition indicators were assessed at biogeoregional scale (Table 3.6.2). To associate the two spatial grain resolutions, each NUTS2 was univocally attributed to the biogeoregion that held the largest area of the NUTS2.

For mapping freshwater ecosystem trajectories, all pressures and condition indicators (Tables 3.6.3 and 3.6.4) for which spatial maps were available were included. Overall, mapping freshwater ecosystem trajectories considered six pressures and three conditions, for a total of nine indicators, namely comprising:

(i) at NUTS2 scale: mean atmospheric nitrogen deposition and share of artificial land in riparian areas;

(ii) at NUTS0 scale: population share treated at secondary level or above (domestic emissions), land take in potentially flooded area, gross nutrient balance of nitrogen and phosphorus, and water abstractions; and

(iii) at biogeoregional scale: the proportion of rivers and lakes protected by Natura 2000 and nationally designated areas.

Figure 3.6.4 shows the number of indicators that showed no change, improving or degrading trends. Spatial patterns mostly reflect the dominance of indicators at NUTS0 scale, especially in terms of improving conditions. Conversely, degrading conditions are sparser. Prevailing stability of indicators (i.e. 7 or 8 indicators showing no change) were in the Iberian Peninsula, parts of Germany, Ireland, Romania and parts of Bulgaria. Degrading and improving trends for pressure and condition indicators may coexist in the same region, which makes it hard to define the general trajectory of freshwater ecosystems regionally. This suggests that some measures with positive effects might have been taken but they have not been sufficient to address the wide range of degrading drivers acting on aquatic ecosystems (e.g., Nõges et al., 2016). In addition, the spatial analysis highlights that changes of pressures and condition indicators vary across regions and average continental values might mask opposed local trends.

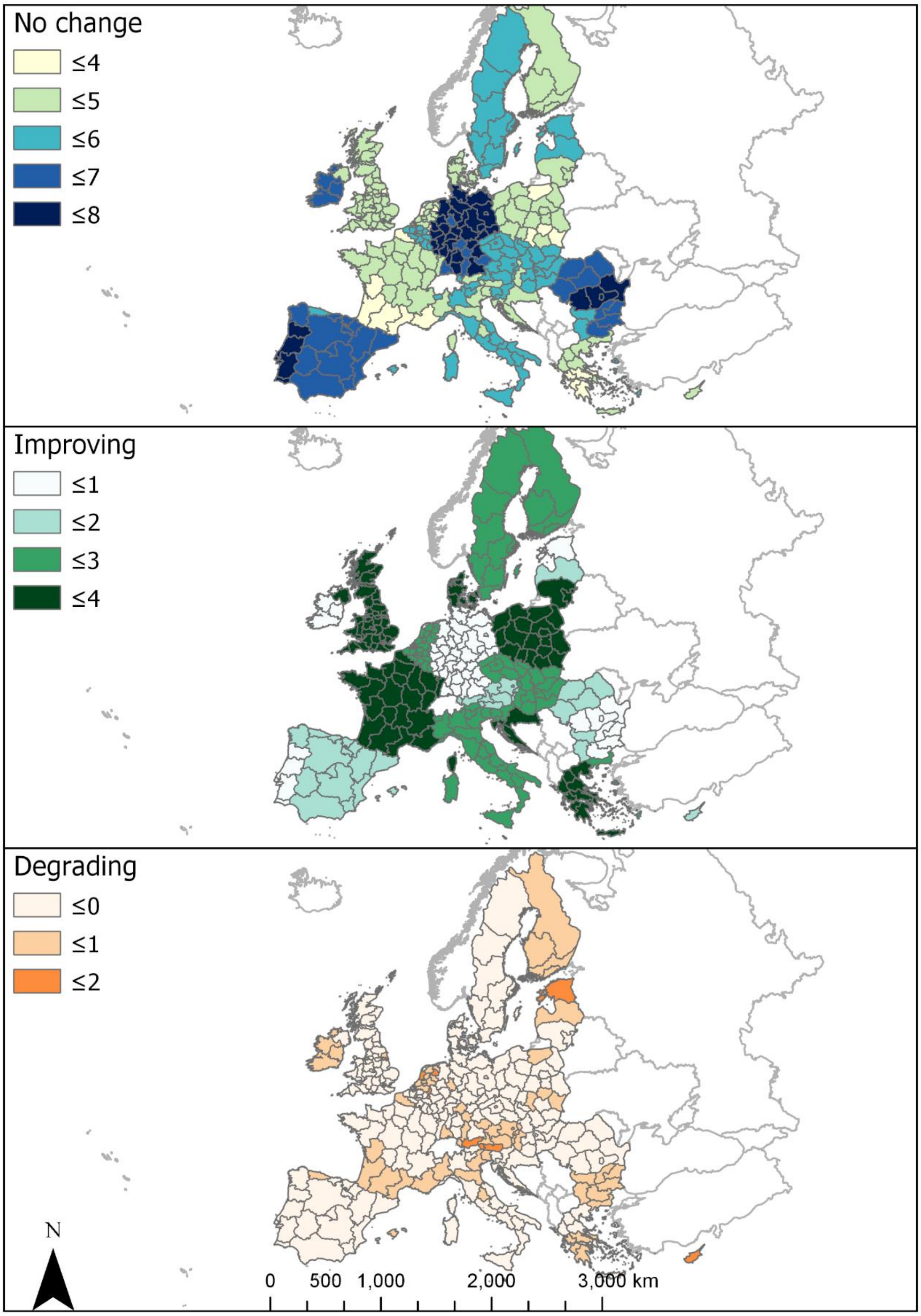

Figure 3.6.4. Mapping of freshwater ecosystem trajectories (pressures and conditions): number of indicators showing no change, improving or degrading trends.

Table 3.6.6 reports the area (calculated at NUTS2 level) subject to indicators showing degrading and improving conditions. About 28% of the EU (25% of NUTS2 units) showed presence of degrading conditions, whereas 32% of the area (37% of units) showed improvement in four indicators out of nine. Prevailing no change conditions account for about 30% of the area.

Regardless, in the interpretation of Figure 3.6.4 and Table 3.6.6, it should be kept in mind that this represents only a partial snapshot of freshwater conditions since only nine out of 36 indicators used for rivers and lakes assessment could be mapped, i.e. 75% of indicator trends remained spatially unresolved/unknown.

Table 3.6.6. European area (in km^2; calculated at NUTS2) per combination of number of indicators showing improving and degrading trajectories.

		Number of degrading indicators			
		0	**1**	**2**	**Total**
Number of improving indicators	**1**	495,583	193,635	45,326	734,543
	2	620,060	181,293	31,441	832,794,
	3	938,759	475,968	8,295	1,423,023
	4	1,081,497	297,106		1,378,603
Total		3,135,899	1,148,003	85,062	

3.6.7 Options for policy

In the EU a comprehensive water policy to protect water resources and aquatic ecosystems has been in place since 2000, when the Water Framework Directive entered into force. The WFD is a pioneering legislation as it includes ecological targets and addresses the complexity of pressures affecting the status of aquatic ecosystems (Carvalho et al., 2019). The legislation requires the development of River Basin Management Plans (RBMPs) containing Programmes of Measures (PoM) to reduce the significant pressures and achieve the Good Ecological and Chemical Status for all water bodies. The PoM should include also measures foreseen by other policies that protect the environment and regulate specific sources of pollution.

As most pressures on aquatic ecosystems derive from human activities, the sustainable use of water resources and the protection of freshwater ecosystems imply trade-offs between different uses of water and require coordination between objectives of economic development and environmental protection. RBMPs are instruments to ensure the coherence and integration of water policy with other sectoral policies and measures, such as the agricultural policy. However, governance dynamics at the administrative and river basin levels have to be integrated.

The WFD also provides the framework for developing and maintaining the monitoring of pressures and ecosystems condition. Long-term monitoring is crucial to understand the effectiveness of measures and the recovery of conditions, as well as to detect new forms of pressure. Generally, assessing ecological responses requires long observation periods (>25 years; Parmesan et al., 2013). Indeed, the present analysis shows improving trends in the EU for some pressures, such as pollution from wastewater treatment plants, but also highlights the lack of sufficient information at the EU level to detect trends on other pressures, such as the impact of climate change or emerging pollutants. The analysis has also shown the limitations of spatial and temporal coverage of important data to assess ecosystem condition, like information on hydromorphological alterations for example. Modelling can be used to understand possible pressures and conditions in regions where data are missing, but it cannot replace real data. Spatial data derived from satellite images, such as information on the land cover, have also shown to be very relevant for detecting trends and they should be further exploited in combination with monitoring data.

While some pressures have shown improving (downward) trends, their current state is still high, which may hinder the recovery of ecosystem condition. Unknowns remain on the presence and trends of other pressures and on the effects of the combination of multiple pressures. Overall, a substantial part of the condition indicators indicated improving trajectory (Table 3.6.5), while degrading trend was detected for riparian zones, due to the increase in the share of artificial areas, with a consequent loss of riparian habitats. Policy measures should address this evidence, by persisting with the reduction of pressures for meeting ecological targets, by gaining new knowledge and information on the different type of pressures, and by halting additional urbanisation and reversing soil sealing in riparian land. In addition, cost-benefit analysis, including all ecosystem services provided by rivers and lakes, could be used to show the advantages of ecosystem restoration (Liquete et al. 2016), as generally more services are provided by aquatic ecosystems in good conditions (Grizzetti et al. 2019).

The current status and trends of freshwater habitats in protected areas points to poor ecosystem condition of rivers and lakes. Strengthening synergies between habitat and biodiversity legislation and strategies with the WFD, e.g. by investing in the recovery of riparian habitats, could generate positive spin-off benefits for improving freshwater habitats and improving delivery of regulatory ecosystem services, such as flood control and water purification. Similar considerations can be extended to floodplains (EEA, 2020).

What is less evident from the present assessment is the role of groundwater in contributing to the conditions of rivers and lakes. Indeed, groundwater represents a fundamental reservoir of freshwater. Any action to protect or restore the quality of rivers and lakes should also address groundwater, as surface and subsurface waters are interconnected, and many ecological functions depend on the exchanges between the two (Kandoorp et al., 2018). Unsustainable groundwater abstractions and pollution legacy, such as nitrates in groundwater, represent important threats to aquatic ecosystems, with long term effects on their condition. The EU WFD covers the groundwater resources, incorporating the specific Groundwater Directive.

Finally, policy should consider the effect of future climate change, which could override the efforts in pressures reduction and ecosystem restoration. This is particularly true in relation to eutrophication impacts, where climate change has been shown to act synergistically with increased temperatures and drought in some regions and lake types (Richardson et al., 2019). Climate change impact on freshwater ecosystems is manifold, and interactions with other pressures are generally significant (Parmesan et al., 2013). Conservation management should thus include consideration of foreseen climate change impacts, qualitative identification of these impacts may often be sufficient to plan for mitigation and adaptation strategies (Parmesan et al., 2013).

3.6.8 Knowledge gaps and future research challenges

Tables 3.6.1 and 3.6.2 shows that important knowledge gaps limited the assessment of freshwaters status. In total, trends for 46% of pressures and 39% of condition indicators included in the convergence of evidence (Table 3.6.5) could not be assessed at the EU-28 scale. These proportions increased at more detailed spatial scale.

Importantly, knowledge gaps included pressures linked to climate change, chemicals and biodiversity issues. Water temperature was identified as an important indicator for climate change, but no homogeneous data at the EU scale was available. Yet, climate change indicators show that the EU-28 will face challenging conditions brought about by altered hydrology (e.g. snow melting cycles, drought, streamflow variability) coupled with changes in temperature. Observations indicate regional patterns of change in river flood occurrence in response to climate change already taking place in Europe, where some regions experience increased flood frequency while other regions experience decreased floods, and these trends are likely to continue in the future (Blöschl et al., 2019). Scenario modelling (Bisselink et al., 2018) indicates that water availability due to climate change will likely result in a north-south pattern whereby water scarcity will substantially increase in the South of Europe, likely resulting in reduced low flows, depleted water availability in peak demand season, and lower groundwater levels. In Central and North Europe, projections indicate increased water availability. Seasonality will likely affect summer and winter periods; with wetter winters and drier summers especially in France, Belgium and the U.K. High flows in autumn and winter are projected to increase by 10 to 30% everywhere in Europe. Spring streamflow is projected to decrease in the Baltic Sea region due to lower snowmelt sources, whereas in summer high flows are likely to increase in Central and Eastern Europe.

Such changes will clearly affect water availability, however the likely impacts on water quality, ecosystems and aquatic habitats have not been assessed. Impacts of climate change are likely to affect freshwater ecosystems differently, also according to initial conditions and amount of change (Cantonati et al., 2020). Changes in water temperature are likely to be less pronounced than those of air temperature, by virtue of water thermal inertia. However it is unclear how water temperature maxima may change, especially if high air temperatures occur at low flow. Furthermore, a reduction of water contribution from colder snowmelt or of groundwater may increase surface water temperature especially in spring, and may impact the reproduction cycle of sensitive aquatic species. A global study has estimated an increase in water temperature of 1.6-2 °C for European rivers, with increases in maxima of 1.8-2.8 °C (van Vliet et al., 2013). Water temperature trends in selected rivers and lakes already show an increase in temperature of 1 to 3 °C over the last century (EEA, 2016b). Local conditions such as thermal pollution, e.g. by releases from cooling systems, or riparian shadowing may exacerbate or, conversely, attenuate these variations. The impact of temperature pattern changes on ecosystem communities varies: it has been observed that different community groups react at different pace, with primary consumers reacting more quickly than secondary consumers. This can cause asynchrony in the trophic interactions that may disrupt the resilience of ecosystems (Thackeray et al., 2010).

In terms of water quality, past monitoring and research had focused on nutrients (organic, nitrogen, and phosphorus), while less data have been collected on priority substances. While data collection has improved, coverage in space and time is still insufficient to provide a consistent picture across Europe. The majority of water bodies fails to achieve good chemical status, mostly due to the presence of ubiquitous substances. Member States are making significant progress in tackling certain individual priority substances, apart from mercury, pBDEs and PAHs. During the first RBMP cycle, Member States made progress in tackling several other priority substances, such as metals (cadmium, lead and nickel) and several pesticides, suggesting that some effective measures were implemented. Particularly for pesticides, the lack of homogeneous monitoring and information on the use of active ingredients (Galimberti et al., 2020) hinders an assessment European scale. Lack of sufficient data on the application and fate of pesticides is a major knowledge gap on the potential impact of intensive agriculture on water quality. Conceptual models at the EU scale show the pervasive distribution of chemicals (Pistocchi et al., 2019). Gathering a robust knowledge base at EU scale is a prerequisite to address the impacts of pesticide pollution in the future.

Hydro-morphological alterations are major issues affecting the ecological status of aquatic habitats. Indicators of altered hydrology and morphology were limited in this assessment to alteration of low flow, water exploitation index, and impacts from barriers on longitudinal connectivity. For these indicators no trend could be assessed. In the future, these baseline condition can be reassessed to monitor progress. However, alteration of hydrological conditions needs longer time to account for the natural inter-annual variability, and other flow alteration indices might become important to be monitored for their impact on biodiversity. Similarly, the assessment of morphological alterations would need to be expanded to include for example impacts of channelization or presence of engineering structures. Improvements in remote sensing data grain and availability may improve detection and mapping of altered morphology condition.

No information was available on fishery conditions, and potential over-exploitation, in freshwaters. Data collection on invasive alien species of Union concern in freshwaters only started quite recently (Tsiamis et al., 2017; 2019). The available data was sufficient to define the current pressure on water bodies, based on the recently established species distribution baselines, but not trends. Essential information on the status of conservation status of species and bird populations was not available in a format that could be used for this assessment (see also chapter 2). In conclusion, a major knowledge gap encompasses all aspects (pressures and condition) of biodiversity in freshwater ecosystems.

Important limits in ecosystem condition datasets stem from inconsistencies in data reporting at continental scale. The implementation of the WFD delivered major improvements in the knowledge of freshwater ecosystem conditions: in the second RBMP reporting round, the knowledge basis for assessing ecological and chemical status has greatly improved, compared to the first round. This was due to both more extensive data collection, and to methodological improvements, e.g. in the inter-calibration of methods for assessing biological quality elements (BQE). Unfortunately, as of today, data on BQEs are still too heterogeneous to provide a clear picture of the EU-28 current condition, let alone trends. These improvements mean that status classification results are now a better interpretation of the general health of the water environment, but hampered detection of status change. Thus, it is too early in the data collection to see trajectories. Yet, the knowledge basis and the reporting consistency will certainly continue to improve in the future.

3.6.9 Conclusions

Water is a key resource for society, necessary for multiple uses. However, land-based human activities produce pressures that affect natural water availability and quality, modify riparian habitats and alter the abundance and composition of plants, fish and micro-organisms living in the aquatic environment. In the river basin, water is at the end of the pollution cascade. Sectoral demands for water, diffuse pollution from agricultural land, spread of invasive alien species, extension of artificial areas in riparian land, pollution of emerging substances from urban land, and climate change put freshwater ecosystem under multiple pressures that need to be addressed in integrated River Basin Management Plans.

Overall, the ecological status of rivers and lakes is at least good in 39% of water bodies. Yet, the EU Habitats Directive data show that most freshwaters protected habitats are still in poor conditions in relation to freshwater biodiversity. The indicators collected for rivers and lakes indicate that while some pressures have decreased, showing some effectiveness of policy implementation, the level of anthropogenic pressures on aquatic ecosystems remains high, thus hindering the recovery of ecosystems.

Major knowledge gaps remain in assessing current rivers and lakes condition across Europe and changes over time in pressures linked to climate change, chemicals and biodiversity issues, and on the response of ecosystems to multiple pressures.

Policy is in place in the EU to protect and restore water resources and aquatic ecosystems. In the light of these chapter findings, there appear to be scope for immediate actions on recovery of riparian habitats, which could strengthen synergies between the WFD and Habitats and Birds Directives.

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3.7 Marine ecosystems

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Summary: Europe's seas and oceans host the largest range of ecosystems in the entire European Union. They are hotspots of global biodiversity and provide our citizens with a steady flow of essential goods (e.g. food) and services (e.g. climate regulation). Approximately 40% of the EU's population lives in coastal areas and for them, the seas and oceans are directly linked with culture, identity and sense of belonging. However, decades of overfishing, discharges of nutrients, contaminants and litter and seismic surveys have severely degraded the condition of marine ecosystems. These pressures are driven by an increasing population and a growing economy put in jeopardy the flow, quality and quantity of benefits that future generations might derive from European seas and oceans. Climate change is an additional pressure, with more and more measurable impacts.

To date, the EU has established one of the most comprehensive policy frameworks in the world, with a holistic, ecosystem-based approach to protecting the marine environment. The Marine Strategy Framework Directive (MSFD), as the environmental pillar of the EU's wider Integrated Maritime Policy (IMP), sets the basis for the achievement or maintenance of the good environmental status (GES) of marine waters by 2020. The MSFD obliges Member States to design their own marine strategies to efficiently and effectively achieve this objective. In that context, the MSFD, and the accompanying Commission Decision (EU) 2017/848, create the proper setting for synergy among the various policies indirectly targeting the marine environment.

This chapter presents the current trends in pressures on, and the condition of, marine ecosystems. Trends are based on the analysis of selected indicators, derived from the best available EU-wide data stemming as much as possible from current policy reporting streams. It provides reflections about the EU's future directions towards protecting our seas and sustainably managing the marine resources.

Of the many indicators of pressures and ecosystem condition initially proposed in the fifth MAES report and retained for the present analysis, only a few have yielded clear trends. Significantly increasing and unresolved trends in pressures highlight the magnitude of the anthropogenic impact to which the marine ecosystem is still subject. Even in the case of decreasing or stable trends, pressure levels remain unsustainably high. This is particularly the case for fishing pressure, where long-term trends in Europe's marine waters are decreasing in the North-east Atlantic Ocean and Baltic Sea and are stable in the Mediterranean Sea and Black Sea. At the same time, some of the assessed commercial fish stocks display signs of recovery in the North-east Atlantic Ocean and Baltic Sea, while they remain critically overfished in the Mediterranean Sea and the Black Sea).

However, a major caveat in the analysis relates to the quality of the datasets available: the lack of data series sufficiently long to derive significant trends points to a need for further efforts in regards of data collection and management at the EU scale. In relation to pressure from fishing activities, for example, the data used are mostly derived from the Data Collection Framework, under the umbrella of the Common Fisheries Policy: here, the ensemble of stocks assessed varies from country to country and from year to year, so that the available datasets are not entirely comparable over time.

In relation to nutrients in coastal waters (under the Water Framework Directive - WFD) and in the marine waters (under the MSFD), monitoring and assessment under the two directives still lack harmonisation in the methodological standards, at regional level (and sometimes even at national level). Therefore it is still difficult to achieve a seamless assessment of nutrient status covering marine waters from coast to open sea. However, current trends point to a general decrease in the input of nutrients to sea in some marine regions.

In relation to contaminants, available data indicate that all four marine regions in Europe still suffer from contamination. Current data availability from policy reporting streams does not yield a harmonised EU-wide dataset allowing the establishment of clear trends at regional sea level. Regional assessments are available through the regional sea conventions (RSCs). Although the general regional trends agree with those presented in this study, they are not comparable with one another due to lack of consistency in the choice of (groups of) substances and in the monitoring protocols.

Trends in pressure from litter are also difficult to assess reliably, as recent progress in data availability seems to cover mostly beach litter, while seafloor litter and micro litter are still largely unknown.

On the other hand, reflecting increasing concern for the protection of our marine environment, the spatial extent of marine protected areas (MPAs) ([79]) has been steadily increasing in the past few years: to date, Europe as a whole has exceeded the Aichi target 11 ([80]) under the Convention for Biological Diversity (CBD). At sub-regional scale, the picture is more variegated, with the Greater North Sea at one end of the spectrum, exceeding 27% areal coverage, and the Aegean-Levantine Sea at the other, with 2.6% (EEA, 2018). When looking in greater detail, shortcomings can be found also in the habitat coverage: the large majority of MPAs are designated near the shore, where coverage largely exceeds the 10% Aichi target. As we move away from the shore, and with increasing depth, coverage reduces drastically. Connectivity and ecological coherence are also far from optimal. The vast majority of MPAs do not benefit from management plans and/or sufficient protection measures, effectively turning many designations into 'paper parks' (WWF, 2019).

As a whole, the EU will most likely fail to achieve GES by 2020, according to the latest assessments reported by Member States (COM/2020/259). The few trends towards decreasing pressures and improving ecosystem conditions are mainly related to marine ecosystem assessments at regional scale performed by the RSCs. Although it integrates marine knowledge in structured national strategies for the first time, the MSFD, as currently implemented, still fails to achieve harmonised monitoring at regional level.

On the other hand the MSFD, as the environmental pillar of the wider IMP, supports explicitly the application of the ecosystem approach (EA) using ecosystem-based management (EBM), based on the knowledge that the EU can get higher returns from healthier seas and oceans. It is accompanied by the Maritime Spatial Planning Directive (MSP, Directive 2014/89/EU), which fosters coherent management of marine space and human activities across borders and sectors. The EA and, in turn, the EBM should achieve concrete form in the programmes of measures (POMs). It is difficult to assess the effectiveness of POMs as reported by Member States in 2016, when about 75% of the proposed measures were actually existing measures, often imported from the implementation plans for other policies. Consequently, it is also difficult to confirm or estimate whether the MSFD and other related EU policies have a large-scale impact on the quality of our marine environment. For instance, further implementation of the circular economy package, together with the recent plastics strategy and the single-use plastics directive, might manage to reduce litter at sea, but there is a need for increased policy coordination and more ambitious targets by Member States and the EU as a whole.

This chapter assesses trends in pressures and conditions for marine ecosystems in the EU. The assessment describes quantitatively the current condition of marine ecosystems, the key drivers of degradation and aspects of improvement. The challenges of climate change and continued biodiversity loss call for a courageous rethinking of the current model of protecting and restoring the marine ecosystems, in line with the transformational changes advocated by the European Green Deal.

3.7.1 Introduction and description of marine ecosystems

In the context of MAES, marine ecosystems are defined as encompassing all marine waters, including waters at the land/sea interface with salinity higher than 0.5 ‰. Following the MAES typology, four ecosystems are considered: marine inlets and transitional waters, coastal waters, shelf waters and open ocean (Maes, 2018). For the purpose of this study, the four ecosystems have been merged into a single assessment.

The EU, including its outermost regions and the overseas countries and territories, has jurisdiction over the largest maritime area globally (EEA, 2007), which is bigger than the total land area of the EU. Costanza et al. (2014) estimated the global monetary value of services provided by coastal and marine ecosystems at about USD 49.7 trillion a year (2011 estimate). Even when accounting for possible limitations in the analysis (Pendleton et al., 2016), and although the absolute number might differ depending on the approach, the contribution of marine ecosystem to human well-being is still of staggering magnitude.

Approximately 40% of the EU population lives in coastal areas, and the marine environment is directly linked with culture, identity and sense of belonging (Eurostat, 2013). The sea and ocean ecosystems supply European citizens with provisioning (e.g. food and raw materials) and cultural (e.g. recreation, heritage) services. EU marine ecosystems also contribute to the global provision of regulating services (e.g. carbon sequestration, climate regulation). There are as yet no studies targeting marine ecosystems services and their

[79] Under the Natura 2000 network, stemming from the habitats directive (Directive 92/43/EEC), and before that the birds directive (Directive 79/409/EEC); reprised by the MSFD, and later by the EU's biodiversity strategy (European Commission, 2011).

[80] Target 11: 'By 2020, at least … 10 per cent of coastal and marine areas … are conserved through … systems of protected areas and other effective area-based conservation measures.'

link to the blue economy at European scale. However, a number of studies (regional, national and local scale), targeting selected marine ecosystem services, show that a significant proportion of the EU's gross domestic product strictly depends on the flow of goods and services provided by marine ecosystems (Addamo et al., submitted), generating a turnover of EUR 750 billion in 2018 (European Commission, 2020).

However, marine ecosystems have globally displayed a rapid decline in condition in recent decades, leading to an estimated loss of value of about USD 10.9 trillion per year, with respect to 1997 values (Costanza et al. 2014). There are multiple causes for this global decline, from overexploitation of marine resources to loss of coral ecosystems, pollution by contaminants and plastics, and decline of seagrasses and, more generally, benthic habitats.

The provision of marine services has been steadily declining. Worm et al. (2006) analysed the global catch database from the UN Food and Agriculture Organization (FAO) and other sources to determine the relationships between biodiversity and ecosystem services: they found that biodiversity loss affects marine ecosystem services across both temporal and spatial scales. At EU level, Liquete et al. (2016) analysed trends in provisions of marine services in the Mediterranean Sea, finding overall more decreasing trends than increasing ones. Beyond the complex analysis of trade-offs and synergies in the provision of services, deserving an entirely separate set of analyses, it is acknowledged that a sustainable delivery of services is closely linked to a good condition of the ecosystems providing them. Thus, the steady decline in the provision of services from the marine environment is due to a decline in the ecosystems' condition, as a consequence of the loss or deterioration of marine natural capital.

In line with the overall objective of this report, the aim of this chapter is to determine and report the trends in the pressures and condition of marine ecosystems relative to the baseline year of 2010. This chapter can thus be used to evaluate progress with respect to the targets of the EU biodiversity strategy for the period to 2020. It is important to stress that this assessment is primarily based on indicators for which Europe-wide, harmonised datasets have been collected. Where needed, more context is provided by citing the relevant literature. However, this chapter did not conduct a systematic review of the literature on pressures on biodiversity and ecosystems.

This chapter delivers the baseline data to establish a (legally binding) methodology for mapping and assessment of ecosystems and their capacity to deliver services and to determine the minimum criteria for good ecosystem condition of marine ecosystems as required by the new "EU biodiversity strategy for 2030". Determining these criteria for marine ecosystems requires also agreement on a reference condition against which the past or present condition can be evaluated. More work will be needed to determine the target and reference levels of pressure and condition indicators in agreement with stakeholders, scientists and policymakers.

EU marine policy

The Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EU), as the environmental pillar of the wider European Integrated Maritime Policy (COM 2007/0575), covers the protection of the marine environment and sustainable use of its resource base, upon which marine-related economic and social activities depend. The MSFD sets down a framework through which EU Member States develop and implement marine strategies, integrating an ecosystem-based approach, with the objective of achieving good environmental status (GES) (Commission Decision (EU) 2017/848) in their marine waters. GES results from the integration of assessments of 11 descriptors, assessing pressures on ([81]), and status of ([82]) EU marine ecosystems. The MSFD explicitly coordinates with other policies related to the marine environment:

- Directive 92/43/EEC (Habitats Directive – HD);
- Directive 2009/147/EC (Birds Directive – BD);
- Directive 2000/60/EC (Water Framework Directive – WFD);
- Directive 91/676/ECC (Nitrates Directive – ND);

[81]Descriptor 2: non-indigenous species; descriptor 3: commercially exploited fisheries; descriptor 5: eutrophication; descriptor 7: permanent alteration of hydrographic conditions; descriptor 8: contaminants; descriptor 9: contaminants in fish and other seafood; descriptor 10: marine litter; descriptor 11: underwater noise and other forms of energy.

[82]Descriptor 1: biological diversity, covering species, pelagic habitats, benthic habitats (link to descriptor 6) and ecosystems (link to descriptor 4); descriptor 4: food webs; descriptor 6: sea-floor integrity.

- Directive 2014/89/EU (Maritime Spatial Planning – MSP)
- Regulation (EU) No 1306/2013 (Common Agricultural Policy – CAP);
- Regulation (EU) No 1380/2013 (Common Fisheries Policy – CFP).

This coordination has the purpose of enhancing complementarity between policy objectives, harmonising assessments and maximising policy impacts, while minimising overall implementation obligations (e.g. reporting) and overlaps. For example, coastal waters fall under the legal umbrella of the MSFD only for those aspects not covered already by the WFD. Thus, efforts continue to this day to ensure the seamless assessment of pressures (namely nutrients, contaminants and hydro-morphological changes) on marine waters and ecosystems under the two directives: WFD chemical status, linked to MSFD descriptor 8, and WFD ecological status, linked to MSFD descriptors 5, 7 and 8 ([83]). Similarly, descriptor 3 is directly linked to the assessments carried out under the CFP. The MSFD is also linked to other directives: e.g. descriptor 9 is connected to the EU policy on food safety (Regulation (EC) No 1778/2002).

3.7.2 Ecosystem extent and change

The second MAES report (MAES, 2014) classified marine ecosystems in four categories: (1) marine inlets and transitional waters; (2) coastal waters; (3) shelf water; and (4) open ocean. While the extent of shelf water and open ocean can be considered constant, the extent of marine inlets, transitional waters and coastal water ecosystems depends on the exchange with land ecosystems at the interface between land and water. Due to the lack of complete datasets specific to each marine ecosystem initially classified in the second MAES report, the four categories are grouped, for the purpose of this study, under the general term of 'marine waters', and are analysed at the level of marine regions (*sensu* the MSFD, except where stated otherwise): North-East Atlantic Ocean, Baltic Sea, Mediterranean Sea and Black Sea (Figure 3.7.1). Coastal wetlands, treated under chapter 3.4, are not considered in the chapter. The extent of each marine region can be considered constant (Table 3.7.1).

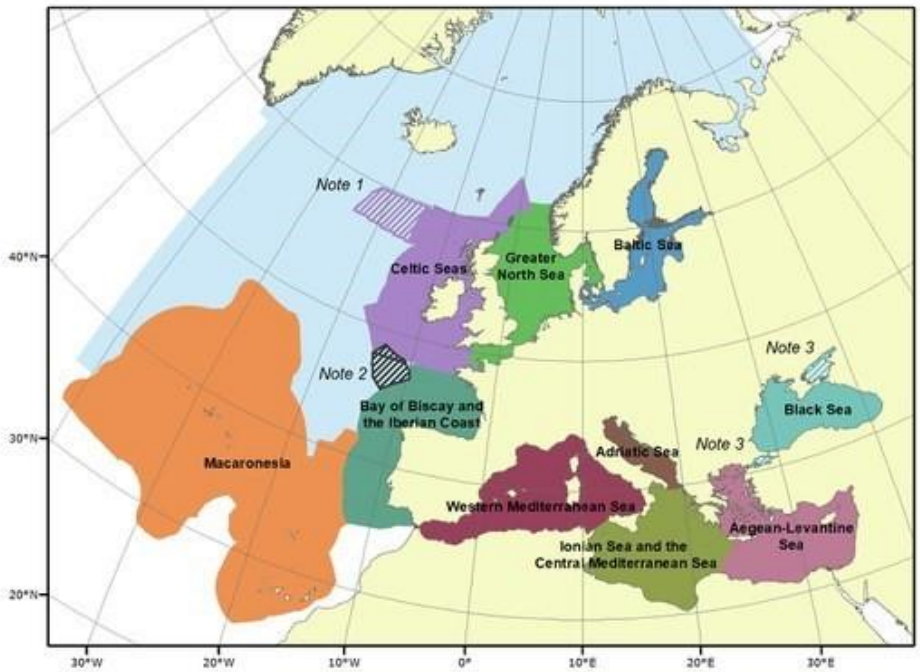

Figure 3.7.1. European marine regions (*sensu* the MSFD): North-East Atlantic Ocean (incl. Greater North Sea, Celtic Sea, Bay of Biscay, the Iberian coast, and Macaronesia); Baltic Sea; Black Sea; Mediterranean Sea (incl. Western Mediterranean Sea, Adriatic Sea, Ionian Sea, Central Mediterranean Sea and Aegean-Levantine Sea)

[83]Note that the data collected to assess the WFD ecological status could also be used for assessments of descriptors 1, 4 and 6.

(For further information see https://www.eea.europa.eu/data-and-maps/data/europe-seas#tab-documents). Overseas countries and territories (OCTs) of the European Union are not included.

Table 3.7.1. Surface area (km^2) of marine regions (*sensu* the MSFD) and other regional seas surrounding Europe (source: EEA, 2018)

Regional seas surrounding Europe	**Regional seas surface area (km^2)**	**EU Member States' share of sea surface area of regional sea**	
		km2	%
North-East Atlantic Ocean (incl. no EU waters: Icelandic, Norwegian and Barents Seas)	7,835,000	4,082,719	52.11
North-East Atlantic Ocean (incl. Macaronesia)	4,247,000	4,082,719	96.13
Baltic Sea	394,000	368,720	93.58
Black Sea	474,000	64,384	13.58
Mediterranean Sea	2,517,000	1,274,892	50.65

3.7.3 Data

The assessment of pressures and condition in marine waters takes as its starting point the guidelines and specific list of indicators identified in the fifth MAES report (Table 3.7.2; Maes et al., 2018). Table 3.7.2 was revised in relation to the availability of data derived from the different policy-reporting streams. It was also decided that, as the marine environment benefits from its own specific, dedicated policy (the MSFD), all MSFD-related indicators should be considered as key indicators. The resulting list of indicators is presented in Tables 3.7.3 and 3.7.4, where some new indicators have been added to the list (e.g. sea water salinity, riverine litter load) and others have been modified (e.g. ratio of nutrients) or eliminated (e.g. fish catch). The following additional considerations, according to the categories of credibility, salience, legitimacy and feasibility (CSFL, Cash et al., 2003; van Oudenhoven et al., 2018), support changes to the original 2018 list of indicators, as follows.

- *Availability of data*. The list of indicators presented in Maes et al. (2018) took into account the ideal data flow resulting from Member States' obligations under the various policy reporting streams. However, those data are not always actually available: for example, in the case of the MSFD, only the 2012 Member State assessments are available (first MSFD reporting cycle). The update of those assessments (second reporting cycle, due in October 2018), was still ongoing and the corresponding data were not available yet at the time of the current analysis. Data available from scientific studies and European/regional assessments could not be collated, due to time constraints; however, relevant outcomes are mentioned where possible (e.g., integrated assessments of the regional sea conventions (RSCs)).

- *Temporal and geographical harmonisation of data*. The lack of harmonised datasets is also a strong limitation to this study. For example, the composition of stocks in the CFP assessment is not constant from one year to the other and from one Member State to the other; therefore, the annual stock assessments are not entirely comparable, even within the same set of reporting Member States; assessments of pressures and ecosystems within the MSFD are not yet harmonised across Member States; and there are no commonly agreed thresholds for the majority of criteria under the various descriptors.

- *Alignment of policy-related assessments*. Reporting streams under the various policies are not fully aligned, and so the picture drawn from data reported under the MSFD cannot be entirely aligned with those reported under other directives (e.g. the WFD or the HD and BD).

- *Differences in the objectives of relevant policies*. Data coming from assessments under various relevant policies are often difficult to align/combine, as differences in policy objectives might lead to distinct definitions and metrics (e.g. ecological and chemical status in the WFD, GES in the MSFD, favourable conservation status in the HD and BD);

- *Policy relevance*. Some of the original indicators in Table 3.7.2 have been replaced by a set of sub-indicators, in relation to the concerned matrix. In the condition assessment this is the case, for example, for contaminants in seafood, replaced by contaminants in biota and in sediments, and litter, replaced by beach litter, seafloor litter and micro litter.

Table 3.7.2. Initial list of indicators for pressure and condition of marine ecosystems (modified from Maes et al., 2018, merger of original Tables 4.6 and 4.7). Indicators in **bold** are key indicators.

Pressures	
Habitat conversion and degradation	Extent of loss of habitat (MSFD-D6C4) (%/year or km2/year)
Climate change	**Acidification (rate; per year)**
	Temperature increase (°C/year)
	Sea level rise (cm/year)
Pollution and nutrient enrichment	**Contaminants (WFD/MSFD-D8) (tonne/year)**
	Nutrient discharge (WFD) (N, P, tonne/year)
	Nutrient release from aquaculture (% increase/year)
Over-exploitation	**Fish catch (tonne/year)**
	Fishing mortality of commercially exploited fish and shellfish exceeding F_{MSY} (fishing mortality at maximum sustainable yield) (MSFD-D3C1) (rate)
Introductions of invasive alien species	**Number of annual introduction of invasive alien species (MSFD-D2C1) (number/year)**
	Number of newly introduced non-indigenous species from aquaculture (number/year)
Ecosystem condition	
Environmental quality	**Chemical Status (WFD)**
	Oxidized N, Orthophosphate, Nitrogen, Phosphorus, BOD (mg/L)
	Chlorophyll-*a* concentration (MSFD-D5C2) (µg/l)
	Dissolved oxygen at the bottom of the water column (MSFD-D5C5) (mg/l)
	Bathing water quality (quality levels)
	Contaminants concentration in seafood (MSFD-D9C1) (mg/kg)
	Composition, amount and spatial distribution of litter (MSFD-D10C1) (number of items/m or /km2)
	Composition, amount and spatial distribution of micro-litter (MSFD-D10C2) (g/m2 or g/kg of sediment)
	Spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources (MSFD-D11C1) (km2)
	Spatial distribution, temporal extent and levels of anthropogenic continuous low-frequency sound (MSFD-D11C2) (km2)
Ecosystem attributes	
Structural ecosystem attributes (general)	**Ecological status (WFD)**
	Spatial extent and distribution of physical loss/disturbance to seabed (MSFD-D6C1 and D6C2) (km2)
	Spatial extent of adversely affected benthic habitat (MSFD-D6C3) (km2)
	Extent of loss of benthic habitat type (MSFD-D6C4) (km2)
	Extent of adverse effect on benthic habitat type (MSFD-D6C5) (km2)
	Habitat extent and condition (MSFD-D1C5) (km2)
Structural ecosystem attributes based on species diversity and abundance	**Population abundance (MSFD D1C2) (number of individuals/species or tonne/species)**
	Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types (MSFD-D2C2) (number of individuals or tonne or km2 per species)

	Proportion of the species group or spatial extent of the broad habitat type which is adversely altered due to non-indigenous species, particularly invasive non-indigenous species (MSFD-D2C3) (ratio or km2)
	Spawning Stock Biomass (MSFD-D3C2) (tonne)
	Age and size distribution of commercially-exploited species (MSFD-D3C3) (% or number or cm)
	Biological quality elements (BQEs) collected to assess ecological status (ex. composition and abundance of aquatic flora, benthic invertebrate fauna, fish fauna, phytoplankton)
	Presence of invasive alien species reported under the EU Regulation (IAS 1143/2014)
Structural ecosystem attributes monitored under the EU nature directives and national legislation	**Natura 2000 and Marine protected areas (% surface area)**
	Population status and trends of bird species of Community interest associated to transitional and coastal waters, shelf and ocean waters (%)
	Conservation status and trends of habitats of Community interest associated to transitional and coastal waters, shelf and ocean waters (%)
	Conservation status and trends of species of Community interest associated to transitional and coastal waters and shelf and ocean waters (%)

The issue of data availability, and, in turn, temporal and geographical data harmonisation, also underlies the decision to carry out the current assessment of the condition of marine ecosystems at the level of EU marine regions (*sensu* the MSFD), rather than at European level. Indeed, aggregating information at regional scale from global and harmonised datasets, whenever possible, allowed comparison of trends at regional level. RSCs datasets could not be used due to significant differences in terms of methodology, indicators, assessment period and the spatiotemporal resolution of monitoring from northern to southern Europe. This is the case of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), and the Baltic Marine Environment Protection Commission (HELCOM), in the North-East Atlantic Ocean and Baltic Sea, respectively, vs. the United Nations Environment Programme-Mediterranean Action Plan (UNEP-MAP) and the Bucharest Convention (BSC), in the Mediterranean Sea and Black Sea, respectively.

Tables 3.7.3 and 3.7.4 present the final list of indicators selected for pressure and condition of marine ecosystems. The tables show the fact sheet number of each indicator, where detailed information can be accessed regarding the characteristics of the input data and the indicator. In addition, the tables show information on the unit of measure, the data period and the source of the input data used for creating the indicators. Indicators for which data are not currently available could not be used for the present assessment, but are still listed for future reference.

Table 3.7.3. Final list of indicators for pressure of marine ecosystems. Temporal coverage, source and fact sheet of the corresponding datasets is indicated. All fact sheets are included in the supplement to this report.

Pressure class	**Indicator**	**Unit**	**Period**	**Source***	**Fact sheet**
Habitat conversion and degradation	Extent of loss of habitat	%	NA	NA	NA
Climate change	Acidification	pH	1993-2015	CMEMS	3.7.101
	Sea surface temperature	Celsius	1993-2015	CMEMS	3.7.102
	Sea level anomaly	metre	1993-2015	CMEMS	3.7.103
	Sea water salinity**	psu	1993-2015	CMEMS	3.7.104
Pollution and nutrient enrichment	Chemical loads	tonnes	Point-in-time:2010	JRC	3.7.105
	Riverine litter	item/hr	Point-in-time:2016	JRC	3.7.106
	Nutrient loads**	tonnes (N; P;)	Point-in-time:2010	JRC	3.7.107
	Nutrient loads (N:P)**	ratio	Point-in-time:2010	JRC	3.7.107
	Nutrients release from aquaculture	%	NA	NA	NA
Exploitation	Fishing mortality (F) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{MSY})	rate	2003-2017	STECF	3.7.109
Introductions of invasive alien species	Number of annual introductions of non-indigenous species	no. spp.	2000-2017	JRC-EASIN	3.7.110
	Number of newly introduced non-indigenous species from human activities/transport	no. spp.	2000-2017	JRC-EASIN	3.7.111

*CMEMS = Copernicus Marine Environment Monitoring Service; STECF = Scientific, Technical and Economic Committee for Fisheries; EASIN = European Alien Species Information Network; EEA = European Environmental Agency; EMODNET = European Marine Observation and Data Network; JRC = Joint Research Centre; MSFD = marine strategy framework directive; WDPA = World Database on Protected Areas; WFD = water framework directive. For further details on the selected datasets, please consult the fact sheets
**Indicators introduced for this study (additional with respect to the list in Table 3.7.2).

Table 3.7.4. Final list of indicators for condition of marine ecosystems. Temporal coverage, source and fact sheet of the corresponding datasets is indicated. All fact sheets are included in the supplement to this report.

Condition class	**Indicator**	**Unit**	**Period**	**Source***	**Fact sheet**
Environmental quality (physical and chemical quality)	Chemical status	% class (Good; Failing to achieve good; Unknown)	1st (2010)-2nd (2016) RBMPs	EEA (WFD)	3.7.200
	Nutrients	mmol/m^3 (N; P;)	1993-2015	CMEMS	3.7.201
	Nutrients (N:P)**	ratio	1993-2015	CMEMS	3.7.201
	Dissolved oxygen	mg/L	1993-2018	CMEMS	3.7.202
	Chlorophyll-*a*	mg/m^3	1993-2015	CMEMS	3.7.203
	Bathing water quality	class	1990-2018	EEA	3.7.204

Condition class	Indicator	Unit	Period	Source*	Fact sheet
	Contaminants in biota	µg/kg	2000-2017	EMODNET	3.7.205
	Contaminants in sediment	µg/kg	2000-2017	EMODNET	3.7.206
	Beach litter***	item/ 100m	2001-2018	EMODNET	3.7.207
	Seafloor litter	item/ haul	2007-2018	EMODNET	3.7.208
	Micro litter	g/m^2	NA	NA	NA
	Spatial distribution, temporal extent and level of anthropogenic impulsive sound sources	pulse/day	2014-2018	EMODNET	3.7.210
	Spatial distribution, temporal extent and level of anthropogenic continuous low-frequency sound	km^2	NA	NA	NA
Structural ecosystem attributes (general)	Ecological status	% class (High; Good; Moderate; Poor; Bad; Unknown)	1st (2010)-2nd (2016) RBMPs	EEA (WFD)	3.7.212
	Spatial extent and distribution of physical loss and disturbance to seabed	km^2	Point-in-time: 2016	EEA	3.7.213
	Spatial extent of adversely affected benthic habitat	km^2	NA	NA	NA
	Extent of loss of benthic habitat type	km^2	NA	NA	NA
	Extent of adverse effect on benthic habitat type	km^2	NA	NA	NA
	Habitat extent and condition	km^2	NA	NA	NA
Structural ecosystem attributes based on species diversity and abundance	Population abundance	no. ind/ species	1911-2018	EMODNET	3.7.218
	Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types	no. ind/ species	NA	NA	NA
	Proportion of species group or extent of habitat type which is adversely altered by non-indigenous and invasive species	ratio	NA	NA	NA
	Spawning stock biomass or biomass index of commercially exploited species (B/B_{2003})	rate	2003-2017	STECF	3.7.221
	Age and size distribution of commercially exploited species	%	NA	NA	NA
	Biological quality elements (BQEs) collected to assess ecological status	% class (High; Good; Moderate; Poor; Bad; Unknown)	1st (2010)-2nd (2016) RBMPs	EEA (WFD)	3.7.223
	Occurrence of invasive alien species	no. event	2000-2016	JRC-EASIN	3.7.224

Condition class	Indicator	Unit	Period	Source*	Fact sheet
Structural ecosystem attributes monitored under the EU nature directives	Share of coastal habitats listed under Annex 1 of the Habitats Directive in favourable conservation status	%	2013-2018	EEA (Art.17 reports)	3.5.203
	Trends of unfavourable conservation status of coastal habitats listed under Annex 1 of the Habitats Directive	%	2013-2018	EEA (Art.17 reports)	3.5.203
	Marine protected area	% cumulative surface area	1897-2019	WDPA	3.7.225

*CMEMS = Copernicus Marine Environment Monitoring Service; STECF = Scientific, Technical and Economic Committee for Fisheries; EASIN = European Alien Species Information Network; EEA = European Environmental Agency; EMODNET = European Marine Observation and Data Network; JRC = Joint Research Centre; MSFD = marine strategy framework directive; WDPA = World Database on Protected Areas; WFD = water framework directive. For further details on the selected datasets, please consult the fact sheets
**Indicators introduced for this study (additional with respect to the list in Table 3.7.2).
***Only referred to coastal and transitional waters.

3.7.4 Drivers and pressures: spatial heterogeneity and change over time

In this section the assessment of 14 pressure indicators (Table 3.7.3) and their respective trends will be presented and discussed. Availability of data allowed the calculation of short-term and long-term trends for only seven indicators: four describing climate trends, one describing exploitation trends and two describing trends in non-indigenous invasive species. No trends in pollution and nutrient enrichment, and no data on the regional extent of habitat loss and nutrients release from aquaculture, were available. Short- and long-term trends, including associated statistics, are presented in Table 3.7.5a-d.

3.7.4.1 Assessment at the level of EU marine regions

Human activities are at the base of the several pressures acting on the marine environment, degrading the condition of its ecosystems. The following classes had datasets available for the purpose of this work: climate change, pollution and nutrient enrichment, and exploitation and introduction of invasive alien species. Data on habitat conversion and degradation were not available at the time of this study at the EU-wide level. Depending on data availability, the assessment of pressures in the four EU marine regions comprises a short term (2010-2018 [84]) or a long-term analysis (see data temporal ranges in Table 3.7.3, and Tables 3.7.5a-d for statistics. Further details are available in fact sheets.

Climate change affects the range and behaviour of marine communities, modifying their traits and composition. For example, due to increasing temperature, some sub-tropical species appear more frequently in Europe's seas, while sub-Arctic species recede northwards (EEA, 2016; EEA, 2020). Such alterations are also at the base of shifts and/or competition in the food chain, causing in turn changes in the balance between the different trophic levels and further changes in communities' composition (IPCC, 2019).

Generally, long-term pressure from climate change seems to be consistently increasing in all four European marine regions, with high confidence scores (see Chapter 2 for an explanation of calculation methodology); the same message can be derived to a large extent from the short-term analysis, where pressure increase is detected in the indicators listed in the climate change class. These results are in line with the ones reported in the most recent Intergovernmental Panel on Climate Change (IPCC) analysis (IPCC, 2019).

Despite the successful implementation of nutrient management strategies and the decreasing trends of nutrient inputs (e.g. in the Baltic Sea, EEA, 2019a,b), nutrient enrichment and pollution of marine ecosystems are still a strong concern in some European marine regions. The former leads to eutrophication and harmful algal blooms (HABs), events that might be exacerbated by the combined effect of anthropogenic impacts and climate change (Sanserverino, 2016), through increased vertical stratification due to rising ocean temperatures. The latter, in the form of chemicals (other than nutrients), leads to disruption of biological

[84]Or to most recent year available in the database.

processes and bioaccumulation in the food chain, with consequences for human health; pollution, in the form of litter, is the cause of increasing mortality rates in fish and marine mammals, due to ingestion and entanglement. Escalating statistics on such events testify to increasing pressure (Kühn et al., 2015). Due to lack of data, trends for riverine litter, chemical and nutrient loads could not be calculated, and were set to "unresolved" both in the short and in the long term. In general, it must be noted that, despite the very large number of pollutants contaminating EU marine waters, no pan-European temporal and harmonised datasets are still available (Tornero and Hanke, 2016, 2017). More regional datasets are available for the North-East Atlantic Ocean and the Baltic Sea, thanks also to the coordination and collection efforts of the RSCs (OSPAR and HELCOM), than in the Mediterranean Sea and Black Sea. Because of this constraint, the EU-wide assessment of drivers and pressures has been limited. The latest European Environment Agency (EEA) analysis on state and outlook of European environment (EEA, 2019c – data not available at the time of this study) in general reports significant concentrations of legacy pollutants (substances since long banned from use in the EU, such as DDT and lindane) and decreasing concentrations of heavy metals. Detection of these substances also comes from the analysis of filter-feeding organisms (shellfish), thus implying that pollution continues to pose a threat not only to ecosystem condition but also to human health directly, through bioaccumulation.

Fisheries are the main marine living resources subject to exploitation. Pressure from fishing activities seems to be slightly decreasing in the North-East Atlantic Ocean and Baltic Sea regions, where some commercial fish stocks show signs of recovery. Conversely, in the Mediterranean Sea and Black Sea regions many commercial stocks are still strongly depleted and fished well above maximum sustainable yield (STECF, 2019). The different levels and quality of monitoring in various regions undermine the reliability of the statistics, meaning that reality might be worse than the picture-drawn data analysis in this and other works (e.g. SOER, 2020). Pressure from bottom trawling damages the seafloor, contributing to (benthic) habitat loss and the decreasing abundance of many sensitive, non-commercial species (Buhl-Mortensen and Buhl-Mortensen, 2018; Kaiser et al., 2003).

The introduction of invasive alien species (IAS) adds a complementary pressure to the marine ecosystem. Combined with the change in the natural range of occurrence of many species as a consequence of climate change, IAS are increasingly altering the ecosystems, with the most affected region being the Mediterranean Sea. Analysis of the newly introduced non-indigenous species (NIS) from human activities confirms maritime transport as the main pathway, in line with results obtained by Tsiamis et al. (2018).

Overall, long-term trends show an increase of pressures in all pressure classes (see Table 3.7.5a-d for statistics) (with the exception of fisheries, where pressures are still decreasing slightly in some EU marine regions, while many stocks are still overfished in others). In the short term, some pressures seem to be stable, while others continue to increase.

Table 3.7.5a. Aggregated pressure indicators in North-East Atlantic Ocean. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation	Extent of loss of habitat				unresolved			unresolved	
Climate change	Acidification	pH	7.96	-0.50	↓	6	-1.01	↓	8
	Sea surface temperature	Celsius	12.26	1.89	↓	6	1.21	↓	8
	Sea level anomaly	meter	-1.36		→	6	1.86	↓	8
	Sea water salinity	psu	35.37	-0.20	↓	6	0.05	↓	8
Pollution and nutrient enrichment	Chemical loads	tonnes	5500.99		unresolved	4		unresolved	
	Riverine litter	item/hr	17.97		unresolved	5		unresolved	
	Nutrient loads (N)	tonnes	1803925		unresolved	4		unresolved	
	Nutrient loads (P)	tonnes	119278		unresolved	4		unresolved	
	Nutrient loads (N:P)	ratio	15.12		unresolved	4		unresolved	
	Nutrients release from aquaculture				unresolved			unresolved	
Exploitation	Fishing mortality (F) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{MSY})	rate	1.13	-24.53	↑	5	-42.75	↑	7
Introductions of invasive aliens species	Number of annual introductions of non-indigenous species	number	8		unresolved	7		unresolved	7
	Number of newly introduced non-indigenous species from human activities/transport	number	4		unresolved	7		unresolved	7

↑: Significant improvement (significant downward trend of pressure indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant upward trend of pressure indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.7.5b. Aggregated pressure indicators in Baltic Sea. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation	Extent of loss of habitat				unresolved			unresolved	
Climate change	Acidification	pH	8.29	-0.22	↓	6	-0.47	↓	8
	Sea surface temperature	Celsius	7.64	5.48	↓	6	33.56	↓	8
	Sea level anomaly	meter	2.38		→	6	2.49	↓	8
	Sea water salinity	psu	18.95	-1.44	↓	6	-4.14	↓	8
Pollution and nutrient enrichment	Chemical loads	tonnes	62.89		unresolved	4		unresolved	
	Riverine litter	item/hr	7.66		unresolved	5		unresolved	
	Nutrient loads (N)	tonnes	491,647		unresolved	4		unresolved	
	Nutrient loads (P)	tonnes	32,979		unresolved	4		unresolved	
	Nutrient loads (N:P)	ratio	14.91		unresolved	4		unresolved	
	Nutrients release from aquaculture				unresolved			unresolved	
Exploitation	Fishing mortality (F) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{MSY})	rate	1.34		→	5	-31.80	↑	7
Introductions of invasive aliens species	Number of annual introductions of non-indigenous species	number	0		unresolved	7	-242.46	unresolved	7
	Number of newly introduced non-indigenous species from human activities/transport	number	0		unresolved	7		unresolved	

↑: Significant improvement (significant downward trend of pressure indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant upward trend of pressure indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.7.5c. Aggregated pressure indicators in Black Sea. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation	Extent of loss of habitat				unresolved			unresolved	
Climate change	Acidification	pH	8.06	-0.16	↓	6	-0.11	↓	8
	Sea surface temperature	Celsius	16.25		→	6		→	8
	Sea level anomaly	meter	0.08		→	6	29.03	↓	8
	Sea water salinity	psu	20.65		→	6	-0.53	↓	8
Pollution and nutrient enrichment	Chemical loads	tonnes	1,349.73		unresolved	4		unresolved	
	Riverine litter	item/hr	13.42		unresolved	5		unresolved	
	Nutrient loads (N)	tonnes	548,284		unresolved	4		unresolved	
	Nutrient loads (P)	tonnes	32,923		unresolved	4		unresolved	
	Nutrient loads (N:P)	ratio	16.65		unresolved	4		unresolved	
	Nutrients release from aquaculture				unresolved	3		unresolved	
Exploitation	Fishing mortality (F) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{MSY})	rate	2.13		→	5		→	7
Introductions of invasive aliens species	Number of annual introductions of non-indigenous species	number	0		unresolved	7		unresolved	
	Number of newly introduced non-indigenous species from human activities/transport	number	0		unresolved	7		unresolved	

↑: Significant improvement (significant downward trend of pressure indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant upward trend of pressure indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.7.5d. Aggregated pressure indicators in Mediterranean Sea. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Pressure class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Habitat conversion and degradation	Extent of loss of habitat				unresolved			unresolved	
Climate change	Acidification	pH	8.01	-0.16	↓	6	-0.07	↓	8
	Sea surface temperature	Celsius	19.51	1.42	↓	6	2.31	↓	8
	Sea level anomaly	meter	0.50	16.64	↓	6	6.05	↓	8
	Sea water salinity	psu	36.74		→	6	0.08	↓	8
Pollution and nutrient enrichment	Chemical loads	tonnes	3,218.28		unresolved	4		unresolved	
	Riverine litter	item/hr	20.43		unresolved	5		unresolved	
	Nutrient loads (N)	tonnes	730,817		unresolved	4		unresolved	
	Nutrient loads (P)	tonnes	67,611		unresolved	4		unresolved	
	Nutrient loads (N:P)	ratio	10.81		unresolved	4		unresolved	
	Nutrients release from aquaculture				unresolved	3		unresolved	
Exploitation	Fishing mortality (F) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{MSY})	rate	2.81	-36.84	↑	5		→	7
Introductions of invasive aliens species	Number of annual introductions of non-indigenous species	number	19		unresolved	7		unresolved	
	Number of newly introduced non-indigenous species from human activities/transport	number	21	-69.83	unresolved	7	-44.41	unresolved	7

↑: Significant improvement (significant downward trend of pressure indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant upward trend of pressure indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

3.7.4.2 *In-depth assessment*

The temporal trends of several indicators have been analysed, to assess the impact of anthropogenic pressures on the marine environment. A spatially explicit analysis of pressures could not be carried out, due to lack of harmonised datasets at EU scale, nor have the assessments made on the different stressors been fully integrated. Assessments of the state of the marine environment are periodically produced by the RSCs for each of the four marine regions; the latest assessments relate to the 2011-2016 period (OSPAR, 2017; HELCOM, 2017; UNEP-MAP, 2017) except for the Black Sea, where the assessment covers the period 2009-2014 (BSC, 2019). Each at its own pace, the RSCs have been progressively aligning their assessments to the requirements of the MSFD. However, there are still important differences in terms of choice of indicators, spatial and temporal monitoring protocols, temporal horizon of the assessment and ambition. Where possible and meaningful, a reference to the results of those assessments has been made.

It is clear that in certain pressure classes, a concerted monitoring effort is needed to close data gaps and acquire relevant, harmonised datasets with adequate temporal and spatial coverage. This is in particular the case for 'habitat conversion and degradation', 'pollution and nutrient enrichment' and 'exploitation' classes. Behind each of these pressure classes stand specific, often long-standing policies that could facilitate consistent and harmonised EU-wide data collection: such as the HD, for habitat conversion and degradation; the WFD, accompanied by the long-standing CAP; the ND, for pollution and nutrient enrichment; and the CFP for exploitation of marine resources. Within this paragraph, an indicator-by-indicator analysis is presented, with caveats and conclusions.

At the time of the analyses, no EU-wide datasets were available that allowed a determination of the extent of loss of habitats for marine ecosystems at European level, and numerous local case studies are available in the literature only on specific habitats (Bekkby et al., 2017). For example, a large body of literature and small-scale datasets documents receding seagrass meadows (e.g., *Posidonia oceanica,* sometimes replaced by *Cymodocea nodosa*) in the Mediterranean Sea, mostly due to human pressure (fishing activities, and tourism) (Weatherdon et al., 2017) but the changes in extent and density at the continental scale remain unclear. Recently, de los Santos et al. (2019) demonstrated that decline is not generalised among seagrasses nowadays in Europe, in contrast with global assessments, and the deceleration and reversal of declining trends is possible, bringing back the services they provide. Most of the available marine habitat maps are derived from the assemblage of *in situ* local data, remote sensing and model outputs, thus high-confidence estimates of actual EU-wide habitat loss are not available. Tempera et al. (2016) have mapped the distribution of seabed-associated ecosystem services capacity and the approach illustrated in the study could provide the basis for a future analysis on the loss of marine habitats.

OSPAR has produced an assessment of benthic habitats in coastal waters, resulting from the WFD assessment of biological quality elements, in relation to nutrient and/or organic enrichment and with regard to macroalgae and angiosperms on one side, and benthic invertebrates on the other side (OSPAR, 2017). An assessment is also available for subtidal habitats of the Southern North Sea. However, regional variations and data gaps do not permit a comprehensive assessment of habitat condition (for example, pelagic habitats are not assessed), or the identification of trends.

HELCOM has produced an assessment of pelagic and benthic (mostly soft bottom) habitats in the Baltic Sea. However, the assessment does not cover all assessment units; coastal areas were assessed using national indicators, and the resulting assessments might not be comparable, partly because of differences in the confidence level of the individual assessments. No trends were produced (HELCOM, 2018a).

In 2019, the Black Sea Commission produced a state of the environment report for the Black Sea, using data for the period 2009-2014/2015. However, a regional assessment of habitat condition and related trends for the Black Sea was not carried out. In the Mediterranean Sea, assessment of marine habitats is hampered by significant data deficiencies in certain countries. UNEP-MAP has mapped broad scale habitats extending the modelling approach adopted by EMODNET in the Western Mediterranean. Recent initiatives (MedMPA network project [85]) and MedKeyHabitats [86]), implemented by the Specially Protected Areas Regional Activity Centre (SPA/RAC)) have produced several new datasets on the distribution of the most important marine key habitats in the Mediterranean. The UNEP analysis (2017) effectively links habitat conservation to the reinforcement of the MPA network, especially in the Southern and Eastern Mediterranean, where current designations still fall largely short of the 10% AICHI target 11. Trends based on the historical observation of selected sea bottom

[85] Further information available at: https://www.rac-spa.org/medmpanetwork
[86] Further information available at: https://www.rac-spa.org/medkeyhabitats

habitats point to continued loss of habitat extent (*Posidonia* meadows) and sometimes to disappearance (kelps in the Adriatic Sea), with no sign of recent recovery (2010 surveys). Most of these losses are linked to intensive trawling. Deep-sea habitats could not be assessed, due to a lack of information, particularly acute in the North African and Eastern Mediterranean Sea. Pelagic habitats were also not assessed. Overall pressure from climate change is getting worse in the long term, despite some sign of short-term stability of some indicators in some marine regions, in line with findings in the latest IPCC report (IPCC, 2019). Indeed, trends in acidification, sea level anomaly, sea surface temperature and salinity have been interpreted as a sign of further degradation. Sea water salinity has been introduced as an indicator for this class because of its importance in biotic and abiotic processes.

In the pressure class of pollution and nutrient enrichment, the datasets examined were not sufficient to provide clear long-term trends: only one-point-in-time results were available, resulting from pilot European projects (e.g. riverine litter, Gonzalez et al., 2018) or as modelling outcomes (e.g. chemicals loads (Pistocchi et al., 2019); and nutrients loads (Grizzetti et al., 2012, submitted; Vigiak et al., 2019)). The nitrogen and phosphorus loads to sea are estimated (by modelling) for two time-series (1985-2012 and 2005-2012) considering different sources (such as fertilisers, atmospheric deposition, human and industrial waste), pathways and retention processes in the river basins. Despite the length of the period covered by simulations trends could be not derived because hydrological variation between the different years (the presence of a wet or dry year influences the amount of nutrients exported to the sea) would bias the trend analysis. Furthermore, differences in model inputs, structure and resolution make the two time-series incomparable (see Fact sheet 3.7.107).

Aquaculture production has increased in the EU since 1990, determining a rise in pressure on adjacent water bodies and associated ecosystems resulting mainly from nutrient release from aquaculture facilities. Improvements in the efficiency of feed and nutrient utilisation and environmental management have to some extent mitigated environmental pressures (EEA, 2010). Unfortunately, nutrients release from aquaculture and trends could be not quantified nor assessed, due to a lack of harmonised datasets at European scale.

The latest EEA report on contaminants (2019a) confirms the difficulties in achieving adequate spatial and temporal coverage of contaminant data, both for coastal and offshore waters. The same report also points at the rapid development of new substances as an issue in keeping up with monitoring and assessment of pollution by chemical substances other than nutrients in the various matrices (water, sediments and biota). In relation to nutrients, the EEA (2019b) confirms that, despite the long-standing policy framework and commitments and efforts, policy targets remain largely unachieved in all European seas.

Analyses of nutrient inputs to marine waters have been produced by each of the RSCs. Due to differences in the spatial and temporal resolution of data, methodology adopted and period analysed, these regional assessments cannot be seamlessly merged to provide a coherent landscape of trends. However, they offer some insights about recent trends in pressure on marine ecosystems. In relation to the North East Atlantic region, for example, the OSPAR assessment (2017, using data from 2011 to 2016) highlights significant reductions in nutrient inputs to many of its sub-regions. Rates of decrease have not been steady: for example, the rate of decrease in phosphorus inputs to the Greater North Sea has slowed down since 2003. However, the assessment concludes that, despite those improvements, eutrophication in several areas is still an issue, and further efforts are needed, in particular for nitrogen. In relation to contaminants, while inputs continue to decrease, issues remain with concentrations, as the fate of contaminants depends both on the specific contaminants and the matrix assessed. In general, concentrations in water keep decreasing, but concerns remain about the high levels of lead, mercury and some polychlorinated biphenyls (PCBs), while concentrations of cadmium and polycyclic aromatic hydrocarbons (PAHs) continue to increase. Issues still remain with matrices other than water (sediments, biota), and bioaccumulation higher up in the food chain.

In the Baltic Sea, the HELCOM assessment (2018b), using data from 2011 to 2016, concludes that overall nitrogen and phosphorus inputs continue to decrease, but many sub-regions still fail to achieve the agreed maximum reduction targets (e.g. the Baltic Proper, the Gulf of Riga and the Gulf of Finland). Concentrations of contaminants in the 2018 assessment remain well above target levels in several of the Baltic sub-basins, with a stable or slightly decreasing level of contamination compared to the previous assessment (HELCOM, 2010). Similarly, the analysis of data in the Black Sea (BSC, 2019, using datasets of varying temporal ranges between 2009 and 2014) concludes that, despite reductions in nutrient inputs, concentrations remain critical in several areas, with permanent regime shifts in the composition of the corresponding biological communities. In relation to contaminants, the assessment includes oil spills, persistent organic pollutants (POPs) PAHs, and trace metals. The main data repository is the Black Sea Database. Data series suffer from temporal and geographical gaps, with many measurements coming from national datasets. In relation to

PAHs, for example, data for coastal waters, sediments and biota are available only for Romania and, to a lesser extent, Ukraine. In relation to POPs and heavy metals in all matrices, only one dataset is available ([87]). The determination of significant trends is therefore not possible.

In the Mediterranean, an insufficient network of coastal stations monitoring nutrient inputs to the sea hampers an assessment of status and trends. With some exceptions (e.g. Aegean-Levantine Sea, eastern Adriatic Sea), the Mediterranean region suffers from scarce data availability and quality. The UNEP-MAP assessment (2017) focuses on Chlorophyll-*a* concentrations and eutrophication assessments, rather than on nutrient inputs or concentrations, and related trends. In relation to contaminants, regular reporting is available only for heavy metals, with lead and mercury concentrations in sediments posing severe concerns. No regular reporting has yet been established for other key contaminants, including concentrations in biota and seafood.

Pressure from fishing activities focuses on the ratio of fish mortality of commercially exploited fish and shellfish to fishing mortality at maximum sustainable yield (F/F_{MSY}), which at best should not exceed 1. Such a value is attained only in the North-East Atlantic Ocean, with significant decreasing short- and long-term trends. Trends seem to be stable in the other marine regions (Baltic Sea, Black Sea and Mediterranean Sea) with F/F_{MSY} being consistently above 1 (way above a value of 2 in the Mediterranean Sea and Black Sea).

Trends in relation to the introduction of non-indigenous species are considered to be unresolved in the short and long term in all marine regions for several reasons; one is that databases are neither harmonised nor complete in some of the marine regions (e.g. Black Sea) with only the year of first introduction in EU waters available. Thus, the introduction of new non-indigenous species could potentially be underestimated in the regional analysis.

As a general remark concerning this exercise, some of the trends presented in Tables 3.7.5a-d have a low statistical significance due, again, to limitations in the respective datasets. Some of the trends in the short-term analysis could reflect the effect of the current policy framework: this might be the case, for example, for the pressure from the introduction of invasive alien species in the Baltic Sea, which seems to have been stable in the last decade, probably as a result of the progressive enrichment of the regulatory framework ([88]) (notably the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 ([89]) and Regulation (EC) No 708/2007 on the use of alien and locally absent species in aquaculture). However, there is a time lag between a decrease in pressure as a result of policy implementation and the response of the ecosystem. One example of this is that eutrophication in the Baltic Sea is still high despite decades of decreased nutrient inputs (Niemistö and Lund-Hansen, 2019)).

3.7.5 Ecosystem condition: spatial heterogeneity and change over time

In this section the assessment of 29 condition indicators (Table 3.7.4) and their respective trends will be presented and discussed. Compared to such a list, the availability of data allowed the calculation of short- and long-term trends for only 12 indicators: eight describing environmental quality trends, three describing trends in structural ecosystem attributes based on species and abundance, and one describing trends in structural ecosystem attributes monitored under the birds and habitats directives. No data were available on the regional extent of adversely affected habitat types, micro litter, continuous low-frequency sounds, species groups or habitat types adversely altered by non-indigenous species, and the age and size distribution of commercially exploited species. Short- and long-term trends, including associated statistics, are presented in Tables 3.7.6a-d.

3.7.5.1 Assessment at the level of EU marine regions

Several indicators have been considered as proxies of ecosystem condition for each of the EU's marine regions. The classes for which data were available for the purpose of this work are related to: environmental

[87]Data were collected during a cruise under the project - "MSFD GUIDING IMPROVEMENTS IN THE BLACK SEA INTEGRATED MONITORING SYSTEM" (MISIS, funded by DG Environment). Further information is available at: https://www.msp-platform.eu/projects/msfd-guiding-improvements-black-sea-integrated-monitoring-system

[88]However Tsiamis et al. (2018) found that a large number of the species introduced in the Baltic have origins in Europe and 50% of these are introduced through interconnecting waterways, including freshwater species; the stabilised pressure could perhaps be related to management and measure (WFD) of these ecosystems but the trend needs to be considered with caution, due to changes in time and space in monitoring effort among the different regions.

[89]Ratified in 2019, and therefore not effective during the period considered in the analysis.

quality, general structural ecosystem attributes; ecosystem attributes based on species diversity and abundance; and ecosystem attributes monitored under the birds and habitats directives. Depending on data availability, the assessment of ecosystem condition in the four EU marine regions comprises a short-term (2010-2018) and/or a long-term analysis (see data temporal ranges in Table 3.7.4, and Tables 3.7.6a-d for statistics). In relation to environmental quality indicators, most of the trends are unresolved, due to: i) incomplete data (e.g. contaminants surveyed are not the same in the four EU marine regions); ii) complex interactions between the proxy selected for a certain phenomenon and other parameters (e.g. Chlorophyll-*a* is used as a proxy for eutrophication, but increasing concentration does not always result in degradation of condition); iii) lack of data (e.g. micro litter). Although all Member States have established thresholds and reported values for physicochemical parameters including nutrients, Chlorophyll-*a* and biological quality elements for coastal and transitional waters through the WFD, data for shelf water and open oceans are not yet available. Indeed, in relation to coastal waters, ecosystem condition is represented within the WFD by the water bodies' chemical status, which provides an overall measure of the condition of contaminants in the aquatic ecosystem. Chemical status assessment includes the priority substances, from which a smaller group was identified as 'priority hazardous substances' ([90]), and whether they exceed the environmental quality standards (EQS) established in the environmental quality standards directive (EQSD, Directive 2008/105/EC). Data for shelf water and open ocean are not available yet. Under the MSFD, contaminants are covered by descriptor 8 (contaminants in the environment and adverse effects) and descriptor 9 (contaminants in seafood). On litter (descriptor 10 of the MSFD), scarce data are available at the EU level (although this information is being collected at national level), except for litter in coastal waters, mainly focused on macro litter. Similarly, there are very few data on underwater noise (descriptor 11 of the MSFD). Work is still ongoing at EU and regional levels on how to seamlessly harmonise assessments under the WFD and the MSFD in relation to nutrients. The issue of discontinuity of aggregation is not geographical, but it refers to parameters selected for monitoring and assessment, and temporal (e.g. seasonal vs annual) and spatial (e.g. density of the grid, depth of the sampling: water column vs top layer) resolution of the assessment.

Amongst the structural ecosystem attributes, the WFD ecological status of coastal and transitional waters is the only indicator that could be assessed, showing no change in the short term. Ecological status assessment comprise the status of biological quality elements (e.g. phytoplankton, angiosperms, macroalgae and benthic invertebrates), supported by physicochemical indicators (e.g. nutrients, dissolved oxygen, transparency), hydromorphological indicators (e.g. tidal regime, morphological conditions) and river-basin specific pollutants (i.e. non-priority substances discharged in significant quantities). On the other hand, it was not possible to assess habitat extent and condition, due again to lack of regional data at the time of the analysis. In relation to structural ecosystem attributes based on species diversity and abundance, the majority of the assessments of condition are made only on biomass of marine organisms, spawning stock biomass of commercially exploited species and invasive species occurrences in EU marine waters. However, incompleteness and/or lack of data did not allow the assessment of trends across the four European regions.

Despite long- and short-term increases in the percentage of European marine protected areas (MPAs), marine habitats, habitat representativeness and geographical coverage remain an issue, as well as connectivity and coherence of the current MPA network. Contrary to the all previous indicators, the conservation status and trends of coastal habitat are reported together due to the scarcity of the data (Table 3.7.6e). Nine coastal (and mostly shallow) habitats are assessed under the Habitats Directive (Sandbanks which are slightly covered by sea water all the time, Posidonia beds (*Posidonion oceanicae*), Estuaries, Mudflats and sandflats not covered by seawater at low tide, Large shallow inlets and bays, Reefs, Submarine structures made by leaking gases, Boreal Baltic narrow inlets, Submerged or partially submerged sea caves). These nine Annex 1 habitats are estimated to cover a total area of 510,241 km^2 which corresponds to 9% of the total marine extent in the EU-28. Spread over five seas (the Habitats Directive recognizes besides the four regional sea basis also the Macaronesian which is in this study part of the North-east Atlantic, Figure 3.7.1), this resulted in 34 habitat assessments. The EU level assessment of the conservation status of coastal habitats concluded that only one assessment (Submarine structures made by leaking gases in the Black Sea, 2.9%, Table 3.7.6e) yielded a favourable conservation status. The remaining assessments delivered a poor status (38.2%), a bad status (32.4%) or unknown (26.5%) (State of Nature report for the period 2013-2018, forthcoming). Of the assessments that resulted in an unfavourable status only 6.7% showing improving trends (Table 3.7.6e).

[90]Defined in the EQSD as ubiquitous, persistent, bio-accumulative and toxic substances (UPBTs): mercury, brominated diphenyl ethers (pBDE), tributyltin and certain polyaromatic hydrocarbons (PAHs).

Table 3.7.6a. Aggregated condition indicators of marine ecosystems in North-East Atlantic Ocean. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Environmental quality (physical and chemical quality)	Chemical status	% class [Good]	55.32		↑	5		unresolved	
	Chemical status	% class [Failing to achieve good]	15.44		↓	5		unresolved	
	Chemical status	% class [Unknown]	29.24		↑	5		unresolved	
	Nutrients anomaly (N)	mmol/m3	-0.95	39.99	↑	6	47.24	↑	6
	Nutrients anomaly (P)	mmol/m3	-0.07	51.96	↑	6	39.96	↑	6
	Chlorophyll-*a*	mg/m3	0.41		→	6		→	8
	Dissolved oxygen	mg/L	4.18		→	6	-0.88	↓	8
	Bathing water quality	class	excellent		→	7	32.13	↑	9
	Contaminants in biota	µg/kg	156,570.64		unresolved	7	141.43	unresolved	7
	Contaminants in sediment	µg/kg	800,886.13	8.72	unresolved	7	-179.33	unresolved	8
	Beach litter	item/ 100m	807.21	-82.55	↑	7	-44.81	↑	8
	Seafloor litter	item/ haul	0.07		unresolved	8	204.93	unresolved	9
	Micro litter	g/m2			unresolved			unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic impulsive sound sources	pulse/ day	248		unresolved	7		unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic continuous low-frequency sound	km2			unresolved	3		unresolved	
Structural ecosystem attributes (general)	Ecological status	% class [High]	20.28		↑	5		unresolved	
	Ecological status	% class [Good]	31.18		↑	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
	Ecological status	% class [Moderate]	17.67		↓	5		unresolved	
	Ecological status	% class [Poor]	7.53		↓	5		unresolved	
	Ecological status	% class [Bad]	0.20		↓	5		unresolved	
	Ecological status	% class [Unknown]	23.13		↑	5		unresolved	
	Spatial extent and distribution of physical loss/disturbance to seabed	km2	27,028		unresolved	3		unresolved	
	Spatial extent of adversely affected benthic habitat	km2			unresolved			unresolved	
	Extent of loss of benthic habitat type	km2			unresolved			unresolved	
	Extent of adverse effect on benthic habitat type	km2			unresolved			unresolved	
	Habitat extent and condition	km2			unresolved			unresolved	
Structural ecosystem attributes based on species diversity and abundance	Population abundance	no. ind./ species	197,025.33	-96.33	unresolved	7	12.94	unresolved	9
	Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types	no. ind./ species			unresolved			unresolved	
	Proportion of species group or extent of habitat type altered by non-indigenous and invasive species	ratio			unresolved			unresolved	
	Spawning stock biomass or biomass index of commercially exploited species (B/B_{2003})	rate	1.11	28.89	↑	5	35.62	↑	7
	Age and size distribution of commercially-exploited species (MSFD-D3C3)	%			unresolved			unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	1.68		↓	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Good]	4.80		↑	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
	Biological quality elements (BQEs) collected to assess ecological status	% class [Moderate]	5.77		↓	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Poor]	6.78		↑	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Bad]	1.57		↑	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Unknown]	73.39		↑	5		unresolved	
	Occurrences of invasive alien species	no. event	29		unresolved	6		unresolved	
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Marine protected area	% cumulativ e surface area	3.87	182.53	↑	8	17.36	↑	8

↑: Significant improvement (significant upward trend of condition indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant downward trend of condition indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.7.6b. Aggregated condition indicators of marine ecosystems in Baltic Sea. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Environmental quality (physical and chemical quality)	Chemical status	% class [Good]	56.23		↓	5		unresolved	
	Chemical status	% class [Failing to achieve good]	30.28		↓	5		unresolved	
	Chemical status	% class [Unknown]	13.48		↑	5		unresolved	
	Nutrients anomaly (N)	mmol/m3	0.29		→	6	32.76	↑	8
	Nutrients anomaly (P)	mmol/m3	-0.01		→	6	-38.78	↑	8
	Chlorophyll-*a*	mg/m3	0.65		→	6	2.51	↓	8
	Dissolved oxygen	mg/L	4.45	10.73	↑	6	9.91	↑	8
	Bathing water quality	class	excellent		→	7	34.09	↑	9
	Contaminants in biota	μg/kg	652.67		unresolved	7		unresolved	
	Contaminants in sediment	μg/kg	28,060,266.7		unresolved	7	-88.13	unresolved	8
	Beach litter	item/ 100m	149.57		→	7		unresolved	
	Seafloor litter	item/ haul	1.48		unresolved	8		unresolved	
	Micro litter	g/m2			unresolved			unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic impulsive sound sources	pulse/ day	137		unresolved	7		unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic continuous low-frequency sound	km2			unresolved	3		unresolved	
Structural ecosystem attributes (general)	Ecological status	% class [High]	0.90	-0.57	↓	5		unresolved	
	Ecological status	% class [Good]	19.36	-0.18	↓	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
	Ecological status	% class [Moderate]	53.42	0.10	↑	5		unresolved	
	Ecological status	% class [Poor]	9.05	1.44	↓	5		unresolved	
	Ecological status	% class [Bad]	3.11	-0.58	↑	5		unresolved	
	Ecological status	% class [Unknown]	14.16	-0.88	↑	5		unresolved	
	Spatial extent and distribution of physical loss/disturbance to seabed	km2	6286		unresolved	3		unresolved	
	Spatial extent of adversely affected benthic habitat	km2			unresolved	3		unresolved	
	Extent of loss of benthic habitat type	km2			unresolved	3		unresolved	
	Extent of adverse effect on benthic habitat type (MSFD-D6C5)	km2			unresolved			unresolved	
	Habitat extent and condition	km2			unresolved			unresolved	
Structural ecosystem attributes based on species diversity and abundance	Population abundance	no. ind./ species	51,585.06	-120.53	unresolved	7	7.76	unresolved	9
	Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types	no. ind./ species			unresolved			unresolved	
	Proportion of species group or extent of habitat type altered by non-indigenous and invasive species	ratio			unresolved			unresolved	
	Spawning stock biomass or biomass index of commercially- exploited species (B/B_{2003})	rate	0.97	48.88	↑	5		→	7
	Age and size distribution of commercially-exploited species	%			unresolved			unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	0.73		↓	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
	Biological quality elements (BQEs) collected to assess ecological status	% class [Good]	11.10		↑	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Moderate]	28.64		↑	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Poor]	11.82		↓	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Bad]	3.59		↑	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Unknown]	44.13		↑	5		unresolved	
	Occurrences of invasive alien species	no. event	3		unresolved	6		unresolved	
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Marine protected area	% cumulativ e surface area	23.82	25.355	↑	9	16.86	↑	8

↑: Significant improvement (significant upward trend of condition indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant downward trend of condition indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.7.6c. Aggregated condition indicators of marine ecosystems in Black Sea. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Environmental quality (physical and chemical quality)	Chemical status	% class [Good]	4.18		↑	5		unresolved	
	Chemical status	% class [Failing to achieve good]	29.08		↑	5		unresolved	
	Chemical status	% class [unknown]	66.74		↑	5		unresolved	
	Nutrients anomaly (N)	mmol/m3	-0.04		↓	6		↓	8
	Nutrients anomaly (P)	mmol/m3	1.62	55.50	↓	6	38.79	↓	8
	Chlorophyll-*a*	mg/m3	0.33		→	6	9.03	↓	8
	Dissolved oxygen	mg/L	3.79	3.65	↑	6	119.15	↑	8
	Bathing water quality	class	excellent		→	7	28.24	↑	9
	Contaminants in biota	μg/kg	99.60		unresolved	3		unresolved	
	Contaminants in sediment	μg/kg	6,6661.52		unresolved	7		unresolved	
	Beach litter	item/ 100m	172.56		→	7		unresolved	
	Seafloor litter	item/ haul	1.23	43.02	unresolved	6		unresolved	
	Micro litter	g/m2			unresolved			unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic impulsive sound sources	pulse/ day			unresolved	3		unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic continuous low-frequency sound	km2			unresolved	3		unresolved	
Structural ecosystem attributes (general)	Ecological status	% class [High]	0		→	5		unresolved	
	Ecological status	% class [Good]	15.29		↓	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
	Ecological status (WFD)	% class [Moderate]	19.73		↓	5		unresolved	
	Ecological status	% class [Poor]	54.85		↑	5		unresolved	
	Ecological status	% class [Bad]	10.12		↓	5		unresolved	
	Ecological status	% class [Unknown]	0		→	5		unresolved	
	Spatial extent and distribution of physical loss/disturbance to seabed	km2	1407		unresolved	3		unresolved	
	Spatial extent of adversely affected benthic habitat	km2			unresolved			unresolved	
	Extent of loss of benthic habitat type	km2			unresolved			unresolved	
	Extent of adverse effect on benthic habitat type	km2			unresolved			unresolved	
	Habitat extent and condition	km2			unresolved			unresolved	
Structural ecosystem attributes based on species diversity and abundance	Population abundance	no. ind./ species			unresolved			unresolved	
	Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types	no. ind./ species			unresolved			unresolved	
	Proportion of species group or extent of habitat type altered by non-indigenous and invasive species	ratio			unresolved			unresolved	
	Spawning stock biomass of commercially-exploited species	rate	0.94		→	5		→	7
	Age and size distribution of commercially-exploited species	%			unresolved			unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	0		→	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Good]	24.57		↓	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
	Biological quality elements (BQEs) collected to assess ecological status	% class [Moderate]	4.53		↓	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Poor]	70.90		↑	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Bad]	0		→	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [Unknown]	0		→	5		unresolved	
	Occurrences of invasive alien species	no. event.	1		unresolved	6		unresolved	
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Marine protected area	% cumulative surface area	3.75	22.84	↑	8	16.47	↑	8

↑: Significant improvement (significant upward trend of condition indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant downward trend of condition indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.7.6d. Aggregated condition indicators of marine ecosystem in Mediterranean Sea. Decadal change is only indicated when changes are statistically significant (p value < 0.05).

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Environmental quality (physical and chemical quality)	Chemical status	% class [Good]	32.81		↑	5		unresolved	
	Chemical status	% class [Failing to achieve good]	1.94		↓	5		unresolved	
	Chemical status	% class [Unknown]	65.26		↑	5		unresolved	
	Nutrients anomaly (N)	mmol/m3	-0.07	360.70	↓	6	143.71	↓	8
	Nutrients anomaly (P)	mmol/m3	0.10	83.68	↓	6	58.70	↓	8
	Chlorophyll-*a*	mg/m3	0.19		→	6	5.84	↓	8
	Dissolved oxygen	mg/L	3.74	-1.28	↓	6	0.76	↑	8
	Bathing water quality	class	excellent		→	7	32.13	↑	9
	Contaminants in biota	µg/kg	14,271.32		unresolved	7	-50.53	unresolved	7
	Contaminants in sediment	µg/kg	479,770.09	-10.44	unresolved	7		unresolved	
	Beach litter	item/ 100m	608.37		→	8		unresolved	
	Seafloor litter	item/ haul	1.18		unresolved	7		unresolved	
	Micro litter	g/m2			unresolved	3		unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic impulsive sound sources	pulse/ day	20,211		unresolved	6		unresolved	
	Spatial distribution, temporal extent, and level of anthropogenic continuous low-frequency sound	km2			unresolved			unresolved	
Structural ecosystem attributes (general)	Ecological status	% class [High]	26.93		↓	5		unresolved	
	Ecological status	% class [Good]	36.65		↑	5		unresolved	
	Ecological status	% class	11.36		↓	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
		[Moderate]							
	Ecological status	% class [Poor]	1.16		↓	5		unresolved	
	Ecological status	% class [Bad]	0.25		↓	5		unresolved	
	Ecological status	% class [Unknown]	23.65		↑	5		unresolved	
	Spatial extent and distribution of physical loss/disturbance to seabed	km2	13,555		unresolved	3		unresolved	
	Spatial extent of adversely affected benthic habitat	km2			unresolved			unresolved	
	Extent of loss of benthic habitat type	km2			unresolved			unresolved	
	Extent of adverse effect on benthic habitat type	km2			unresolved			unresolved	
	Habitat extent and condition	km2			unresolved			unresolved	
Structural ecosystem attributes based on species diversity and abundance	Population abundance	no. ind./ species	16,666.13	-1.10	unresolved	5	63.48	unresolved	6
	Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types	no. ind./ species			unresolved			unresolved	
	Proportion of species group or extent of habitat type altered by non-indigenous and invasive species	ratio			unresolved			unresolved	3
	Spawning stock biomass or biomass index of commercially- exploited species (B/B_{2003})	ratio	1.00	60.78	↑	5		→	7
	Age and size distribution of commercially-exploited species	%			unresolved			unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	26.75		↓	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	29.54		↑	5		unresolved	
	Biological quality elements (BQEs) collected to	% class	4.29		↓	5		unresolved	

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
	assess ecological status	[High]							
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	0		→	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	0		→	5		unresolved	
	Biological quality elements (BQEs) collected to assess ecological status	% class [High]	39.42		↓	5		unresolved	
	Occurrences of invasive alien species	no. event	14	-168.14	unresolved	6	-76.05	unresolved	7
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Marine protected area	% cumulative surface area	5.42	40.65	↑	9	16.98	↑	9

↑: Significant improvement (significant upward trend of condition indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant downward trend of condition indicator) Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment

Table 3.7.6e. Habitat conservation status aggregated for all regional seas.

Condition class	Indicator	Unit	Baseline value (value in 2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Structural ecosystem attributes monitored under the EU nature directives and national legislation	Share of coastal habitats listed under Annex 1 of the Habitats Directive in favourable conservation status*	%	2.9						
	Trends in unfavourable conservation status of coastal habitats listed under Annex 1 of the Habitats Directive*	% improving		6.7	↑				
		% stable		26.7	→				
		% deteriorating		13.3	↓				
		% unknown		52.3	unresolved				

*The indicators on coastal habitat conservation status have been treated differently than the other indicators with a different baseline year and different time period (2013–2018); so the percent change is expressed for a period of 6 years instead of 10 as for the other indicators. The trends in conservation status are only available for coastal and marine habitats in an unfavourable conservation status. Please check chapter 2 for details.

3.7.5.2 In-depth assessment

Several indicators and their relative temporal trends have been analysed to assess the condition of the marine environment and its ecosystems. As in the case of many pressure classes, relevant, harmonised datasets with adequate temporal and spatial coverage are missing for several condition classes, indicating that concerted efforts to achieve harmonised monitoring and reporting need to be stepped up. This is the case for all indicators in the 'environmental quality' class, benefiting from several decades of implementation of the WFD, supported by CAP and ND data. In particular, for litter and noise, data scarcity can be related to suboptimal implementation of the 'relatively young' MSFD, only recently complemented for litter by the plastics strategy (COM/2018/028) and the single use plastics directive (Directive (EU) 2019/904).

Chemical status, under the WFD, is assessed within three categories ('good', 'failing to achieve good' and 'unknown'). Member States reported on chemical status in 2010 and 2016 (first and second WFD river basin management plans (RBMPs), respectively). A comparison of the data reported by Member States in 2010 and 2016 is not possible, given that many elements changed between the two reporting cycles. However, looking at the general outcome of the two reporting exercises, a few conclusions can be derived: the proportion of EU coastal and transitional waters with unknown chemical status dropped significantly between the two cycles, from 68% to 39% (Figure 3.7.2); a large proportion of the water bodies classified as unknown in the first cycle were classified as being in good chemical status at the time of the second reporting.

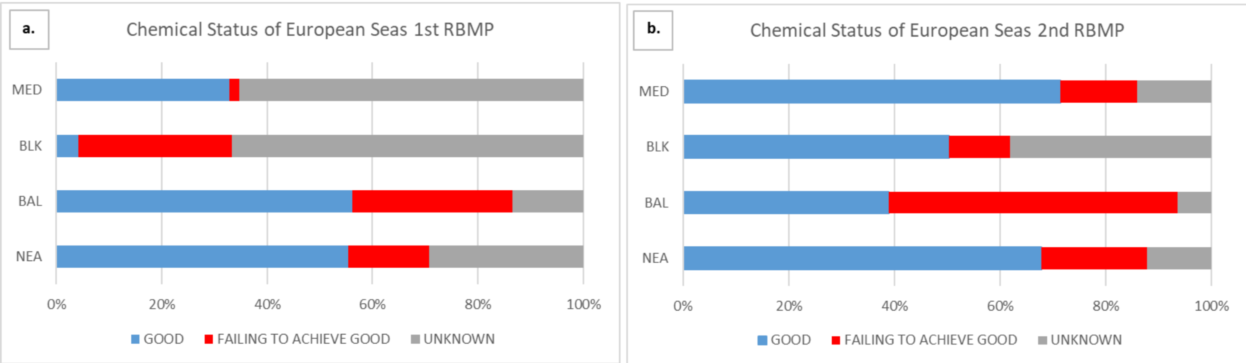

Figure 3.7.2. Chemical status reported in the (a) 2010 and (b) 2016 River Basin Management Plan reporting exercise. Data source: results are based on the WISE-WFD database (version 3), including data from 22 Member States (Lithuania not included for 2010 and Greece for 2016).

In relation to nutrients, the region-specific N:P ratio, indicating the atomic ratio of nitrogen and phosphorus that varies between marine regions, has been considered only for the photic zone basin-specific as proxy indicator for the marine condition. Statistically, there is a significant increase in the concentration of nitrates and phosphates, with significant deterioration of condition affecting the southern EU marine regions. The total nutrient concentrations are decreasing, both in the short and in the long term, only in the North-East Atlantic Ocean region. In the Baltic Sea, total nutrient concentrations are decreasing only in the long term. In the Mediterranean Sea and Black Sea regions, nutrient concentrations are continuing to increase, both in the long and in the short term. Some regions and sub-regions may also be experiencing the effect of policies in neighbouring non-EU countries, where the EU environmental policy does not apply. Such results could be also explained by the presence of a time lag between pressure decrease and ecosystem condition improvement. This is the case, for example, for the Baltic Sea where, despite decreased inputs, nutrient concentrations are decreasing more slowly than expected. This is due mainly to the dissolution of nutrients from re-suspended sediments, a process that plays a particular role in the Baltic Sea, given that over a quarter of its basin lies at relatively shallow depth (less than 20 m, Niemistö and Lund-Hansen, 2019). Nutrient enrichment leads to eutrophication, as also confirmed by increase of chlorophyll-*a* concentrations in the long term for the Baltic Sea, Mediterranean Sea and Black Sea. No change of chlorophyll-*a* concentrations for the North-East Atlantic Ocean both in the long and in the short term has been observed. Similar conclusions are also reached in the EEA's latest state of the environment and outlook report (EEA, 2019c).

Long time-series datasets (1993-2018) of dissolved oxygen close to the bottom present a downward trend (degradation) in the North-East Atlantic Ocean and Mediterranean Sea, in the long term and short term, respectively, while upward trends (improvement) in both long- and short-term have been observed in the Baltic Sea and Black Sea.

Bathing water quality (for transitional and coastal waters only) indicates no change in the short term, and a significant improvement in the long term in all marine regions. This parameter was introduced for the environmental quality class because bathing waters are mentioned under the WFD (they have to be included in the register of protected areas of the RBMPs) and under the MSFD (measures taken pursuant to the Bathing Water Directive (Directive 2006/7/EC) must be integrated in the programme of measures (PoMs). Poor bathing-water quality flags issues of pollution from untreated sewage and/or livestock.

Data on contaminants in biota and sediments yielded unresolved short- and long-term trends, due to the variability over time in the list of chemicals considered in the sampling. No harmonised thresholds are yet available at EU or regional levels. The EEA (2019a,c) draws similar conclusions. Beach litter data were available only for transitional and coastal waters, while seafloor litter could be analysed for all habitats. Beach litter seems to be decreasing across Europe in the short term, except for the Mediterranean Sea region. Long-term trends for beach litter are available only for the North-East Atlantic Ocean, where the situation seems to be improving. Seafloor litter occurrence over the long term is difficult to assess due to a lack of data, except for the North-East Atlantic Ocean region, where it seems to be increasing. On contrary, short-term trends are signalling a worsening of condition everywhere except in the Baltic Sea region. Micro litter could not be assessed in the short or long term, due to lack of data. Floating litter might be considered as an additional indicator in the assessment of the condition of marine ecosystems.

Data on underwater noise are recent and not complete. Only data on impulsive noise are available. There are no data for continuous low-frequency sounds as yet.

Ecological status is assessed within six categories ('high', 'good', 'moderate', 'poor', 'bad' and 'unknown'). As in the case of chemical status, the assessment of ecological status has changed between the first (2010) and second (2016) WFD RBMP reporting cycles. Thus, the datasets related to the two reporting cycles cannot be compared. However, a few general observations can be made when looking at the changes in the assessments made by Member States (Figure 3.7.3): there was an overall marked reduction in the proportion of transitional and coastal water bodies classified as being of 'unknown' status in 2016, with respect to 2010, and this change benefits, inter alia, from the widespread application of intercalibrated biological assessment methods. There is also a marked overall reduction in the proportion of water bodies classified as being in 'bad' status. Overall, marine water bodies classified as being in 'good' to 'high' ecological status in 2016 range from a low 7%-18% (Black Sea and Baltic Sea, respectively) to 65%-70% (North-East Atlantic Ocean and Mediterranean Sea respectively, Figure 3.7.3b). Similar observations can be made on the biological quality elements (BQEs, Figure 3.7.4). The 2016 reporting is characterised, again, by a reduction in the 'unknown' condition class with respect to 2010, and the decrease of the number of water bodies classified as in 'poor' or 'bad' status.

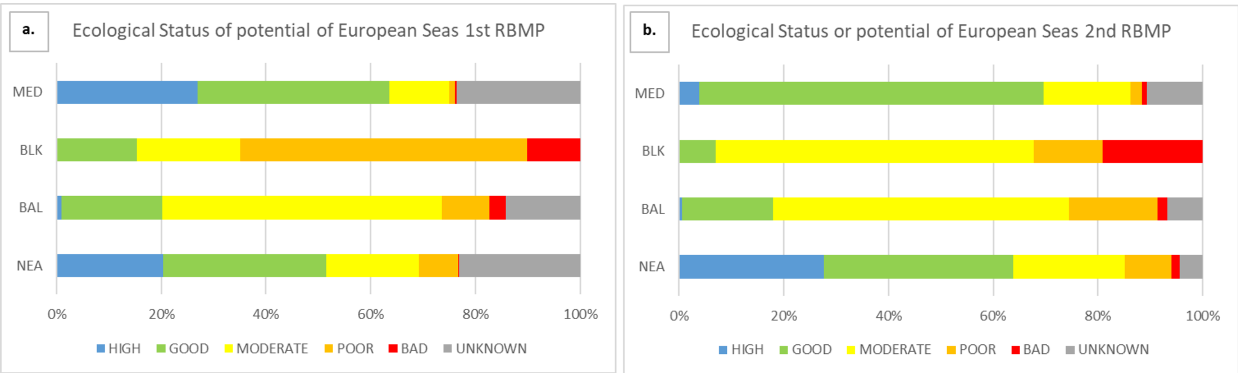

Figure 3.7.3. Ecological status reported in the (a) 2010 and (b) 2016 River Basin Management Plan reporting exercise. Data source: results are based on the WISE-WFD database including data from 22 Member States (Lithuania not included for 2010 and Greece for 2016).

The potential extent of seafloor's physical loss and disturbance is the only indicator available for seafloor integrity, but no trend could be calculated at marine regions scale. The dataset used could just provide point-in-time results for all marine regions (EEA, 2019d). An EEA/ETC report (ETC/ICM, 2019) includes an analysis of the two broad classes of pelagic and benthic habitats in Europe's seas. Assessments of pelagic habitats are still difficult, and rely mostly on primary production data, thus connecting to eutrophication and harmful algal blooms (HABs) as pressures, rather than to the actual loss of habitat. The HEAT+ (HELCOM Eutrophication Assessment Tool) integrated assessment metrics, developed for the pan-European assessment, was used for this study in the North-East Atlantic Ocean and the Baltic Sea. The approach, however, follows the WFD rather than the MSFD GES concept. No regional assessment was available for the Mediterranean Sea and Black Sea pelagic habitats. Benthic habitats are assessed at regional and subdivision levels using the same tool. In this case, fishing activities (bottom trawling in particular) are the main source of pressure from human activities (Buhl-Mortensen and Buhl-Mortensen, 2018; Kaiser et al., 2003).

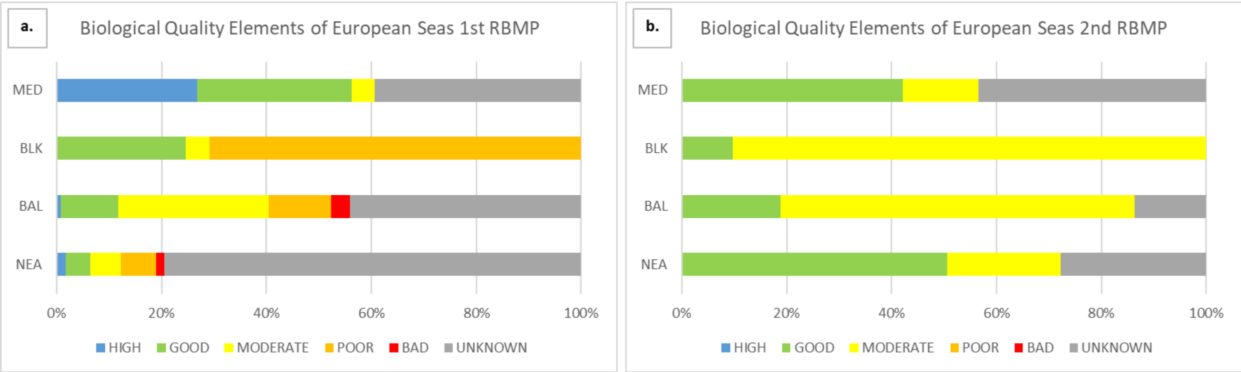

Figure 3.7.4. Biological quality elements (BQEs) reported in the (a) 2010 and (b) 2016 River Basin Management Plan reporting exercise. Data source: results are based on the WISE-WFD database including data from 22 Member States (Lithuania not included for 2010 and Greece for 2016).

Trends of population abundance of all marine species included in the survey were classified as unresolved in all marine regions, because of the incompleteness and variability of databases. Datasets on population abundance differ in marine species, number of surveys, technology applied and recent interest in some habitats (e.g. deep sea). Nevertheless, using the average of Biodiversity Quality Ratio (BQR), the biodiversity status (including the abundance, distribution, productivity and physiological and demographic characteristics of key species and species groups) for the North-East Atlantic Ocean, Baltic Sea, and Mediterranean Sea has been assessed at 0.56, 0.58, and 0.40, respectively (Figure 3.7.5; ETC/ICM, 2019). These values indicate that European marine regions (no data were available for the Black Sea) have not yet achieved a good status (Figure 3.7.5) (ETC/ICM, 2019). The BEAT+ (HELCOM Biodiversity Assessment Tool) integrated assessment multi-metrics tool was developed for and used only in the assessment of the ecosystem health of the Baltic Sea. However, Nygård et al. (2018) have recently further developed the multi-metric indicator-based tool to better fit the MSFD objectives and requirements, making it potentially available for a pan-European assessment in the future.

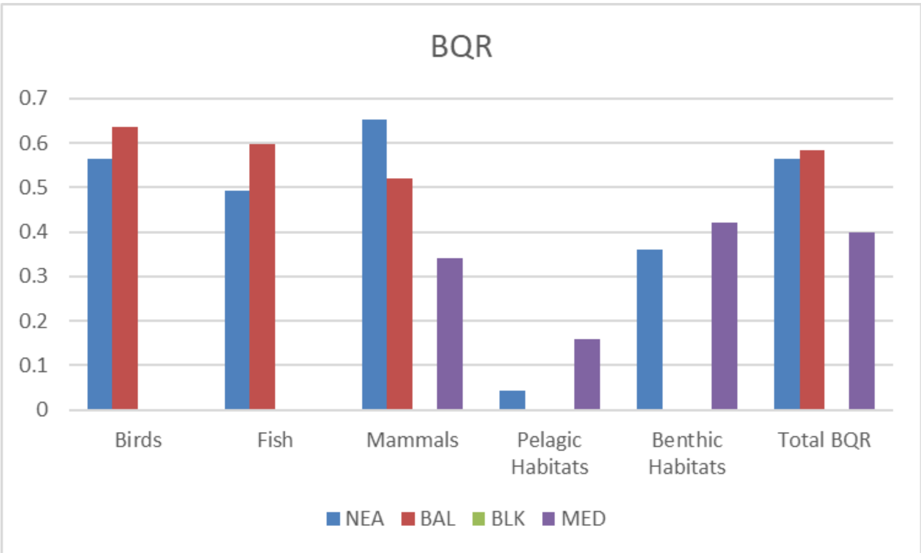

Figure 3.7.5. Biodiversity quality ratios (BQRs) by species groups in the European marine regions: North-East Atlantic Ocean, Baltic Sea, Mediterranean Sea and Back Sea. Data Source: EEA update 24 Jan 2020, (ETC/ICM, 2019).

Spawning stock biomass has been modelled (STECF, 2019) and exhibits an improving trend in the short term, but no change in the long term in all regions. Age and size of commercially exploited species are only available in ICES reports (i.e. no datasets) for North-East Atlantic Ocean and Baltic Sea. Time and resources constraints within the current exercise did not allow data from the literature to be assembled for analysis, thus the several ICES reports have been not considered in this study.

Trends in relation to the occurrence of invasive alien species are considered to be unresolved in the short and long term in all marine regions. The data are not harmonised and complete throughout marine regions (e.g. Black Sea), moreover they only indicate the year of first introduction into the EU of the new invasive species, potentially underestimating the newly introduced species. No data are available on the abundance of invasive alien species and their impacts on biodiversity and habitat types.

Data on the extent of MPAs display significant upward trends in all European marine regions, both in the long and in the short term. The highest percentage of total MPA surface area, registered up to 2019, is in the Baltic Sea (28.25%), followed by the North-East Atlantic Ocean (10.06%), the Mediterranean Sea (6.93%) and the Black Sea (4.34%) (Fact sheet 3.7.225). However, despite long- and short-term increases in the percentage of European marine waters being protected under Natura 2000, habitat representativeness and geographical coverage remain an issue, as well as connectivity and the coherence of the current MPA network (EEA, 2018).

As a general observation on this exercise, some of the trends could not be assessed due to limitations in the respective datasets. However, there is a time lag between an improvement in condition as the result of policy implementation and the response of the ecosystem that should be also considered in the context of the ecosystem restoration perspective.

3.7.6 Convergence of evidence

The convergence of evidence was based on the number of indicators that were improving, degrading, showed no change or remained unresolved (either because a trend could not be computed or because the trend was unclear). A group of indicators that could provide a balanced overview of pressures (Table 3.7.5a-d) or condition (Table 3.7.6a-d) of marine ecosystems were selected for the general assessment. Given the nature of indicators in marine ecosystems, which are mostly linked to dynamic processes but whose change might take time to be visible and tangible, the convergence of evidence was differentiated on short-and long-term trends.

3.7.6.1 Summary of the trends in pressure and condition

Tables 3.7.7 and 3.7.8 summarise the short- and long-term trends of pressures and condition indicators, respectively. The tables include the indicators on chemical, ecological and biological quality elements status, although they do not result in a single trend as the rest of marine indicators.

Trends of marine pressures were calculated using 12 indicators with available data (Table 3.7.7). The assessment reveals the following differences between marine regions.

- *North-East Atlantic Ocean*. In the short term, three indicators show negative change resulting in degradation, one shows no change, one shows a positive change resulting in improvement and seven have unresolved trends. In the long term, four indicators show negative change resulting in degradation, one shows a positive change resulting in improvement, and two have unresolved trends.
- *Baltic Sea*. In the short term, three indicators show negative change resulting in degradation, one shows no change and seven have unresolved trends. In the long term, four indicators show negative change resulting in degradation, one a positive change resulting in improvement, and two with unresolved trends;
- *Black Sea*. In the short term, one indicator shows negative change resulting in degradation, four show no change, and seven have unresolved trends. In the long term, three indicators show negative change resulting in degradation, two show no change and two have unresolved trends;
- *Mediterranean Sea*. In the short term, four indicators show negative change resulting in degradation, one shows a positive change resulting in improvement and seven have unresolved trends. In the long term, four indicators show negative change resulting in degradation, one shows no change and two have unresolved trends.

Trends of marine condition were calculated using 29 indicators with available data (Table 3.7.8). The assessment reveals the following differences between marine regions.

- *North-East Atlantic Ocean*. In the short-term trend, 13 indicators show improvement, three no change, six degradation, and seven indicators show unresolved trend. While in the long-term trend, five indicators indicate improvement, one no change, one degradation, and five show unresolved trend.
- *Baltic Sea*. In the short-term trend, 11 indicators show improvement, four no change, seven degradation, and seven indicators show unresolved trend. While in the long-term trend, four indicators indicate improvement, one no change, one degradation, and four show unresolved trend.
- *Black Sea*. In the short-term trend, seven indicators show improvement, nine no change, six degradation, and six indicators show unresolved trend. While in the long-term trend, three indicators indicate improvement, one no change, two degradation, and three show unresolved trend.
- *Mediterranean Sea*. In the short-term trend, seven indicators show improvement, five no change, ten degradation, and seven indicators show unresolved trend. While in the long-term trend, three indicators indicate improvement, one no change, two degradation, and four show unresolved trend.

Table 3.7.7. Summary table for pressures in EU marine regions

		North-East Atlantic Ocean		Baltic Sea		Black Sea		Mediterranean Sea	
Pressure class	**Indicator**	**Short-term trend (since 2010)**	**Long-term trend**	**Short-term trend (since 2010)**	**Long-term trend**	**Short-term trend (since 2010)**	**Long-term trend**	**Short-term trend (since 2010)**	**Long-term trend**
Habitat conversion and degradation	Extent of loss of habitat								
Climate change	Acidification	↓	↓	↓	↓	↓	↓	↓	↓
	Sea surface temperature	↓	↓	↓	↓	→	→	↓	↓
	Sea level anomaly	→	↓	→	↓	→	↓	↓	↓
	Sea water salinity	↓	↓	↓	↓	→	↓	↓	↓
Pollution and nutrient enrichment	Chemical loads								
	Riverine litter								
	Nutrient loads (N)								
	Nutrient loads (P)								
	Nutrient loads (N:P)								
	Nutrients release from aquaculture								
Exploitation	Fishing mortality (F) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{MSY})	↑	↑	→	↑	→	→	↑	→
Introductions of invasive alien species	Number of annual introductions of non-indigenous species								
	Number of newly introduced non-indigenous species from human activities/transport								

↑: Significant improvement (significant downward trend of pressure indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant upward trend of pressure indicator) Grey cells refer to Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment.

Table 3.7.8. Summary table of ecosystem condition indicators in EU marine regions

		North-East Atlantic Ocean		**Baltic Sea**		**Black Sea**		**Mediterranean Sea**	
Condition class	Indicator	Short-term trend (Since 2010)	Long-term trend	Short-term trend (Since 2010)	Long-term trend	Short-term trend (Since 2010)	Long-term trend	Short-term trend (Since 2010)	Long-term trend
Environmental quality	Chemical status [Good]	↑		↓		↑		↑	
	Chemical status [Failing to achieve good]	↓		↓		↑		↓	
	Chemical status [Unknown]	↑		↑		↑		↑	
	Nutrients anomaly (N)	↑	↑	→	↑	↓	↓	↓	↓
	Nutrients anomaly (P)	↑	↑	→	↑	↓	↓	↓	↓
	Chlorophyll-*a*	→	→	→	↓	→	↓	→	↓
	Dissolved oxygen	→	↓	↑	↑	↑	↑	↓	↑
	Bathing water quality	→	↑	→	↑	→	↑	→	↑
	Contaminants in biota								
	Contaminants in sediment								
	Beach litter	↑	↑	→		→		→	
	Seafloor litter								
	Micro litter								
	Spatial distribution, temporal extent, and level of anthropogenic impulsive sound sources								
	Spatial distribution, temporal extent, and level of anthropogenic continuous low-frequency sound								
Structural ecosystem attributes (general)	Ecological status [High]	↑		↓		→		↓	
	Ecological status [Good]	↑		↓		↓		↑	
	Ecological status [Moderate]	↓		↑		↓		↓	
	Ecological status [Poor]	↓		↓		↑		↓	
	Ecological status [Bad]	↓		↑		↓		↓	
	Ecological status [Unknown]	↑		↑		→		↑	
	Spatial extent and distribution of physical loss/disturbance to seabed								
	Spatial extent of adversely affected benthic habitat								

		North-East Atlantic Ocean		Baltic Sea		Black Sea		Mediterranean Sea	
	Extent of loss of benthic habitat type								
	Extent of adverse effect on benthic habitat type								
	Habitat extent and condition								
Structural ecosystem attributes based on species diversity and abundance	Population abundance								
	Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types								
	Proportion of species group or extent of habitat type altered by non-indigenous and invasive species								
	Spawning stock biomass or biomass index of commercially- exploited species (B/B_{2003})	↑	↑	↑	→	→	→	↑	→
	Age and size distribution of commercially-exploited species								
	Biological quality elements (BQEs) collected to assess ecological status [High]	↓		↓		→		↓	
	Biological quality elements (BQEs) collected to assess ecological status [Good]	↑		↑		↓		↑	
	Biological quality elements (BQEs) collected to assess ecological status [Moderate]	↓		↓		↓		↓	
	Biological quality elements (BQEs) collected to assess ecological status [Poor]	↑		↑		↑		→	
	Biological quality elements (BQEs) collected to assess ecological status [Bad]	↑		↑		→		→	
	Biological quality elements (BQEs) collected to assess ecological status [Unknown]	↑		↑		→		↓	
	Occurrences of invasive alien species								
Structural ecosystem attributes monitored under the EU nature directives and national legislation: Marine protected area		↑	↑	↑	↑	↑	↑	↑	↑

↑: Significant improvement (significant upward trend of condition indicator) →: No change (the change is not significantly different from 0% per decade) ↓: Significant degradation (significant downward trend of condition indicator) Grey cells refer to Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment. Indicators of conservation status of habitats, species and birds are excluded.

3.7.7 Options for policy

The EU has enjoyed to date one of the most comprehensive policy frameworks in the world, with a holistic, ecosystem-based approach for the protection of the marine environment. The MSFD, as the environmental pillar of the wider European integrated maritime policy, sets the basis for achievement or maintenance of good environmental status of waters and obliges Member States to design their own marine strategies to efficiently and effectively achieve that objective. In that context, Commission Decision (EU) 2017/848 refers in its text to the most relevant, previously existing policies already targeting, among others, the marine environment, creating the proper setting for synergy among the various policies objectives. This is the case, for example, of the CFP, the WFD, the BD, HD and MSP.

Regarding the land–sea interface, the WFD is complemented by the older nitrates directive (91/676/EEC), regulating the introduction of nitrogen into the environment from agriculture as a diffuse nutrient source, and the urban wastewater treatment directive (91/271/EEC), ultimately limiting the impact of point sources and diffuse sources of nutrient and contaminants pollution. In relation to invasive alien species, the IAS regulation is complemented by the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM), adopted by the International Maritime Organization in 2004), and the aquaculture regulation (Council Regulation (EC) 708/2007), addressing two paths of introduction, respectively: ballast water; aquaculture escapees of alien and locally absent species.

This work has confirmed that, despite the wealth of data available in the EU on pressures and condition of marine ecosystems, stemming for the largest part from research projects and from national and regional monitoring programmes, there is a need for stronger regional cooperation for the collection of harmonised datasets, not only in data-poor areas (Black Sea and, to a slightly lesser extent, Mediterranean Sea) but also in areas where regular reporting processes have been well established for a long time (Baltic Sea, North East Atlantic).

Although restoration practices are fundamental for re-establishing and recovering degraded ecosystems, the prospect of their long-term success is yet unknown, as they might mitigate anthropogenic impacts only temporarily. The spatial scale of assessment is also relevant. In this context, the environmental impact assessments (EIA, Directive 2014/52/EU) required for the licensing of specific projects and the strategic environmental assessments (SEA, Directive 2001/42/EC) complement the preparation and implementation of the maritime spatial plans (MSP, Directive 2014/89/EU), providing a mechanism for the strategic assessment of alternative plans and the potential development of mitigation measures (Greiber and Knodel, 2007). In addition, these tools promote sustainable development through the integration and balance of environmental considerations and objectives into decision-making processes. In particular, within the area-based approach to marine management of the MSP, targeting improved decision-making for the sustainable use of marine resources and space, the EIA and SEA contribute to the implementation of the ecosystem-based approach, as they frame the evaluation of impacts on species and habitats of conservation importance. They are two environmental assessment procedures that aim to 'facilitate sound, integrated decision-making in which environmental considerations are explicitly included' by providing 'clear, well-organised information on the environmental effects, risks and consequences of development options and proposals' in order to achieve or support environmental protection and/or sustainable development (Sadler, 1996).

Last but not least, there is a need to increase the level of understanding of the reciprocal influence of humans and the ocean among decision makers and policymakers, marine stakeholders and individuals, enhancing ocean literacy. It should become a policy priority in the light of the upcoming UN Decade of Ocean Science for Sustainable Development, as change cannot be successful if it only stays at the policy level. Rather, change has to done with political commitment while being implemented from the bottom up as well.

Looking at the broader perspective stemming from this exercise, it appears that the EU would probably benefit more from an intensification of the coordination and integration of policy objectives than from further increases in its regulatory framework. But first and foremost, there is a clear need for stronger ambition in the implementation of existing policies and the achievement of policy targets at the EU, regional, national and sub-national levels. The achievement of GES in all European seas, at regional, sub-regional and local levels, would definitely bring us closer to good safeguarding of the marine environment, and having marine ecosystems in a condition that would ensure full capacity for ecosystem service delivery.

As highlighted in the chapter, often data were not linked to policy reporting, scaled at a standard geographical resolution, or were not available for this study: thus, results might be not sufficiently robust nor conclusive. For this reason, it is difficult and premature to provide robust technical recommendations about the indicators (e.g. whether an indicator should be taken forward or not), or the policy impact of, for example, the WFD or the MSFD (e.g. how to measure the outcomes from policy instruments). Although several pressure and condition indicators have been already included in the current study, additional indicators should be taken into consideration for the assessment of marine ecosystems condition of European marine regions (e.g. maritime traffic, glacier and sea ice melting). Moreover, the time lag between a decrease in pressure and the response of the ecosystem though an improvement in condition as a result of policy implementation should be also considered. For example, Commission Decision (EU) 2017/848 sets the criteria and methodological standards for the good environmental status of marine waters, providing specifications and standardised methods for monitoring and assessment; unfortunately current national and regional datasets do not yet benefit from a full implementation of the decision. Hence it is very evident that further analyses with more complete, standardised, and harmonised data, linked to policy reporting, including modelling scenarios in different marine areas (that are ecologically relevant), are still necessary and propaedeutic to technical recommendations.

3.7.8 Knowledge gaps and future research challenges

Marine ecosystems are key assets of society, with multiple uses of their resources. However, both land-based and sea-based human activities produce pressures that affect the condition of marine ecosystems, altering biogeochemical processes and threatening the abundance and composition of flora and fauna within them. Overall, the assessment indicated that marine ecosystems are still in poor condition. The assessment of pressures and condition trends in the EU marine regions shows that, while some pressures are improving, anthropic pressures on marine ecosystems remain high, thus hindering their recovery.

However, important knowledge gaps limited the assessment of the marine ecosystems' status in space and changes in time of direct anthropogenic impacts (e.g. chemicals, nutrients discharge, litter and underwater noise), habitat loss and biodiversity issues, and of the ecosystems' response to multiple pressures. Most of the pressure and condition indicators (> 70%) could not be assessed at EU marine regions' scale (see Tables 3.7.5a-d and 3.7.7a-d). The remaining indicators (< 30%) listed for pressures and conditions can be summarised as belong to three main groups.

- *Datasets that are poorly populated or not available*. Importantly, knowledge gaps included pressure and condition indicators linked to direct anthropogenic impacts (e.g. chemicals, nutrients discharge, litter and underwater noise), and to habitat loss and biodiversity (e.g. seafloor integrity, species with no commercial interest), for which either there was no clear pattern in short-term trends or it could not be assessed.
- *Data are available, but are not harmonised and/or are highly uncertain*. Data collection on fishery and invasive alien species in marine ecosystems is sufficient to define the condition and short-term and/or long-term trends, but datasets contain variability at a temporal and spatial scale (e.g. different number of fish stocks; missing data on IAS; contaminants in the Black Sea).
- *Data are available with time-series*. Mainly, these are data on pressure indicators linked to climate change (e.g. acidification, sea surface temperature, sea level and salinity) and data on ecosystem condition indicators linked to marine productivity and water quality (e.g. nutrients, chlorophyll-*a*, bathing water quality). Thus, short-term and/or long-term trends could be assessed.

A number of indicators, which are not listed in Tables 3.7.3-4 because they are not directly linked to any policy directive, might be worth considering for inclusion in future analyses because of their relevance in defining the status of pressures and conditions of marine ecosystems. They comprise for example safe biological limits of commercially exploited fish stocks, sea ice melting, wave regime, tidal range, trophic level, connectivity, maritime traffic, tourism, underwater seismic surveys, and tourism.

In the analysis of pressures and condition, the use of modelling can make up for the lack of harmonised databases in those areas where data acquisition is challenging. Such efforts are much needed for an exhaustive assessment of the condition of the marine ecosystems in Europe and beyond. Indeed, an important future step in the EU-wide assessment of marine ecosystem conditions should go beyond Europe, and include the EU's outermost regions and overseas territories, where the majority of marine hotspots are concentrated (e.g. coral reefs, deep-sea habitats).

The MSFD aims to protect and restore marine ecosystems and their resources, but the full and harmonized implementation of Commission Decision (EU) 2017/848 is still lagging behind. The geographical scale of assessment is also an issue, both within the MSFD and between the MSFD and other policies, and this undermines the integrated assessment of marine ecosystems' condition and its improvement. For example, descriptor 3 is based on fishing areas of International Council for the Exploration of the Sea (ICES), General Fisheries Commission for the Mediterranean (GFCM) and Food and Agriculture Organization of the United Nations (FAO), while descriptor 4 is based on regional/subregional levels and descriptor 5 is assessed both in coastal waters and beyond. On the other hand, the WFD includes all freshwater bodies on land and coastal waters out to 1 nautical mile. In the light of the presented findings, there should be immediate actions to restore and rehabilitate habitats, and continuous actions to decrease pressures on marine ecosystems (i.e. promotion of conservation, sustainable thresholds for use and precautionary principle) as scientific evidence about marine environmental health and hazards is still uncertain and the stakes are high. Such actions could indeed strengthen synergies among MSFD, CFP, WFD, BHD, the BWM and IAS regulation, and other policies relevant for the marine and coastal environment.

In conclusion, while data collection has improved, coverage in space and time is still insufficient to provide a consistent picture across European marine regions and further analyses are needed for an exhaustive assessment of the condition of marine ecosystem ins Europe (incl. the outermost regions and overseas territories). Research programmes and policy requirements should also focus on further spatial and non-spatial data acquisition and reporting; establishing common standards of data quality and harmonisation; improving data accessibility, integration and interoperability; aligning environmental indicators with policy criteria; and setting standards to measure progress in marine ecosystem condition and policy impact

Marine ecosystems services ([91])

An important focus should be on risks and challenges to delineate the framework of marine ecosystem services, and the reason why the marine ecosystem services assessment cannot as yet be performed in a comprehensive way. This is primarily because of lack of data (e.g. regulating services, cultural services, non-monetary data on ecosystem service values) or inappropriate geographical scales resolution (e.g. locally based), resulting in a scattered ecosystem assessment. Clear indicators, thresholds and targets are needed to perform any kind of assessment of the condition of ecosystem services.

Since most pieces of information and data available are related to the potential supply of services, it is important to understand the following:

- the actual use of marine ecosystem services (e.g. how many of the ecosystem services used are mainly available for fishery-related services and sometimes for cultural services);
- real demand for marine ecosystem services and the trade-offs among different services (e.g. inaccessibility of sensitive data on fisheries or recreation);
- marine ecosystem services flows across scales (i.e. flows from the point of supply to different regions across scales);
- linkage between ecosystem condition and the level of ecosystem services supply;
- threshold values at which ecosystems can no longer deliver services;
- impact of how changes in ecosystem services flow affect the wellbeing of dependent communities and society in general;
- the different linkages to terrestrial activities that influence marine ecosystem services;
- mapping methodology that can fit the 3D ecosystem, capturing the dynamics of the marine ecosystems, and can also include approaches related to flow, value and demand;
- uncertainty associated with the mapping and its role in policy (e.g. uncertainty is rarely communicated to decision-makers);
- risks related to the use of the information for ecosystem services supply levels (e.g. it might promote extra exploitation of marine resources) and the effect of the introduction of sustainable management measures on that supply;

[91]Including outcomes from preliminary discussion between the Joint Research Centre and the Ecosystems Services Partnership - Biome Working Group – Marine systems of the (ESP - BWG1) (Evangelia Drakou (University of Twente, UT), Ana Ruiz (Mediterranean Institute for Advanced Studies, IMEDEA-CSIC), Maria C. Uyarra (AZTI Tecnalia)).

- the value of marine ecosystem services, which is still very vaguely defined, and the adoption of relational values can lead to a more sustainable, ethical and socially just future.

The focus is mostly on monetary values and biophysical assessments, and there is no real evidence about cultural and relational values as these are disregarded by policy, even though the integration of relational values is key in the achievement of pluralistic valuations of ecosystem services, i.e. sustainability and social justice. Cultural value or community cohesion around the marine ecosystems are still key points that are systematically omitted from current ecosystem services assessments and data. The integration of non-monetary valuations and innovative methods applied in the assessment of cultural ecosystem services needs further consideration.

In conclusion, assessing and mapping marine ecosystem services means facing several challenges and risks, from purely the technical (e.g. current mapping methods are mainly adaptations of terrestrial approaches, therefore the outcome is always a great simplification of reality) to the theoretical (e.g. oversimplification of information based on current mapping approaches can lead to false assumptions). As already mentioned for pressure and condition, it is important to remember that for marine ecosystem services the scientific research and funding should also focus on the enhancement of spatial and non-spatial data acquisition; the improvement of data quality, data harmonisation following established standards, accessibility, integration and interoperability; the establishment of targets and thresholds, to measure progress; marine resources traceability (e.g., through trade, tourism); the expansion of knowledge about pluralistic valuations and wellbeing dependencies through cross-sectoral approaches; and establishing links between environmental conditions and ecosystem service conditions. Last but not least, knowledge on marine ecosystem services needs to be tailored to, and interoperable with, end-users using appropriate scientific vocabulary to communicate with all relevant stakeholders.

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4 Cross-cutting ecosystem assessments on climate, invasive alien species, landscape mosaic and soil

This chapter consists of four sections which describe the trends in climate change (section 4.1), invasive alien species (section 4.2), landscape mosaic (section 4.3), and soil (section 4.4).

Chapter 4 (Cross-cutting ecosystem assessments) includes strategic reports on invasive alien species, climate change, landscape mosaic, and soil. These assessments are relevant for all ecosystems and are related to processes that can be assessed on a higher spatial scale than the scale at which ecosystems are assessed.

The different cross-cutting ecosystem assessments have been carried out by different research teams. So each section mentions the coordinating and contributing authors. The first coordinating author is the main point of contact for questions regarding the ecosystem assessment under his or her supervision. The section also lists the reviewers that have commented on an earlier draft (insofar reviewers agreed that their names can be disclosed).

Figure and table numbers always start with the number of the section followed by a number expressing their order of use in the section.

The different sections contain references to indicator fact sheets which provide additional details on the data used in this assessment. The fact sheets are encoded with 5 digits of which the first two refer to the section number. All the fact sheets of this report are bundled in a separate supplement of this report. This supplement can be downloaded here: https://publications.jrc.ec.europa.eu/repository/handle/JRC120383

4.1 Climate change

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Summary: The aim of this chapter is to provide a quantitative assessment of observed trends derived from a set of well-established bioclimatic indicators for the EU. Climate change is a significant and increasing pressure on ecosystems. Indeed, it is one of the five main pressures on ecosystem condition in the MAES framework. In the MAES ecosystem assessment, significant trends in the selected bioclimatic indicators are considered as major cross-ecosystem drivers of degradation. As ecosystems are adapted to specific local climate regimes, significant trends in bioclimatic indicators, both downward and upward, are considered pressures affecting ecosystems. The exceptions are the indicators of climate extremes, for which only increase was considered as pressure on ecosystems. The analysis of susceptibility and resilience of ecosystems to these pressures is out of the scope of the assessment.

The obtained spatial information on trends in bioclimatic indicators shows that despite regional differences, bioclimatic indicators have already been changing in an important extent of the EU-28 territory. For example, mean annual temperature shows a significant increase in most of the EU-28 territory (97%), whereas precipitation-related indicators exhibit significant trends (pressures) in 13-25% of the area. Likewise, effective rainfall showed significant changes in 26% of the area. There is a significant increase in extreme climate indicators in 9-47% of the EU-28 area, whereas seasonality indicators have shown significant changes in 10-31% of the domain.

The integrated assessment of the bioclimatic indicators shows that 38% of the EU-28 land area is affected by at least seven significant climate pressures, half of the area by 4-6 climate pressures, and the remaining 12% by three to one.

4.1.1 Introduction

Climate change is one of the five main pressures on ecosystems considered in the MAES framework, similarly to the direct drivers of change in nature in the IPBES framework (2019). The strongest drivers of biodiversity loss have been agriculture, forestry, infrastructure, urban encroachment and climate change (IPBES, 2018). According to projections, climate change is one of the drivers of biodiversity loss with the greatest increase between 2010 and 2050 (IPBES, 2019). The Intergovernmental Panel on Climate Change (IPCC) reported with high confidence that many plant and animal species experienced range size and location changes, shifts in seasonal activity and changes in abundance due to climatic changes in the recent decades, and that regional climate zones have shifted already (Cramer et al., 2014; IPCC, 2019). It is very likely that ecosystems will be exposed to disturbances larger than the natural variability as a result of climate change, even under low- to medium-range changing scenarios (IPCC, 2019). The shift of regional climatic zones in Europe have been shown by various studies (e.g. Jylhä et al., 2010, King et al., 2018, Ceglar et al., 2019, Barredo et al., 2016, 2019).

On the one hand, changes in climate affect ecosystems in multiple ways in interaction with the other pressures (habitat conversion, introduction of invasive alien species, pollution and nutrient enrichment, over-exploitation), exacerbating their extent and impacts (Cramer et al., 2014; IPBES, 2019). These changes then have considerable influence on the condition of the ecosystems and the supply of ecosystem services (Scheffers et al., 2016; Pecl et al., 2017; Runting et al., 2017). On the other hand, healthy ecosystems contribute to climate change mitigation, in fact climate regulation is a key ecosystem service. The IPBES report calls for a coordinated action to address climate change and land degradation as they have two-way interactions. Nature conservation and ecosystem restoration have to take into consideration climate drivers on ecosystems, and at the same time, conserving and restoring ecosystems helps to tackle climate change (IPBES, 2019). However, land-based climate adaptation and mitigation actions can have unintended negative impacts on biodiversity and ecosystem services so they must be implemented carefully (IPCC, 2019).

The aim of this assessment is to provide information on observed trends in a set of well-established bioclimatic indicators as an overview of climatic pressures within the MAES ecosystem assessments. Changes in climate are considered as a cross-cutting pressure in the present assessment, considering the fact that this pressure affects all ecosystems in the EU. Climate change metrics do not directly describe the responses of species and ecosystems to climatic changes, however they are often considered as first-order surrogates of the potential effects. They are important assessment tools as the measurement of the actual effects is extremely difficult due to the complexity of species and community dynamics (Garcia et al., 2014). Considering that climate impacts are well covered in other high level assessments, in particular in the regularly updated IPCC Assessment Reports (AR5: IPCC, 2014; AR6: scheduled for 2021), it is out of the scope of the current MAES ecosystem condition assessment to provide an analysis of the reciprocal impacts between climate and ecosystems.

The EU Biodiversity Strategy to 2020 (European Commission, 2011) acknowledged that the two most critical global environmental threats, biodiversity loss and climate change are inextricably linked. It emphasised that valuing nature's worth in climate change mitigation and adaptation through ecosystem-based approaches can contribute to the strategic objective of a more climate-resilient, low-carbon economy as a cost-efficient solution. Target 2 to maintain and restore ecosystems and their services was also aimed to help mitigate and adapt to climate change. The UN Biological Diversity, Climate Change and Desertification Conventions have also recognised the need for an integrated, coherent, multi-dimensional approach to address the effects of a changing climate (Join Statement of the Executive Secretaries of the Rio Conventions, 2017).

Ecosystem-based approaches to mitigate climate change or to adapt to its impacts rely on biodiversity and ecosystem services. Such approaches are included in mainstream climate change mitigation and adaptation strategies, including the EU strategies on Adaptation to Climate Change (2013) and Green Infrastructure (2013). The inventories of greenhouse gas emissions in the UN Framework Convention on Climate Change (UNFCCC) LULUCF (Land Use, Land-Use Change and Forestry) measure the contributions of ecosystems to climate change mitigation (Decision 14/CP.11). The LULUCF sector is included in the EU 2030 climate target under the Paris Agreement.

Also other policies relevant for ecosystems and ecosystem services address mitigation and adaptation to climate change. The EU Regulation on Invasive Species (2014) addresses the issue that climate change increases the risk of the introduction and spread of invasive species. Additionally, the direct relations between soil condition, soil biodiversity and climate change are considered in the Thematic Strategy for Soil Protection (2006). The effects of climate change has been taken into account in the management guidelines of the Natura 2000 sites (European Commission, 2013). Risks, vulnerability and adaptation potential of Natura 2000 species and habitats has been assessed and an adaptive management approach was proposed for the planning of conservation actions.

The Biodiversity Strategy for 2030 (European Commission, 2020) calls for transformative changes. It foresees improved legislation and implementation of policies, focus on efficient ways to improve the condition of ecosystems to enhance their ecosystem services including climate regulation, in line with the climate neutrality ambition of the European Green Deal. It announces that 25% of the EU climate action budget will be dedicated to biodiversity and nature-based solutions. As part of the European Climate Pack, the Commission will help to create a European Business for Biodiversity movement to promote nature-based solutions.

Changes in climate over time can be measured using a vast array of variables. In the domain of biodiversity conservation different indicators represent distinct dimensions of climate change, each with different implications and expected impacts. Bioclimatic indicators are categorised in two main groups, local and regional indicators (Garcia et al. 2014). The focus of this assessment is in local indicators that measure (bio)climatic state at the Earth surface, at specific locations over time.

The local bioclimatic indicators relevant for the EU-wide ecosystem assessment have been classified in three classes according to the classification of Garcia et al. (2014):

1. Climate means: the central tendencies of major climatic parameters determining ecological processes at a given location (e.g. mean annual temperature, precipitation, effective rainfall, soil water deficit).

2. Climate extremes: the magnitude or frequency of extreme climate events at a given location (e.g. drought frequency, number of summer days)

3. Climate seasonality: the relative or absolute timing of bioclimatic events (e.g. growing season length)

While ecosystems (or socio-ecological systems, in the case of anthropogenic ecosystem types) are in principle well adapted to the local prevailing climate conditions, changes in climate conditions represent pressures on them. They trigger changes in ecosystem condition in various ways as a consequence of changes in species distribution, species traits such as phenology, physiology and movement, community composition, and interactions between species (Cramer et al., 2014; IPBES, 2019). Accordingly, significant trends (downward or upward) in the selected indicators is the focus of this assessment. In the case of climate extremes, we considered only the upward trends (towards the more extreme) as a pressure on ecosystems.

In this assessment we selected the most widely used and relevant local indicators from the collections of the CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI) (Zhang et al. 2011), Bioclim (Nix 1986; Xu and Hutchinson 2011) and the European Drought Observatory (EDO, http://edo.jrc.ec.europa.eu/edov2, Table 4.1.1). The aim was to provide a short but complete set of easily understandable indicators. The selection criteria were thematic relevance, prevalence in biodiversity-related studies (more specifically in species distribution modelling, Barbet-Massin & Jetz, 2014) and availability. The selected indicators had to be available or calculable from available data.

Any selection of indices is arbitrary because each indicator represents specific features of climate change. Therefore, the set of selected indicators should not be seen as comprehensive. However, they provide complementary information about different dimensions of climate change. So, together they build a robust base of information for assessing climate drivers of change with implications for biodiversity and the condition of ecosystems.

In line with the overall objective of this report, the aim of this chapter is to determine and report the trends in the climatic pressures on ecosystems. It is important to stress that this assessment is primarily based on indicators for which European wide, harmonized datasets have been collected. Where needed more context is provided by citing to relevant literature. However, this chapter did not make a systematic review of the literature on pressures on biodiversity and ecosystems.

This chapter delivers the baseline data to establish a (legally binding) methodology for mapping and assessment of ecosystems and their capacity to deliver services and to determine the minimum criteria for good ecosystem condition of ecosystems as required by the new EU Biodiversity Strategy to 2030. Determining these criteria of ecosystems requires also agreeing on a reference condition against which the past or present condition can be evaluated. More work will be needed to determine the target and reference levels of pressure and condition indicators in agreement with stakeholders, scientists and policymakers.

4.1.2 Trends in climate indicators

4.1.2.1 Assessment at the level of EU-28

Trends for each indicator were calculated at EU-28 level (Table 4.1.1 and Figure 4.1.1-3) and at grid cell level (Figure 4.1.4-18) covering the whole terrestrial domain of the EU. To avoid bias in the trend analysis, some grid cells with incomplete data series were excluded from the E-OBS data analysis and the period 1985-2018 was selected from the MARS database (see Annex A).

For each indicator the annual value was calculated on each grid cell based on the algorithms shown in Table 4.1.2 in Annex B. Annual spatial data were used for detecting trends on each grid cell. We used robust regression to mitigate the effect of anomalous years. Regression slopes were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012) because it accommodates non-normal distributions and is a robust trend slope estimator resistant to the effects of outliers. Additionally, a two-sided Mann-Kendall (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test was used to assess the significance of monotonic trends.

At EU-28 level, the following indicators show a significant trend, therefore represent a major pressure on ecosystems based on the definition of pressure in the MAES framework: annual mean temperature, mean temperature of warmest and coldest quarter, effective rainfall, extreme drought event frequency, summer days and growing season length (Figure 4.1.1, Figure 4.1.2, Figure 4.1.3, Table 4.1.1). The rest of the indicators do not exhibit significant trends at EU-28 level, but for all indicators there are regions where they show a significant trend locally. The maps of Figures 4.1.4 to 4.1.18 show these regions for all of the studied indicators.

Table 4.1.1 Bioclimatic indicators for ecosystem condition assessment. Trends significant at α = 0.05 according to Mann-Kendall trend test. Fact sheet 4.1.101 contains all maps (Supplement of this report).

Class	Indicator	Range	Data source	Spatial resolution	Trend at EU-28 level
Climate means	Annual mean temperature (°C)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	Significant +0.325 °C/decade
	Mean temperature of warmest quarter (°C)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	Significant +0.311 °C/decade
	Mean temperature of coldest quarter (°C)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	Significant +0.350 °C/decade
	Annual precipitation (mm)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Precipitation of wettest quarter (mm)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Precipitation of driest quarter (mm)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Effective rainfall (mm)	1960–2016	PET: CRU TS 4.01. P: Full data monthly (v2018) GPCC DWD	0.5 degree (~43x43 km)	Significant -12mm/decade
Climate extremes	Extreme drought events frequency (number of extreme drought events in 5 years)	1950-2018	E-OBS (v 19.0e), EDO**	0.25 degree (~25x25 km)	Significant +0.017 events/decade
	Drought events frequency (number of drought events in 5 years)	1950-2018	E-OBS (v 19.0e), EDO**	0.25 degree (~25x25 km)	No significant trend
	Total drought severity (5 year- accumulated index)	1950-2018	E-OBS (v 19.0e), EDO**	0.25 degree (~25x25 km)	No significant trend
	Summer days (number of days where daily max. temp > 25 °C)	1985-2018	MARS database***	25x25 km	Significant +3.76 days/decade
	Soil moisture (soil water deficit)	1951-2013	E-OBS (v 19.0e), EDO (Cammalleri et al., 2016)	5x5 km	No significant trend (chart not available)
Climate seasonality	Growing season length (number of days)	1985-2018	MARS database***	25x25 km	Significant +5.46 days/decade
	Temperature seasonality (coefficient of variation [% of values in K])	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Precipitation seasonality (coefficient of variation [%])	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend

* https://www.ecad.eu/download/ensembles/download.php
** http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000
*** https://agri4cast.jrc.ec.europa.eu/DataPortal/

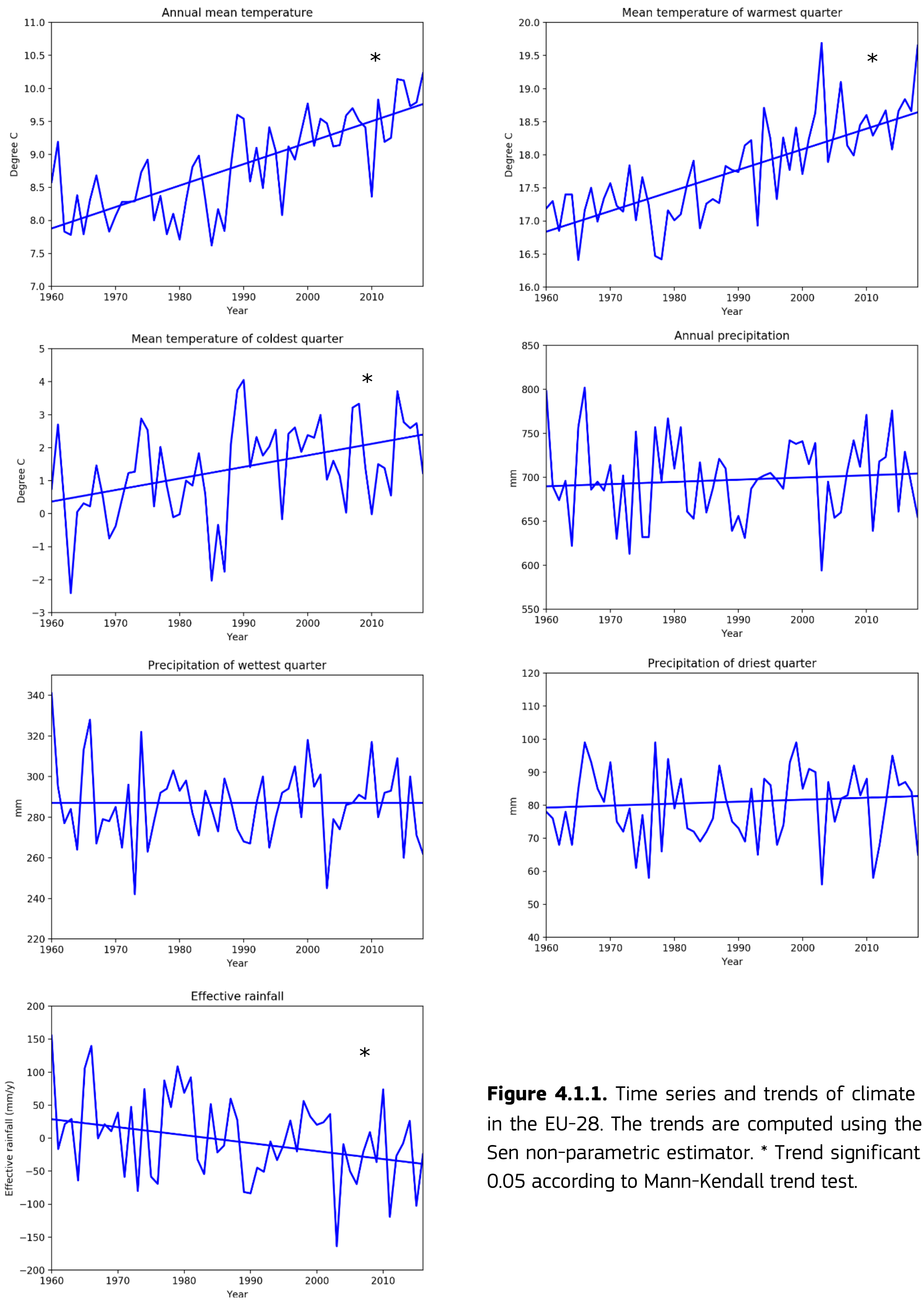


Figure 4.1.1. Time series and trends of climate means in the EU-28. The trends are computed using the Theil–Sen non-parametric estimator. * Trend significant at α = 0.05 according to Mann-Kendall trend test.

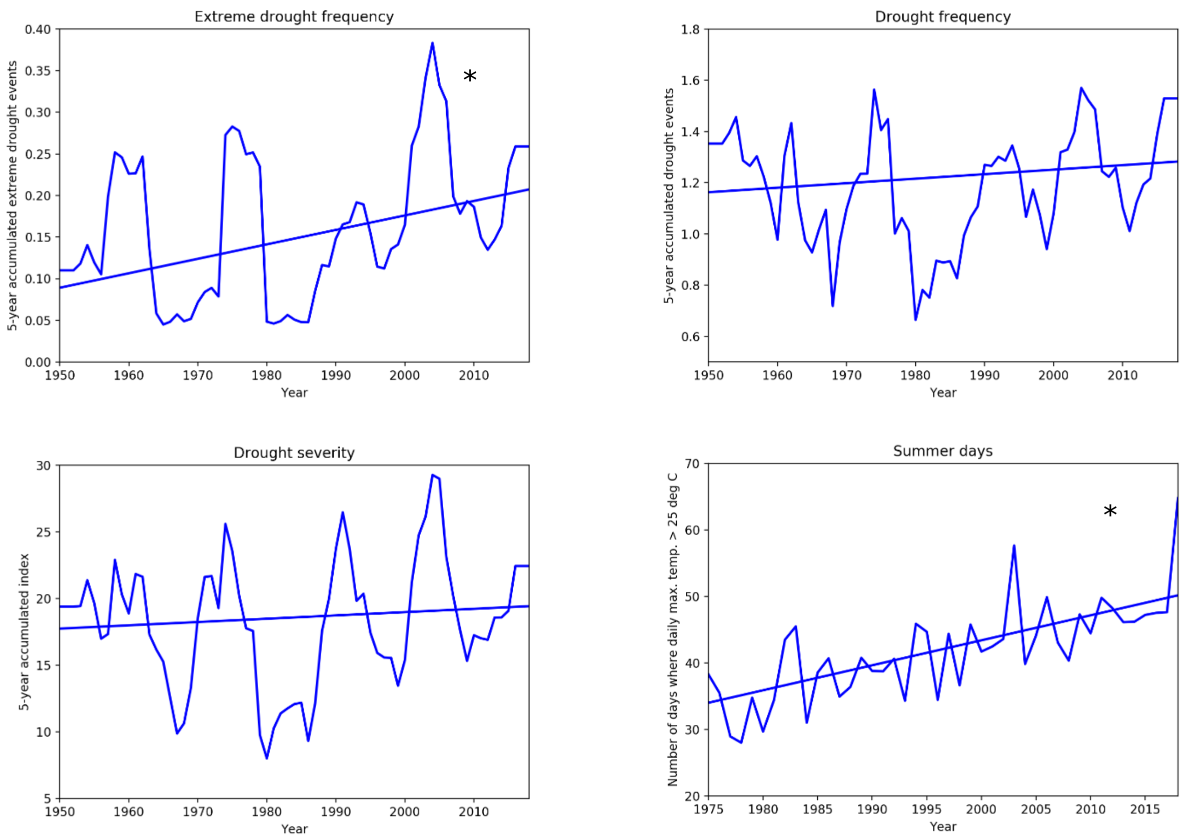
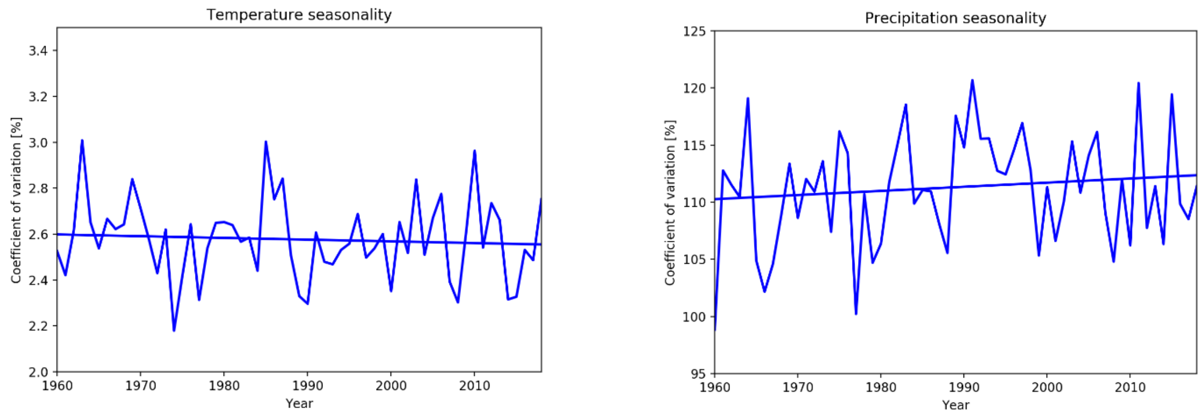


Figure 4.1.2. Time series and trends of climate extremes bioclimatic indicators in the EU-28. Trend line computed using the Theil–Sen non-parametric estimator. * Trend significant at α = 0.05 according to Mann-Kendall trend test.



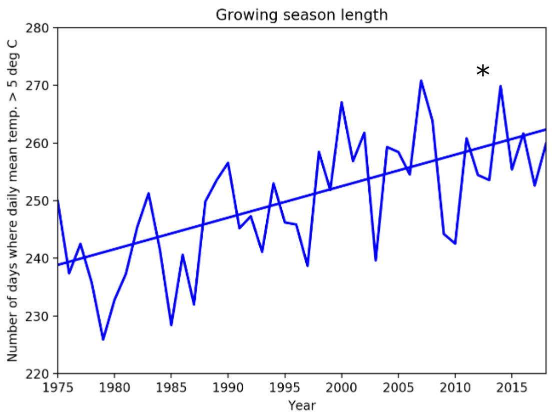


Figure 4.1.3. Time series and trends of climate seasonality bioclimatic indicators in the EU-28. Trend line computed using the Theil–Sen non-parametric estimator. * Trend significant at α = 0.05 according to Mann-Kendall trend test.

4.1.2.2 In-depth assessment

The definition of the indicators can be found in Annex B.

4.1.2.2.1 Trends in climate means

The annual and seasonal mean temperatures approximate the energy inputs available for ecosystems. The mean temperatures of these broad periods determine key physical processes for all organisms. Annual and seasonal temperatures are among the most important climatic factors shaping species distributions.

The annual mean temperature has been increasing significantly in virtually all the EU-28 land (Figure 4.1.4). The non-significant changes in Bulgaria and Greece seem to be caused by inconsistencies in the baseline data. In fact, the annual mean temperature time series of the MARS climate database (1975-2018) suggest a significant temperature increase in these areas.

The mean temperature of warmest quarter has been increasing significantly almost in the entirety area of the EU-28, some patches exhibiting not significant changes are mainly in Northern Europe (Figure 4.1.5). The change is more pronounced in some areas of Central and Southern Europe.

The mean temperature of coldest quarter has also been increasing in almost the entirety of the EU-28 domain. However, areas exhibiting no significant changes are more prominent (Figure 4.1.6) than in the case of the mean temperature of the warmest quarter. Yet, the share of areas without significant changes is still rather small. Higher upward trends are evidenced in Northern and Eastern Europe, as well as South Italy.

Annual precipitation describes the total water input to an ecosystem. Together with temperature, the annual and seasonal distributions of precipitation define part of the environmental space of all animal and plant species. Therefore, precipitation is among the most important factors shaping species distributions.

Trends of annual precipitation are regionally differentiated in Figure 4.1.7. Upward trends are exhibited mainly in some areas of Northern Europe, the Alpine region and the British Islands. Downward trends are observed mainly in some areas of the Mediterranean region and Central Europe. It is remarkable a large share of the EU-28 area exhibiting no significant changes.

A decrease in precipitation in the wettest quarter, when ecosystems are normally recharged with water, can reduce the capacities to cope with the dry period and thus pose a major pressure on ecosystems. Significant changes in precipitation of the wettest quarter affected less areas than changes of annual precipitation (Figure 4.1.8). Following a similar pattern as the trends of annual precipitation, the direction of the change was upward mainly in Northern Europe and in the Alpine region and downward in areas of the Mediterranean region and Central Europe. More areas are affected by downward than upward trend.

Changes in the precipitation of the driest quarter (Figure 4.1.9) follow a similar pattern in some areas as the precipitation of the wettest quarter. While significant declines dominate for the wettest quarter precipitations, for the dry seasons a significant increase was observed more frequently than a significant decrease. Downward trend can be observed mainly in Southern Europe. The upward trends found mainly in Northern Europe can shorten the period without wetness and excess water, which like any change in the major biophysical limiting factors can be seen as a pressure.

Effective rainfall is the difference between mean annual precipitation and mean annual potential evapotranspiration (Figure 4.1.10). It is considered an index of plant productivity, where values below zero indicate that evaporative demands exceeds precipitation and values above zero that precipitation exceeds evaporative demands. Therefore, the amount of effective rainfall indicates the degree of water deficiency at a given location. The productivity of terrestrial biological systems is related to available moisture, which in turn is linked to the balance of local rainfall and evaporative demand. Downward trends of effective rainfall are exhibited mainly in Southern Europe and in some areas of Central Europe. Upward trends are evidenced in some areas of Northern Europe and in Sicily.

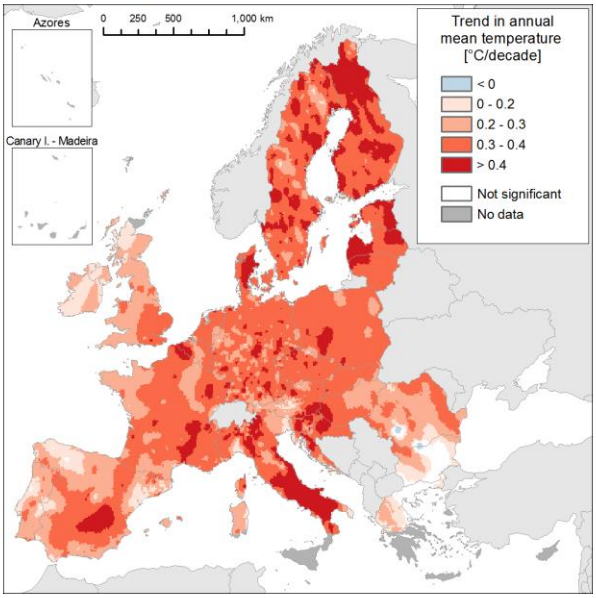


Figure 4.1.4. Trends in annual mean temperature 1960-2018 (significant at α = 0.05 level according to the Mann-Kendall test).

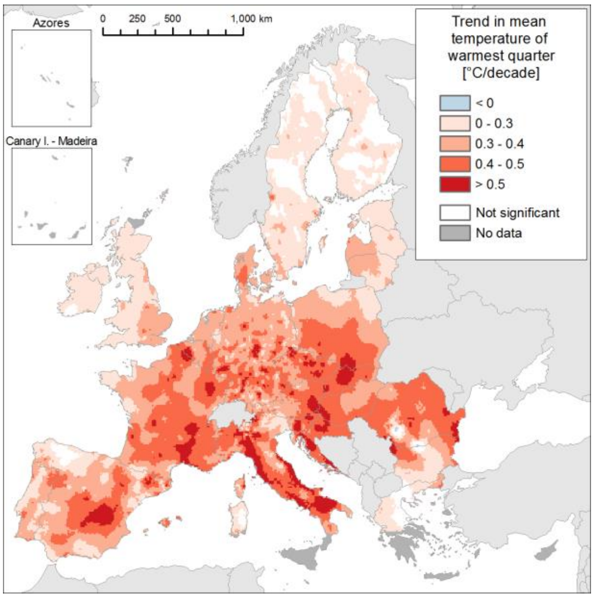


Figure 4.1.5. Trends in mean temperature of warmest quarter 1960-2018 (significant at α = 0.05 level according to the Mann-Kendall test).

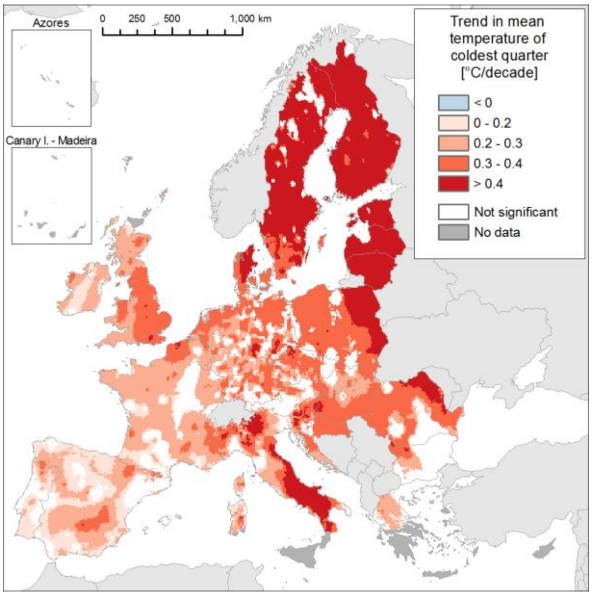


Figure 4.1.6. Trends in mean temperature of coldest quarter 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

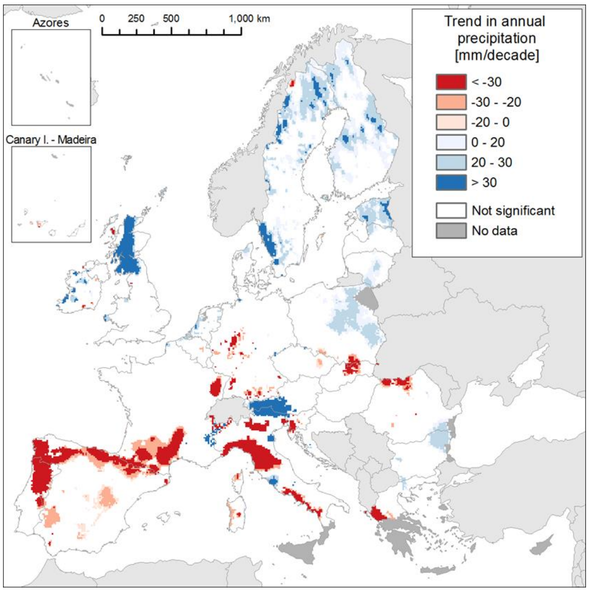


Figure 4.1.7. Trends in annual precipitation 1960-2018 (significant at α = 0.05 level according to the Mann-Kendall test).

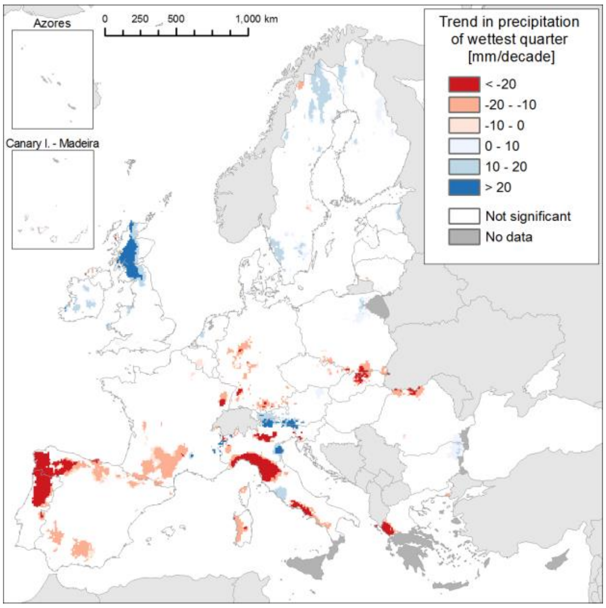


Figure 4.1.8. Trends in precipitation of the wettest quarter 1960-2018 (significant at α = 0.05 level according to the Mann-Kendall test).

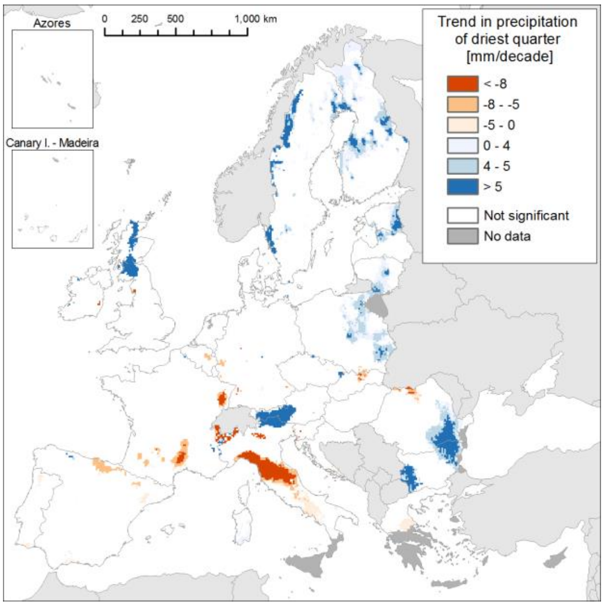


Figure 4.1.9. Trends in precipitation of the driest quarter 1960-2018 (significant at α = 0.05 level according to the Mann-Kendall test).

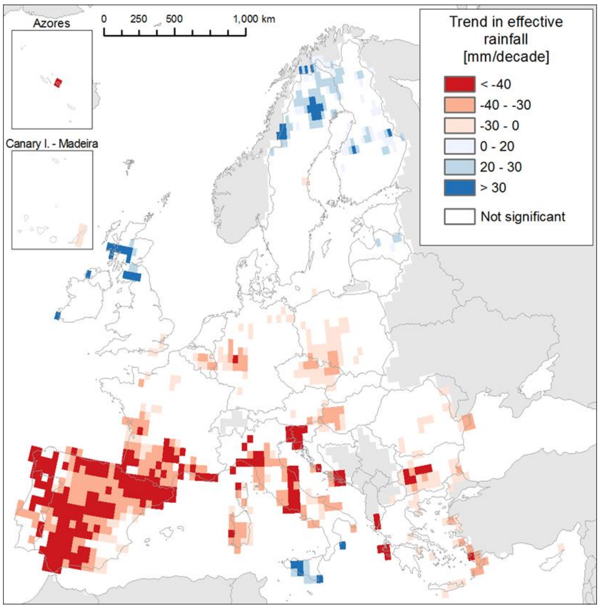


Figure 4.1.10. Trends in effective rainfall 1960-2016 (significant at α = 0.05 level according to the Mann-Kendall test)

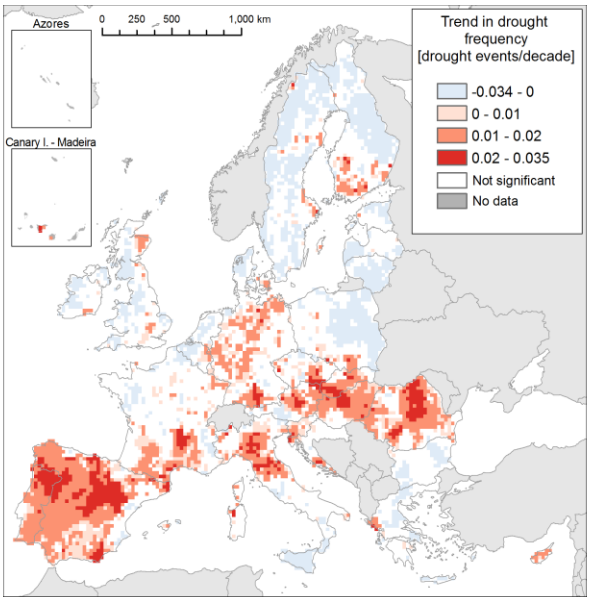


Figure 4.1.11. Trends in drought frequency for 1950-2018 (significant at α = 0.05 level according to the Mann-Kendall test). Blue areas in this map are not considered as a pressure.

4.1.2.2.2 Trends in climate extremes

A meteorological drought is an extreme event with an anomalous precipitation deficit compared to long-term average conditions. Trends in the frequency and severity of drought events are used to assess pressures of extreme events on biodiversity and ecosystems, specifically lack of precipitation and drying effects of rising temperatures. Drought events were defined based on the Standardised Precipitation-Evapotranspiration Index (SPEI). SPEI is one of the most widely used indices to describe climatological droughts. It takes into account not only precipitation but also potential evapotranspiration.

The frequency of drought events (climatological drought condition for at least 2 months, SPEI < -1) have been increasing in large areas of the Mediterranean, Central and Eastern European parts of the EU-28 (Figure 4.1.11). In contrast, the frequency has been decreasing in other areas of Southern and Northern EU. Drought is a rare event, the frequency of drought events was found to be between 0 and 5 per 5 years in the EU-28, the average over the whole period is 1.19 event per 5 years.

The frequency of extreme drought events (extreme climatological drought condition for at least 2 months, SPEI < -2) exhibits upward trends in the Mediterranean, Central and Eastern Europe, but also in some Northern areas of the EU-28 (Figure 4.1.12). Downward trends are evident in some areas of Northern Europe, British Islands and some areas of Eastern EU.

Upward trends of drought severity are evident mainly in the Mediterranean, Central and Eastern EU-28 regions. The spatial pattern of the trends is similar as that of drought frequency, but occurring in larger area of the EU-28 (Figure 4.1.13). However, changes in drought severity are not significant in some areas with significant upward trends in drought frequency. Downward trends of drought severity are shown in large areas of Northern Europe, the British Islands and Poland.

Summer days are usually defined as the days where the daily maximum temperature goes above 25 °C. The number of such days can indicate the impact of heat stress on ecosystems. The number of summer days has been increasing in the EU, especially in Southern and Eastern Europe. However, upward significant changes are also evidenced in Central Europe and in some parts of Northern Europe (Figure 4.1.14).

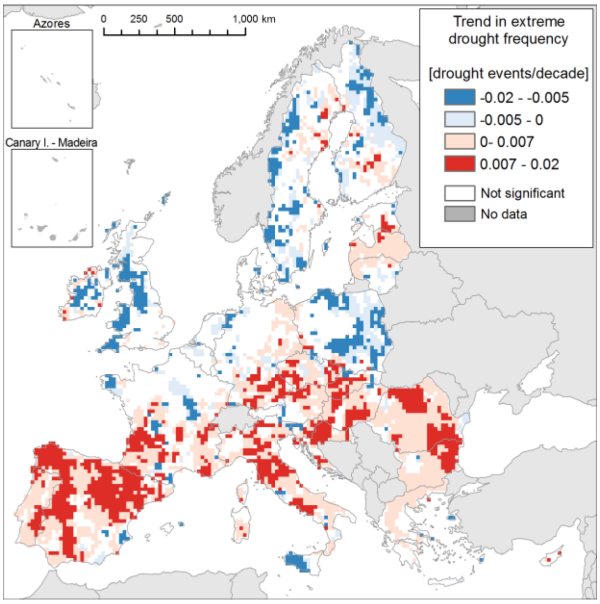


Figure 4.1.12. Trends in extreme drought frequency 1950-2018 (significant at α = 0.05 level according to the Mann-Kendall test). Blue areas in this map are not considered as a pressure.

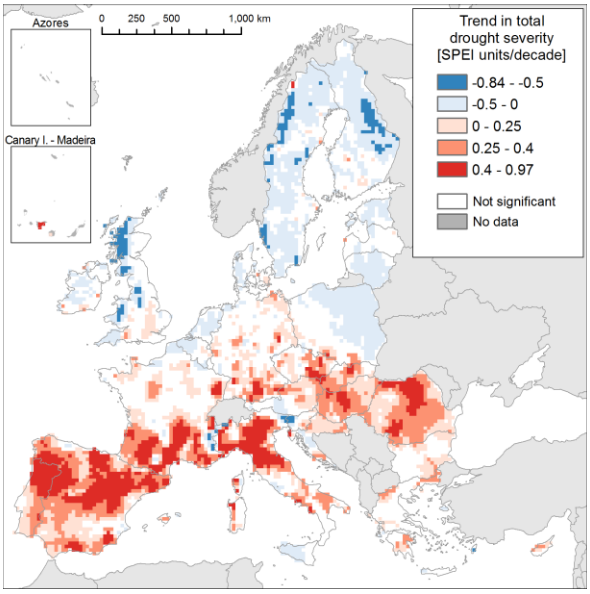


Figure 4.1.13. Trends in drought severity 1950—2018 (significant at α = 0.05 level according to the Mann-Kendall test). Blue areas in this map are not considered as a pressure.

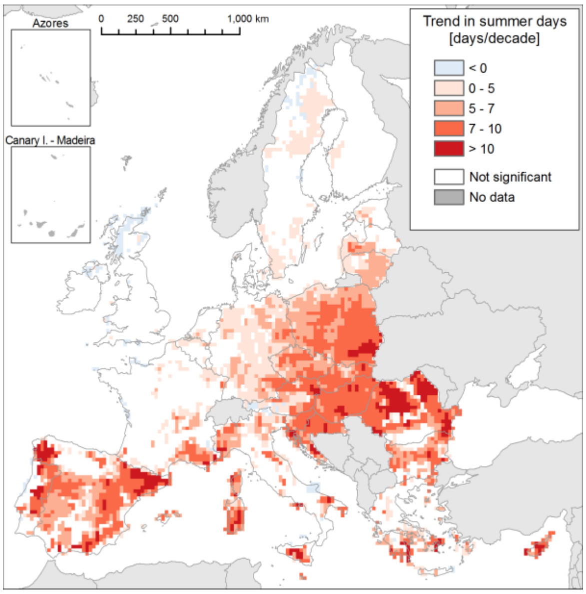


Figure 4.1.14. Trends in summer days (days with daily maximum temperature > 25 °C) 1985-2018 (significant at α = 0.05 level according to the Mann-Kendall test). Blue areas in this map are not considered as a pressure.

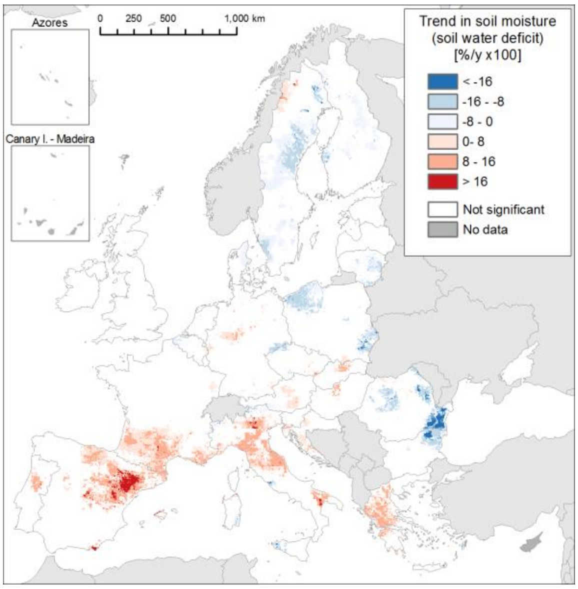


Figure 4.1.15. Trends in soil moisture deficit 1985-2018 (significant at α = 0.05 level according to the Mann-Kendall test). Blue areas in this map are not considered as a pressure.

Soil water deficit is a synthetic descriptor of the amount of water actually available to plants for their primary processes. Thus, it can be considered an important parameter influencing the condition of ecosystems in the long term. The central role of soil moisture as feedback into the atmospheric system, as well as a key environmental variable in the terrestrial biosphere, suggests that its analysis can provide relevant synthetic information on the hydrological balance. Soil moisture deficit (Figure 4.1.15) has been decreasing (soil getting less dry) in some Northern and Eastern areas and increasing (drier soils) in some Southern and Central European areas of the EU-28 (Cammalleri et al., 2016).

4.1.2.2.3 Trends in climate seasonality

The thermal growing season refers to the period of the year when temperature permits plant growth. Growing season length is defined as the number of days in a year above a base temperature (5°C). This metric can be used to assess the pressure resulting from changes in temperature seasonality on ecosystems and species distribution, as well as the agricultural sector.

There is a significant upward trend in growing season length in areas of South-Eastern Europe, the Mediterranean, Atlantic and Boreal regions (Figure 4.1.16).

Temperature seasonality describes the degree of changes in weekly mean temperatures over the course of a year. The larger the value of the indicator, the more fluctuating the temperature of a location is. Species need to adapt to intra-annual seasonality, which makes this indicator highly relevant for ecosystems and species distributions. Significant upward trends of temperature seasonality are observed in areas of Southern Europe, Romania and Bulgaria. In contrast, downward trends are evidenced in Northern Europe (Figure 4.1.17). Upward trends of temperature seasonality suggest greater variability of weekly temperature within the year, and downward trends less variability, i.e. more homogeneous weekly temperature across the year (see Table 4.1.2 in Annex B).

Precipitation seasonality describes the degree of changes in weekly precipitation over the course of a year. The larger the value of the indicator, the more variable the precipitation of a location is. Species need to adapt to intra-annual seasonality also in precipitation, which makes this indicator highly relevant for ecosystems and species distributions. Significant upward trends of precipitation seasonality (rains becoming more variable) are observed in areas of Southern and Eastern Europe. In contrast, downward trends (more even distribution of precipitation) are exhibited in some areas of northern Europe (Figure 4.1.18) (see also Table 4.1.2 in Annex B).

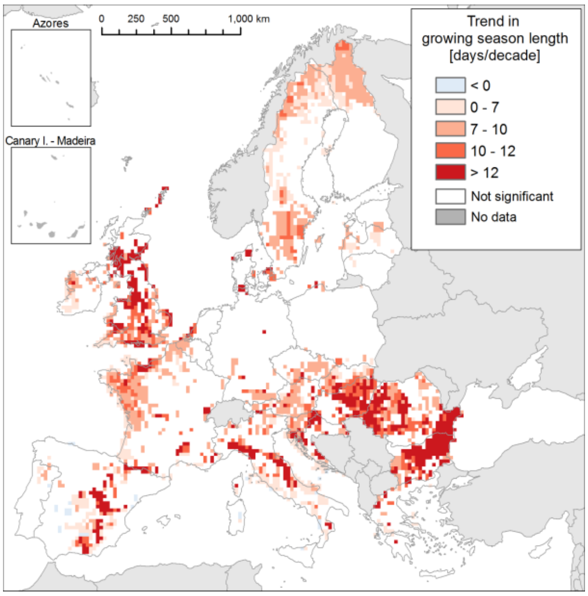


Figure 4.1.16. Trends in growing season length 1985-2018 (significant at α = 0.05 level according to the Mann-Kendall test).

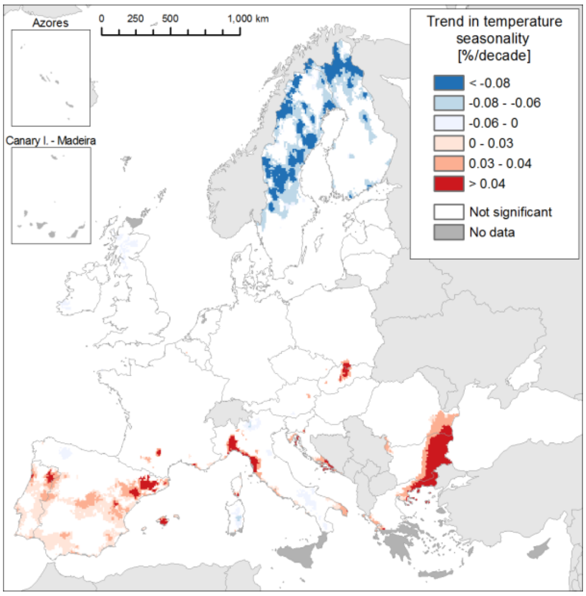


Figure 4.1.17. Trends in temperature seasonality (coefficient of variation [%] – Temperature in °K) 1960—2018 (significant at α = 0.05 level according to the Mann-Kendall test).

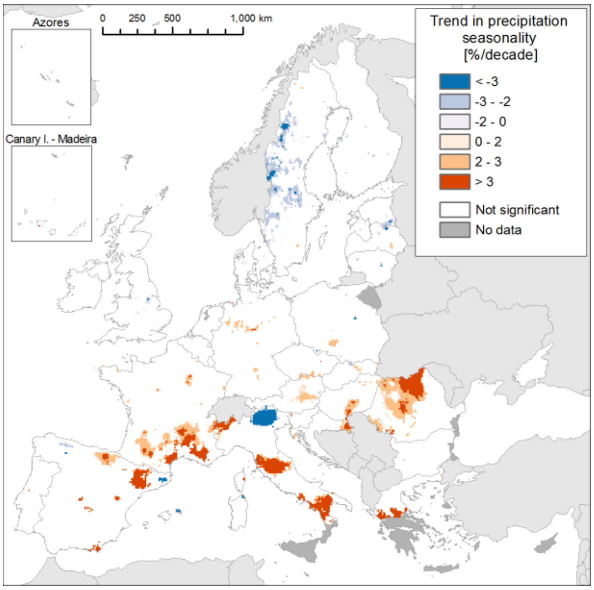


Figure 4.1.18. Trends in precipitation seasonality (coefficient of variation [%]) 1960—2018 (significant at α = 0.05 level according to the Mann-Kendall test).

4.1.3 Integrated assessment of bioclimatic indicators

The share of EU-28 terrestrial area where each of the 15 bioclimatic indicator showed a significant trend was calculated taking into consideration no-data areas (Figure 4.1.19). Climatic changes are considered to pose pressure on ecosystems in these areas according to the definition of pressure in the MAES framework. EU-28 area covered with data was 89% for most indicators (E-OBS data), 97% for summer days and growing season length (MARS data), and 100% for effective rainfall and soil moisture.

The indicators of mean temperatures revealed significant pressure in almost the whole EU-28 area (82-97% of area covered by available data), whereas the precipitation-related indicators represent climatic pressures in 13-25% of the area. Effective rainfall, which incorporates both precipitation and temperature (through evapotranspiration) has been changing significantly in 26% of the area. Pressures posed by a significant increase in extreme climate events affect 9-47% of the EU-28 area, whereas seasonality has been changing significantly in 10–31% of the area. In summary:

- Almost the total EU-28 area is affected by climatic pressures due to changes in the temperature regime,
- Around half of the area is affected by pressures caused by an increase in extreme climate events,
- Around one-third of the area is affected by pressures due to changes in seasonality, and
- One-quarter of the EU-28 area is affected by pressures related to changes in precipitation or available water.

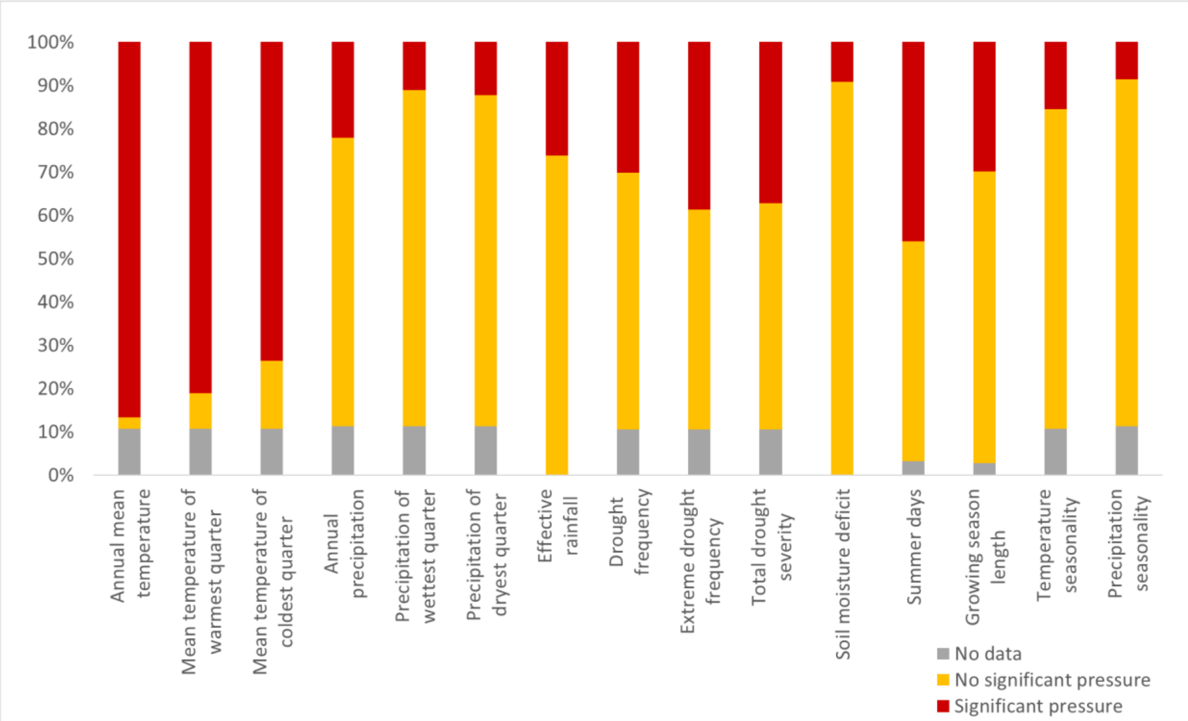


Figure 4.1.19. Share of area (%) affected by climatic pressures within the EU-28 territory based on the trends in 15 bioclimatic indicators (significant pressure), share of area with no significant pressure and with no data.

Additionally, the number of indicators representing significant pressure was mapped on 10 km grid cells from the individual trend maps of the bioclimatic indicators. This was done separately for the three indicator types and also integrating all the 15 indicators. The results show that changes in climate means affect the whole EU-28 territory (Figure 4.1.20). Increases in climate extremes affect mostly Southern and Central-Eastern Europe (Figure 4.1.21). Changes in seasonality affect mostly Southern, Central-Eastern and some parts of Northern Europe (Figure 4.1.22). Western EU-28 seems to be slightly less affected by the climatic pressures. In summary, 38% of the EU-28 land area is affected by at least seven climatic pressures out of the 15, half of the area by 4-6 climate pressures, and the remaining 12% by three to one (Figure 4.1.23 and Figure 4.1.24).

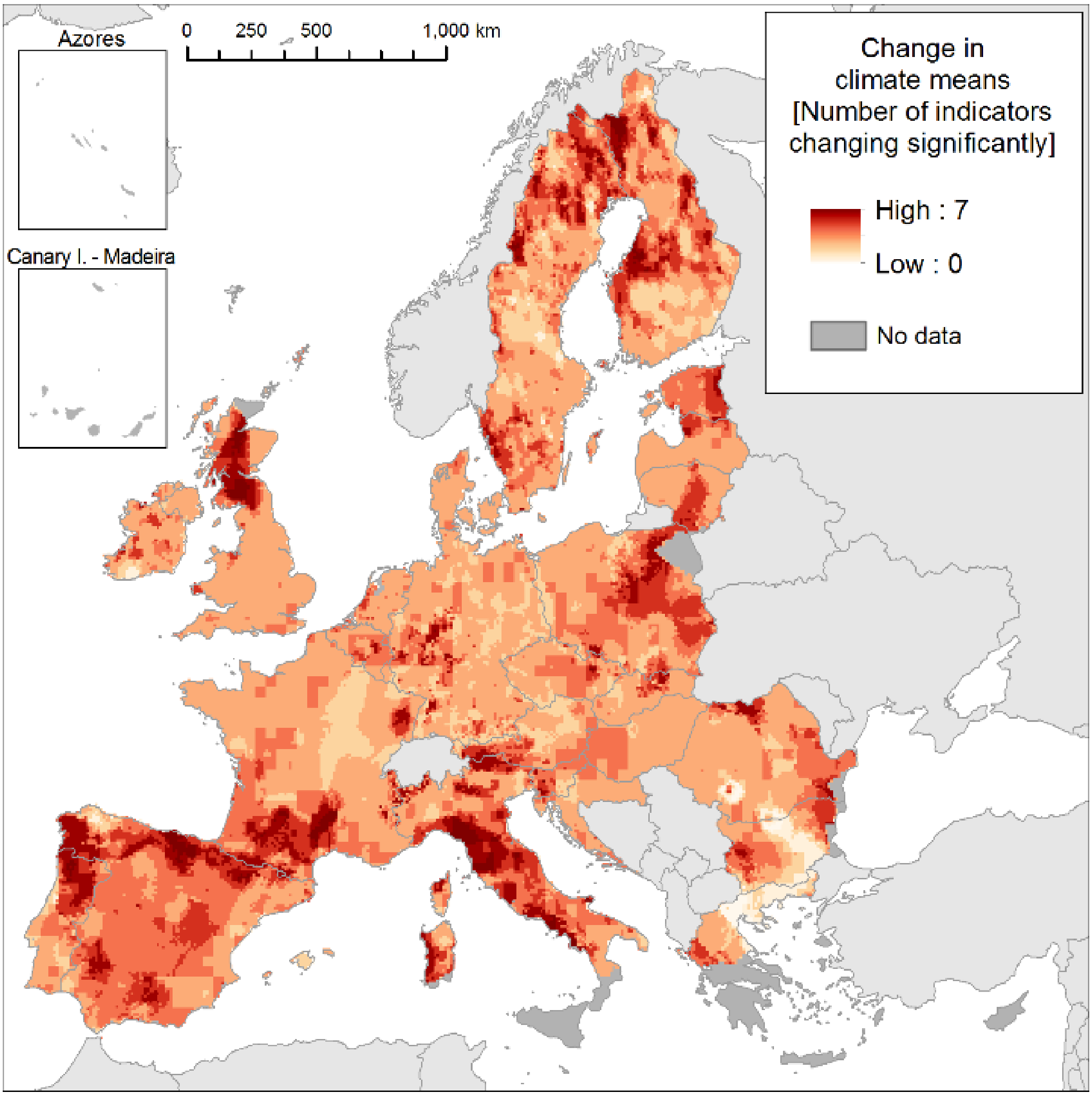


Figure 4.1.20. The number of bioclimatic indicators (climate means indicators) that pose a significant pressure on ecosystems and biodiversity.

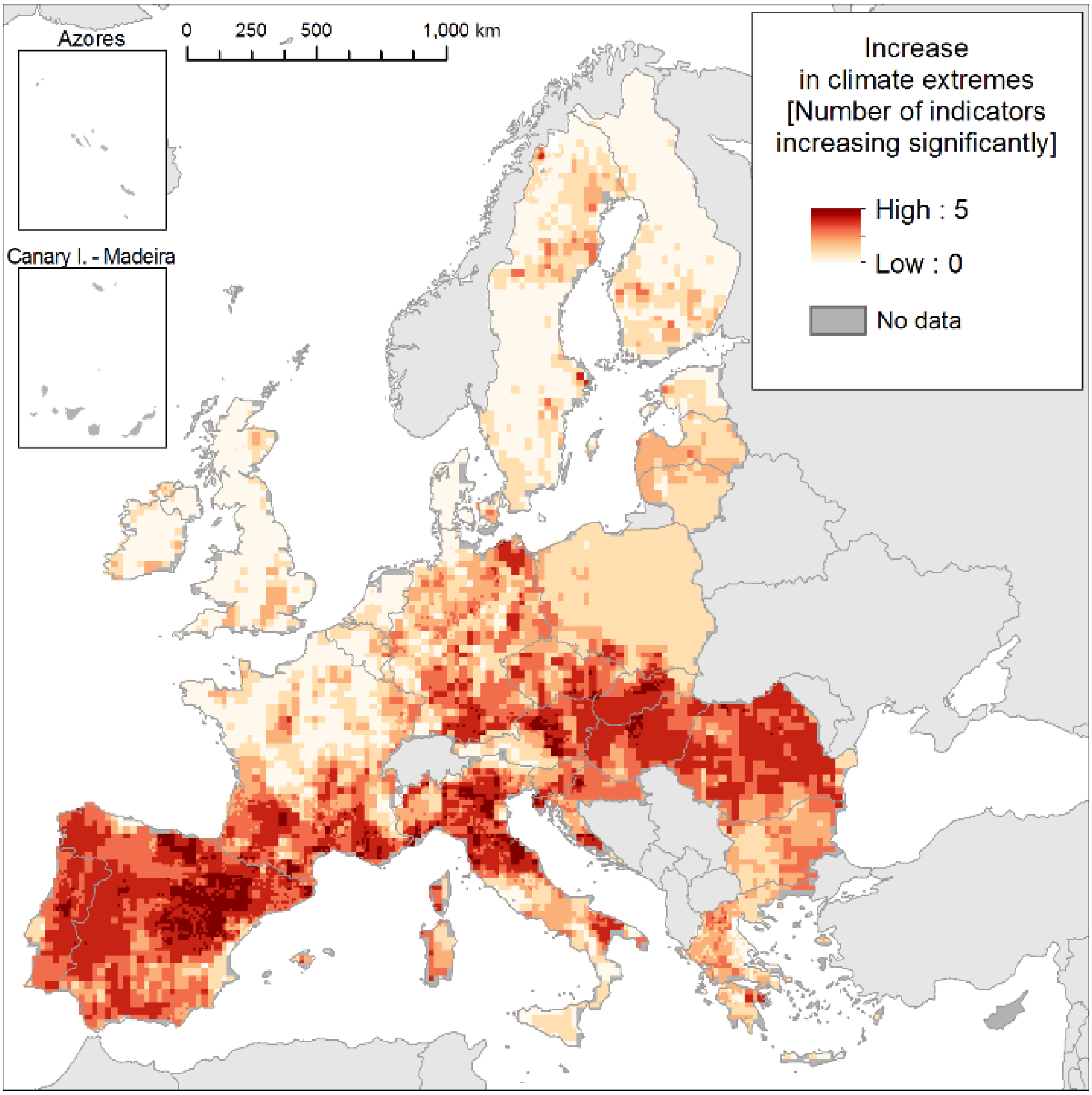


Figure 4.1.21. The number of bioclimatic indicators (climate exteme indicators) that pose a significant pressure on ecosystems and biodiversity.

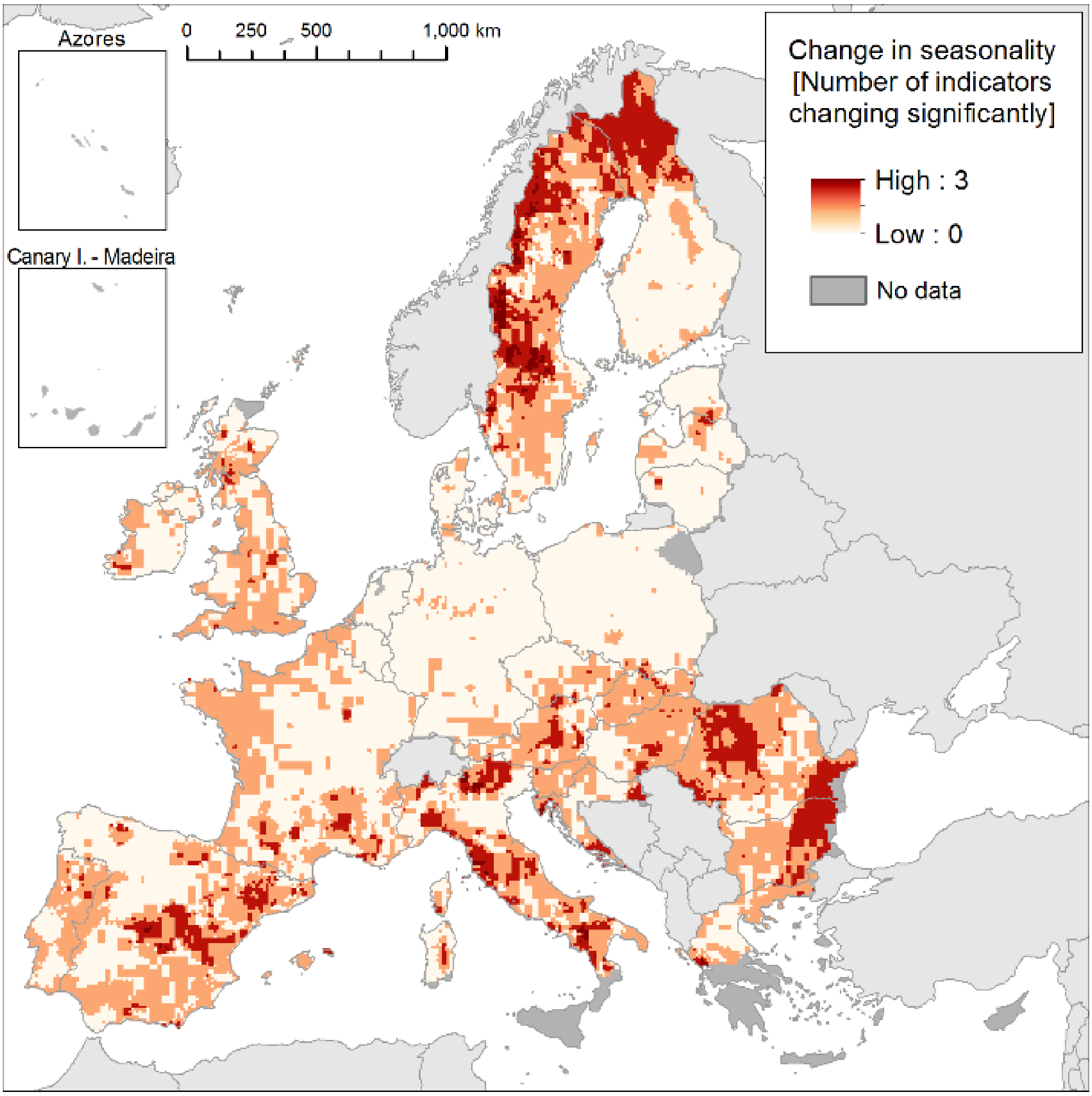


Figure 4.1.22. The number of bioclimatic indicators (climate seasonality indicators) that pose a significant pressure on ecosystems and biodiversity.

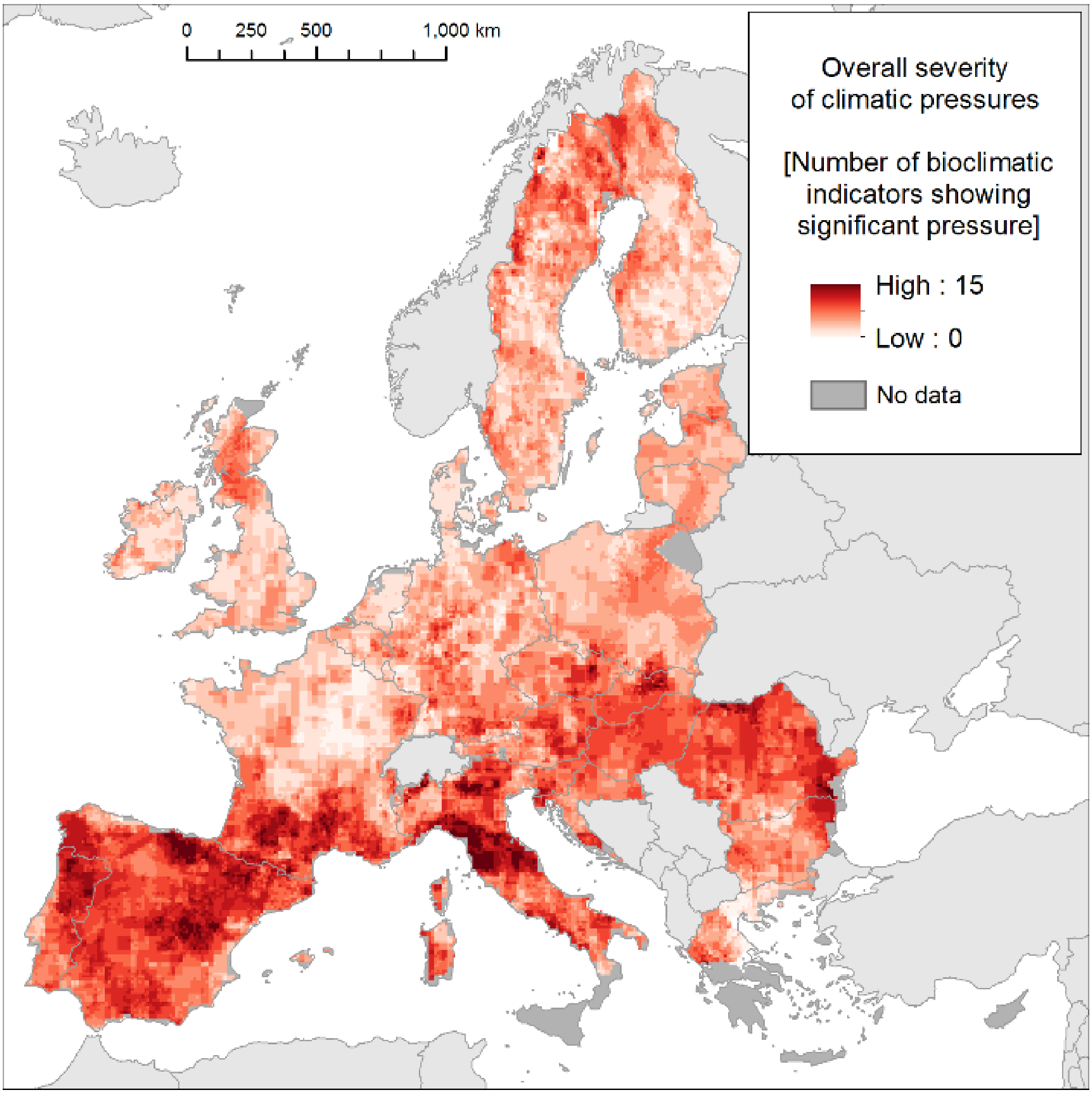


Figure 4.1.22. The number of bioclimatic indicators (all indicators) that pose a significant pressure on ecosystems and biodiversity.

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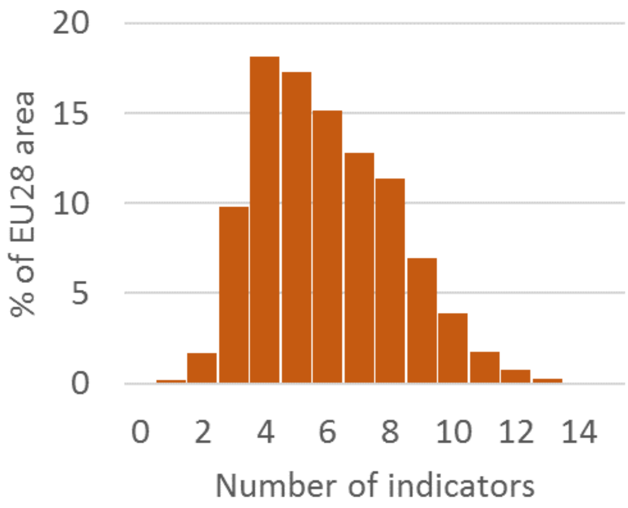

Figure 4.1.24. Share of the EU-28 area in relation with the number of bioclimatic indicators exhibiting statistically significant trends regarded as a pressure. For example, the value of 10 as the number of indicators on the x axis points to the percentage of EU-28 area affected by significant trends in 10 indicators.

4.1.4 Knowledge gaps and future research challenges

There is a huge demand from policy makers and the public in Europe to have robust information about the already observed impacts of climate change and related risks. Long-term climate data is available in Europe especially for the simpler indicators, despite they are affected by uncertainties mainly due to statistical interpolation, inconsistencies and urbanisation (van der Schrier et al., 2013). Availability and accessibility of the data is improving and there is an increasing demand for open access platforms to ease the processing of climate data that can be handled more easily by a wider range of researchers, including those from the environmental and biodiversity field.

The challenge to detect and especially to attribute effects of climate change on ecosystems remains a relevant area of research, and the knowledge regarding the mechanisms involved in changes of natural systems is still limited (Stone et al., 2013). The IPCC Working Group II (WGII, "Impacts, Adaptation and Vulnerability") provide comprehensive assessments on regular basis, which enumerate the impacts already observed and help to understand the associated risks. There is a large body of evidence on climate-induced changes in the ecosystems, however more studies are needed to have a comprehensive understanding of the cascading impacts of climate change on ecosystem functioning, condition, and services (Settele et al., 2014; Cramer et al., 2014). A systematic overview of the potential and ongoing impacts of climate change on ecosystem condition is particularly missing, and the concept of ecosystem condition has not been integrated into the works of the climate impact assessment community yet. Studies that can identify the most relevant climatic parameters for different ecosystem types can also help to create a more consistent and streamlined representation of climatic pressures in future ecosystem assessment and accounting studies.

A further research challenge is to explore the interactions between climate and other pressures. Adaptation and mitigation measures can also have negative impacts on ecosystems, creating new pressures or exacerbating existing ones (e.g. a large-scale implementation of "negative emission technologies" can result in widespread land use change, IPCC, 2019). Climatic pressure impacts ecosystems in a complex manner, including dynamic feedbacks and interactions between the various drivers (e.g. land use, management practices) varying in space and time (Stone et al., 2013; Runting et al., 2017). Therefore, the identification of interconnections and a more integrated approach for modelling is needed, which enables the joint analysis of the climate, the natural, and the human systems. Such models connecting will lay more focus on ecosystem condition and services, which can be seen as the fundamental link between nature and society. Luckily, both IPCC and IPBES are actively encouraging the development of these multidisciplinary modelling approaches that bridge natural and socio-economic domains, policy sectors, biomes, and scientific disciplines (Jia et al., 2019).

Additionally, it is also important to understand the susceptibility, resilience of ecosystems, the ways they react to pressure, adapt to or limit its impacts. Habitat suitability models provide a mechanistic understanding of the likely changes in the distribution of species. However, a functional understanding (e.g. including trophic relations) is needed for a more comprehensive picture. Ecosystems and species respond to climatic changes in multiple and complex ways (Jetz, 2019). Nevertheless, simple, policy relevant indicators, reflecting a good understanding of the responses have yet to be developed (Czúcz et al., 2011; Timpane-Padgham et al., 2017). This type of knowledge can provide a more robust basis to the design of actions aimed to mitigate the impacts and to restore degraded ecosystems.

Concerning possible adaptation and mitigation actions, there are knowledge gaps about the applicability and efficacy of certain actions. Furthermore, synergies and trade-offs between different options are not always well known. Anticipation and evaluation of interrelationships between possible actions and knowledge gaps can help to analyse costs and benefits and support evidence-based policy making (IPCC, 2019).

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Annex A. Data sources used in the chapter on climate change

The observational climate databases used to derive the indicators are the following:

E-OBS

• Data holder: EU-FP6 project UERRA (http://www.uerra.eu) and the Copernicus Climate Change Service, and the data providers in the ECA&D project (https://www.ecad.eu)

• Weblink: http://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php

• Time-series range: 1950 – 2018

• Version: 19.0e

• Access date: 20/03/2019

E-OBS ensemble version 19.0e (Cornes et al. 2018) at 0.1 degree horizontal resolution was sourced from the EU-FP6 project UERRA and the Copernicus Climate Change Service, and the data providers in the ECA&D project. E-OBS is a European high-resolution gridded daily data set of surface mean temperature, minimum temperature, maximum temperature, precipitation sum and averaged sea level pressure. E-OBS covers the land areas within 25–75°N latitude and 40W–75°E longitude.

E-OBS contains gridded meteorological data interpolated and error-corrected from observations of the national meteorological observational networks. It is a comprehensive database of observational climate in Europe that is widely used by a large number of research organisations and projects. However, a number of limitations have been documented in the literature. We present here a summary of these limitations. Cornes et al. (2018) and Spinoni et al. (2017) indicate that some temporal changes computed with E-OBS are likely attributable to inhomogeneities in the reference stations rather than particular changes in the gridded data. In light of this, they suggest that caution should be used when using the E-OBS data set. Similarly, Spinoni et al. (2017) indicate that some grid cells of E-OBS can be derived from non-homogeneous station data. Nevertheless, quality checks on the monthly series performed by Spinoni et al. (2017) indicate that only a minor fraction (0.7%) of monthly data grid cells did not pass all the tests. The "problematic" grid cells were mainly located in the Scandinavian Mountains and Latvia.

CRU TS

• Data holder: University of East Anglia

• Weblink: http://doi.org/10/gcmcz3, https://crudata.uea.ac.uk/cru/data/hrg/

• Time-series range: 1950 – 2016

• Version: 4.01

• Access date: 20/03/2019

The CRU TS database contains historical data that originates from observational datasets (Harris et al., 2014). It uses globally available observational datasets derived from the Climate Research Unit (CRU) of the University of East Anglia. These datasets are widely accepted as reference datasets in climate research. CRU provides gridded historical datasets derived from observational data and provides quality-controlled temperature and rainfall data as well as derivative products including monthly climatologies and long term historical climatologies. Historical trends use CRU data to quantify changes in the annual mean temperature and annual total precipitation, for the period from 1901 to 2016. Historical data are derived from 3 sources, all quality controlled by leading institutions in the field.

GPCC DWD (Full data monthly v2018)

• Data holder: Deutscher Wetterdienst (DWD)

• Weblink: https://www.dwd.de/EN/ourservices/gpcc/gpcc.html

• Time-series range: 1891 – 2016

• Version: Full Data Monthly v2018

• Access date: 20/05/2019

Gridded monthly data of precipitation at 0.5 degree (1891-2016) was sourced from the Full Data Monthly product version 2018 provided by the Global Precipitation Climatology Centre (GPCC) of the Deutscher Wetterdienst (DWD). Version 2018 was created by merging in situ time-series of rain gauge data based on more than 53,000 stations globally. This dataset has been widely used in many applications and is an accepted reliable data.

MARS

• Data holder: European commission, Joint Research Centre (JRC)

• Weblink: https://agri4cast.jrc.ec.europa.eu/DataPortal/

• Time-series range: 1985 – 2018

• Access date: 20/05/2019

The MARS meteorological database contains gridded meteorological data on maximum air temperature (°C), minimum air temperature (°C), mean air temperature (°C), mean daily wind speed at 10m (m/s), vapour pressure (hPa), sum of precipitation (mm/day), potential evaporation from a free water surface (mm/day), potential evapotranspiration from a crop canopy (mm/day), potential evaporation from a moist bare soil surface (mm/day), total global radiation (KJ/m2/day), snow depth. The parameters are interpolated from weather station data on a 25 x 25 km grid. The data is available on a daily basis from 1975 up to near real time, covering the EU-28 Member States, neighbouring European countries and the Mediterranean countries. In the present assessment the MARS data series starting from 1985 is used to avoid potential inhomogeneities that can lead to uncertainties in the trend analysis.

Annex B. Methodology (chapter climate change)

The definition and approach for computing the indicators used in the ecosystem assessment are shown in Table 4.1.2.

Table 4.1.2. Bioclimatic indicators. Definition and interpretation according to O'Donnell and Ignizio (2012), Xu and Hutchinson (2011), and Cammalleri et al. (2016).

Metrics	**Definition and interpretation**
Annual mean temperature (°C)	For computing annual mean temperature the average temperature for each month is averaged across the year.
Mean temperature of warmest quarter (°C)	To calculate this metric, first the warmest quarter of the year, i.e. consecutive 13 weeks was identified and then the average temperature for the 13 weeks in the warmest quarter was calculated.
Mean temperature of coldest quarter (°C)	The same as previous but for the coldest quarter.
Annual precipitation (mm)	This metric is the sum of total precipitation across the year.
Precipitation of wettest quarter (mm)	To calculate this metric we first identified the quarter with the highest cumulative precipitation of the year, i.e. consecutive 13 weeks. We then calculated the cumulative precipitation for the 13 weeks in the quarter.
Precipitation of driest quarter (mm)	The same as previous but for the driest quarter.
Effective rainfall (mm)	Effective rainfall is the difference between mean annual precipitation and mean annual potential evapotranspiration (PET). PET was sourced from the CRU TS dataset (see method in Harris et al. 2014).
Drought frequency (DRF)	Drought events were defined based on the Standardised Precipitation-Evapotranspiration Index (SPEI). SPEI was computed for 12-month accumulation periods. It means that the sum of 12 monthly values of difference (actual months and 11 months before) were compared to the long-term values. SPEI is in units of standard deviation from the long-term mean. A drought event happens when the SPEI is below -1 for at least 2 months. The period starts when the SPEI falls below -1. It ends when SPEI returns back above zero, so the recovery period is included. The number of drought events in 5 years was calculated using a 5-year moving window.

	The initial input data was E-OBS daily grids (Haylock et al., 2015a, 2015b) of temperature and precipitation. PET was calculated with Hargreaves method as the available data were not sufficient to calculate Penman-Monteith PET. So, PET is driven by temperature only. Monthly values were calculated from the daily data for the calculation of SPEI. The results have to be considered the “upper bound case” because potential evapotranspiration is driven by temperature only in the calculation of SPEI.
Extreme drought frequency (ExDRF)	An extreme drought event happens when the SPEI value is below -2 for at least 2 months. It starts when the SPEI falls below -2 and ends when SPEI returns back above 0. The number of extreme drought events in 5 years was calculated using a 5-year moving window.
Total drought severity (DRS)	Total drought severity was defined as the sum of all negative SPEI values (in absolute values) during the drought events in 5 years. The drought severity values were smoothed using a 5-year moving window weighted average.
Summer days (number of days where daily max. temp > 25 °C)	Summer days were defined as days with maximum temperature above 25 °C. The indicator is the number of such days in a year at a particular location.
Soil moisture (soil water deficit) (%)	Soil water deficit (d%) was derived from modeled soil moisture in the top-soil root zone using an s-shape conversion based on a certain soil moisture condition (average between soil water content at wilting point and 50% of field capacity) by Cammalleri et al. (2016). Soil water deficit ranges between 0 (no deficit) and 100 (full deficit). The annual average soil water deficit was derived from daily d% values by means of simple average.
Growing season length (number of days)	Growing season length is defined as the number of days in a year above a base temperature. The base temperature is 5°C in present study as this can be used as a temperature threshold for active growth of most temperate crops grown in Europe (Trnka et al., 2011). The period starts with the fifth day of the first 5 consecutive days in the year having daily average temperature (T_{avg}) above 5°C. The end of the period was defined as the fifth day when at least 5 consecutive days have their average daily temperature below 5°C.
Temperature seasonality (coefficient of variation [%])	Temperature seasonality is the amount of temperature variation over a week. It is calculated as the ratio of the standard deviation of the weekly temperature to the mean weekly temperature, knows as the coefficient of variation (variance) of weekly temperature measured in K. It is expressed as percentage. This metric measures of temperature change over the course of a year. The larger the coefficient of variation, the greater the variability of temperature.
Precipitation seasonality (coefficient of variation [%])	Precipitation seasonality is the amount of precipitation variation over a week. It is calculated as the ratio of the standard deviation of the weekly precipitation to the mean weekly precipitation, knows as the coefficient of variation (variance) of weekly precipitation. It is expressed as percentage. This metric measures precipitation change over the course of a year. The larger the coefficient of variation, the greater the variability of precipitation.

4.2 Invasive Alien Species

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Summary: This chapter assesses the pressure caused by 49 regulated Invasive Alien Species (IAS) on terrestrial and freshwater ecosystems in Europe. Alien species are organisms introduced by human activities into a new environment outside their natural geographic range. Alien species can be introduced deliberately or accidentally and some of them may find conditions that can favour their rapid spread. Thus, alien species can become invasive, with negative impacts on many elements of the invaded environment. Negative impacts include, for instance, competition with native species and transmission of diseases to local species, which in turn can lead to changes to ecosystem process. Invasive alien species, therefore, can cause significant pressure on their new environment, with negative consequences also on ecosystem services, human health and the economy. Target 5 of the EU Biodiversity Strategy 2020 requires that “by 2020 IAS are identified, priority species controlled or eradicated, and pathways managed to prevent new invasive species from disrupting European biodiversity”. This aims to avoid that movements of goods and people contribute to additional introductions. To assess the pressure caused by IAS on European ecosystems, we developed an indicator that links the presence of a species to the ecosystems that can be affected. The assessment is computed for the 49 terrestrial and freshwater species on the list of IAS of (European) Union concern as of 2017, which can be thus taken as a baseline against which future assessments can be performed.

The results of the assessment show that urban areas and grasslands in Europe are particularly affected by IAS, with an estimated pressure on over 60% of the total extent of these ecosystem types. For croplands, forest and freshwater the total area affected by IAS is estimated between 36% and 46%. Natural ecosystem types are less affected (16% of the surface area). In general, pressure by IAS affected proportionally larger areas in Atlantic and Continental regions than in other biogeographical regions; this can indicate the presence of several alien species in the same area, the invasion of a large portion of ecosystem by one or more species, a greater availability of information on the presence of IAS in these areas, or a combination of these factors. The distribution and the magnitude of the pressure across the EU-28 were assessed through the analysis of the IAS distribution and at the extent of affected ecosystems. A threshold of what constitutes a ‘critical pressure’ is currently lacking. Hence, we cannot translate the results of this exercise into an assessment of ecosystem quality. Despite this gap, the results obtained so far suggest that large portions of European ecosystems are under the pressure posed by several of the species on the Union list. As per other examples of pressures, the consequences on ecosystems can be greater than their sum, and could reach a point beyond which ecosystem functioning is severely or irreversibly compromised. When considering habitats protected by the Habitats Directive, invasive alien species of union concern are most often reported by member states in coastal habitats, followed by forest and freshwater habitats.

The results of this assessment can provide a baseline for future assessment, and can be updated as more information on IAS distribution and impacts becomes available. We have indicated some knowledge gaps and research areas that could be addressed to help quantify the magnitude of impacts and therefore identify priority areas for intervention. Developing standardised protocols to quantify IAS pressures, for instance, is a crucial aspect to devise tools for policy and management support

4.2.1 Introduction

4.2.1.1 Problem

Alien species are animals, plants and other organisms introduced by human activities into a new environment from their natural geographic range. Introductions can be deliberate, as in the case of cultivated and ornamental plants, farmed animals or animals introduced as pets or for biological control of pests; but introductions can also be accidental, for instance seeds and organisms moved during people’s travels, or through ballast water of ships (Vitousek et al., 1997).

In new environments, many alien species lack natural antagonists or other limiting factors, such as food scarcity and competition with other species, all conditions that can favour their rapid spread (Keane and Crawley, 2002; Mitchell and Power, 2003). Thus, alien species can become invasive, displace and cause the loss of native species, modify habitats, change community structure, affect food-web relationships and ecosystem processes (Grosholz et al., 2000; Byers, 2000; Lavergne et al., 1999; Vitousek and Walker, 1989). Furthermore, many alien species can carry diseases (van Riper III et al., 2002; Plowright, 1982) exacerbating the potential threat to local biodiversity.

Invasive alien species (IAS), therefore, can represent a significant pressure to their new environment, with potential negative consequences also on ecosystem services (Barbet-Massin et al., 2020) human health and the economy. In this note, we are concerned with their pressure on biodiversity and related ecosystem services.

Due to the increased movements of goods and people, new IAS are likely to be transported from their native areas to new environments (Early et al., 2016). Therefore, to avoid the risk of new introductions and potential damage, coordinated actions on prevention and management are needed. In particular, efforts should aim to identify and control pathways of introduction, rapid eradication at early stages of invasion and to prevent the spread of alien species already introduced.

4.2.1.2 Policy context

Target 5 of the EU Biodiversity Strategy 2020 requires that by 2020 IAS are identified, priority species controlled or eradicated, and pathways managed to prevent new invasive species from disrupting European biodiversity (Aichi Biodiversity Target 9: "By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated and measures are in place to manage pathways to prevent their introduction and establishment").

The EU Regulation 1143/2014 (EU, 2014) "on the prevention and management of the introduction and spread of invasive alien species" (the IAS Regulation) entered into force on 1 January 2015 to achieve these objectives. In particular, Article 4 of the IAS Regulation requires the European Commission to adopt a list of IAS of Union concern ('the Union list') which is updated regularly. The Union list is based on risk assessments of IAS and on further specifications on acceptable evidence on the capability of establishing and spreading, pursuant to Article 5 of the EU Regulation 1143/2014.

In addition, Article 20 of the IAS Regulation requires the adoption of measures to assist restoring damaged ecosystems, unless cost-benefit analysis demonstrates that costs related to restoration are disproportionate to the benefits.

The IAS of Union concern are subject to concerted actions at European Union level. The first Union list entered into force in 2016 with 37 species (EU, 2016); the first update in 2017 (EU, 2017) added 12 species, while the second update in 2019 (EU, 2019) added further 17 species, bringing the total to 66. This study was carried out after the first update of the Union list, thus addressing 49 IAS of Union concern.

Some of the species on the Union list are also recorded amongst the world's worst IAS (Lowe et al., 2000) such as the Water hyacinth (*Eichhornia crassipes*), the Chinese mitten crab (*Eriocheir sinensis*), the Red-eared, Yellow-bellied and Cumberland slider (different subspecies of *Trachemys scripta*), the Grey squirrel (*Sciurus carolinensis*) and the Small Asian mongoose (*Herpestes javanicus*). Their impact can include out-competition and predation of native biodiversity, impairing ecosystem functioning, and damages to agricultural systems and human infrastructures (See Box 4.21 for examples).

Box 4.2.1. Invasive alien species listed both on the Union list and among the 100 world's worst invasive aliens, and examples of their impacts.

Water hyacinth, a South American native aquatic weed, with large purple and violet flowers, a feature that makes this aquatic plant a popular ornamental choice. Its fast growing pace can lead to infestations, blocking waterways and limiting boat traffic, swimming and fishing. Ultimately, infestations by this plant can also limit the penetration of sunlight and oxygen into the water column, reducing biological diversity and ecosystem functioning in aquatic ecosystems.

Chinese mitten crab is another invader of aquatic ecosystems, native to eastern Asia. It has probably entered Europe through the ballast water of merchant ships, spreading rapidly from marine and estuarine habitats to inland freshwater systems. This species causes major ecological and economic damages: it predates and competes with native species, and its burrowing activity damages industrial infrastructures such as dams and flood defences, as well as fishing gears. Once established it is very difficult to control; hence control measures should aim not only at managing existing population, but also at preventing further introductions and spread.

Slider is a large freshwater turtle native to eastern and central United States. It is a popular pet in the US, and it has become popular in the rest of the world, too. Its spread is due to individuals escaped or deliberately released in the wild. Once established, individuals cause negative impacts in the ecosystems they occupy: they have some advantages over the native populations of turtles (i.e. a lower age at maturity, higher fecundity rates, and larger body size), which favour them when competing for basking, nesting sites and food resources. Additionally, they are a possible reservoir for salmonella, and hence a potential threat to human health.

Small Asian mongoose has a native range extending from Iran to northern India and Indochina. It was deliberately introduced to a number of islands worldwide to control local populations of species considered as pests, such as rats or venomous horned viper (e.g., in Croatian islands). Being a highly adaptable species and opportunistic feeder, however, it can predate also a number of native species of reptiles, amphibians and farmland birds, causing major loss of biodiversity as well as significant economic damages. This mongoose has therefore become a major pest in many locations worldwide.

Grey squirrel is native to the deciduous forests of North America. It was introduced first to Britain as a fashionable addition to the estates (https://www.telegraph.co.uk/news/earth/wildlife/10705527/History-of-grey-squirrels-in-UK.html, Accessed 12 August 2019), and then to Ireland and Italy. It is rapidly expanding its distribution range, and it out-competes the native Red squirrel (Sciurus vulgaris), in shared areas. In addition to threatening the local survival of the native squirrel, the Grey squirrel causes damages to woodland through bark stripping, and in urban areas can become a garden pest by digging up bulbs and feeding on the bark of ornamental plants.

4.2.2 Assessment

4.2.2.1 Scientific approach

The work outlined here contributes to the assessment of the pressures caused by IAS on the terrestrial and freshwater ecosystems across EU-28, for the 49 IAS listed on the Union list up to 2017 (EU, 2017) (23 plant and 26 animal species).

Their pressure was assessed as the summed occurrence of the IAS present in an area, weighted by the extent of the ecosystem(s) affected (see Box 2). Therefore, our assessment is not yet an indicator of damage (negative impact), as the damage an IAS causes will also depend on the susceptibility of an ecosystem to one or more IAS.

To quantify the pressure, we considered three main components:

The species distribution records from the baseline distribution of IAS of Union concern (Tsiamis et al., 2017; Tsiamis et al., 2019) available on the European Invasive Species Information Network (EASIN https://easin.jrc.ec.europa.eu/easin) at the 10 km spatial resolution of the European Agency Reference grid (https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2). Distributional data are available for all species with the exception of *Persicaria perfoliata* and *Microstegium vimineum*, which were not present in the EU at the time of establishment of the baselines (and still absent to our knowledge).

The pressure caused by IAS under study on each ecosystem. This information was based on the traits of the IAS, obtained from Tsiamis et al. (2017) for the first 37 species of Union concern, and from Tsiamis et al. (2019), for the 12 species added to the list in 2017. Specifically, the information on the known impact caused on invaded ecosystems and reported in Table 4 of Tsiamis et al. (2017; 2019) was linked to the pressure on the relevant ecosystem (Annex 1).

The distribution and extent of MAES ecosystem types, derived from the 2012 version of CORINE land cover classification system, mapped at a spatial resolution of 100 m and linked to the relevant pressure (Annex 2).

Detailed information on the input data is provided in fact sheet 4.2.101 for pressure on terrestrial ecosystems, and in fact sheet 4.2.102 for pressure on freshwater ecosystems (Supplement to this report).

For every area where an IAS was recorded, we quantified the pressure as the cumulative extent of all ecosystems affected by the presence of IAS. Our additive model therefore, is a conservative approach based on the CIMPAL Index proposed by Katsanevakis et al. (2016). Unlikely the CIMPAL Index, our conservative approach assesses the pressure in a binary way (evidence of pressure, or absence of pressure): we do not weight the magnitude of pressure based on the impact caused by IAS, nor we distinguish between impact types.

Box 4.2.2 describes the formula we adopted to quantify the cumulative pressure on each 100 km^2 area across EU-28.

The assessment is presented for terrestrial and freshwater ecosystems separately. The results of this assessment provide a baseline for the estimated pressure by IAS on terrestrial and freshwater ecosystems across EU-28. The results are presented for the entire EU-28 (Section 4.2.2.2), as well as for each ecosystem type separately (Section 4.2.2.3).

Given the broad bioclimatic variability characterising the EU-28, for each ecosystem type we also looked at the pattern of invasions in the different biogeographic regions. Specifically, we compared the relative extent of each biographic region with the relative extent invaded by IAS.

Box 4.2.2. Formula adopted to quantify the cumulative pressure of IAS on each invaded area.

Given a 100 km2 grid cell, the cumulative pressure is computed as the relative extent of each ecosystem that could be affected by any IAS recorded on that cell:

$$I_c = \sum_{s=1}^{S} \sum_{e=1}^{E} O_s H_e w_{s,e}$$

Where:

I_c = Cumulative pressure for cell c (0 to S);

s = Invasive Alien Species;

e = Ecosystem type;

O_s = Occurrence of species in cell c (0, 1);

He = Proportion, share, of ecosystem type e within cell c (0 to 1);

$w_{s,e}$ = Evidence of pressure of species s on the ecosystem type e (0, 1).

It follows that the cumulative pressure for a cell and all its ecosystems ranges between zero and the total number of IAS species recorded on that cell.

4.2.2.2 Assessment at the level of EU-28

Table 4.2.1 shows summary statistics of the cumulative pressure by IAS on each ecosystem type considered in the analysis. The classification of ecosystems follows MAES (Annex 2: Table 3 in Maes et al. 2013) with the exception of freshwater, which includes the MAES ecosystem types “rivers and lakes” and “wetlands”.

Table 4.2.1. Summary statistics of the cumulative pressure by invasive alien species across ecosystem types. Freshwater is an aggregated ecosystem type, which includes wetlands, rivers and lakes.

Ecosystem type	Arithmetic mean ± SD	Min (>0)	Max	Median	Mode	Invaded area (%)
Urban	0.181 ± 0.402	0.001	7.753	0.061	0.003	69.29
Cropland	0.630 ± 0.495	0.001	4.418	0.547	0.005	46.75
Grassland	0.363 ± 0.541	0.001	5.653	0.171	0.003	65.96
Forest	0.595 ± 0.556	0.001	5.027	0.449	0.015	43.51
Heathland and shrub	0.122 ± 0.197	0.001	2.307	0.044	0.003	16.87
Sparsely vegetated land	0.056 ± 0.105	0.001	1.509	0.017	0.003	16.42
Freshwater	0.050 ± 0.132	6.25E-06	4.509	0.018	0.009	36.68

Urban and grassland ecosystems show the greatest percent of areas under IAS pressure (> 60%), whereas the lowest (< 20%) is found in heathland and shrub and sparsely vegetated land.

Maximum cumulative pressure happens in urban ecosystems (7.753) and lowest in sparsely vegetated land (1.509).

The highest average is recorded in cropland, followed by forest. The magnitude of the standard deviation observed across all ecosystems assessed, however, suggests that local conditions might sensibly affect the average pattern of invasion.

Figure 4.2.1 and Figure 4.2.2 show the cumulative pressure across all terrestrial and freshwater ecosystems respectively. The values indicate the total pressure by IAS present in the area. Pressure values are grouped in intervals, with darker shades of red used for intervals with higher values. Large areas of greater pressure on terrestrial ecosystems can be seen across Great Britain, Northern Ireland, Netherlands, Belgium, the western part of Poland and the Po River valley in Italy (Figure 4.2.1). Across freshwater ecosystems, areas of greater pressure can be recognised across the Scandinavian countries, and the northern part of the Netherlands and Italy (Figure 4.2.2). The central part of Spain shows large areas of relatively low pressure across terrestrial as well as freshwater ecosystems.

It is also noted here that according to recent MS reports under the Habitats Directive (State of Nature report, forthcoming) pressures on Annex I habitats caused by IAS of Union concern are most often reported for coastal habitats, followed by forest and freshwater habitats. (The difference with the results reported in Table 4.3.1 are explained by a different scope of the Annex 1 habitat assessments by the Member States: Annex 1 habitats represent 24% of the EU territory and they don’t include urban ecosystems; marine ecosystems were not assessed in this ecosystem assessment and are not included in Table 4.2.1).

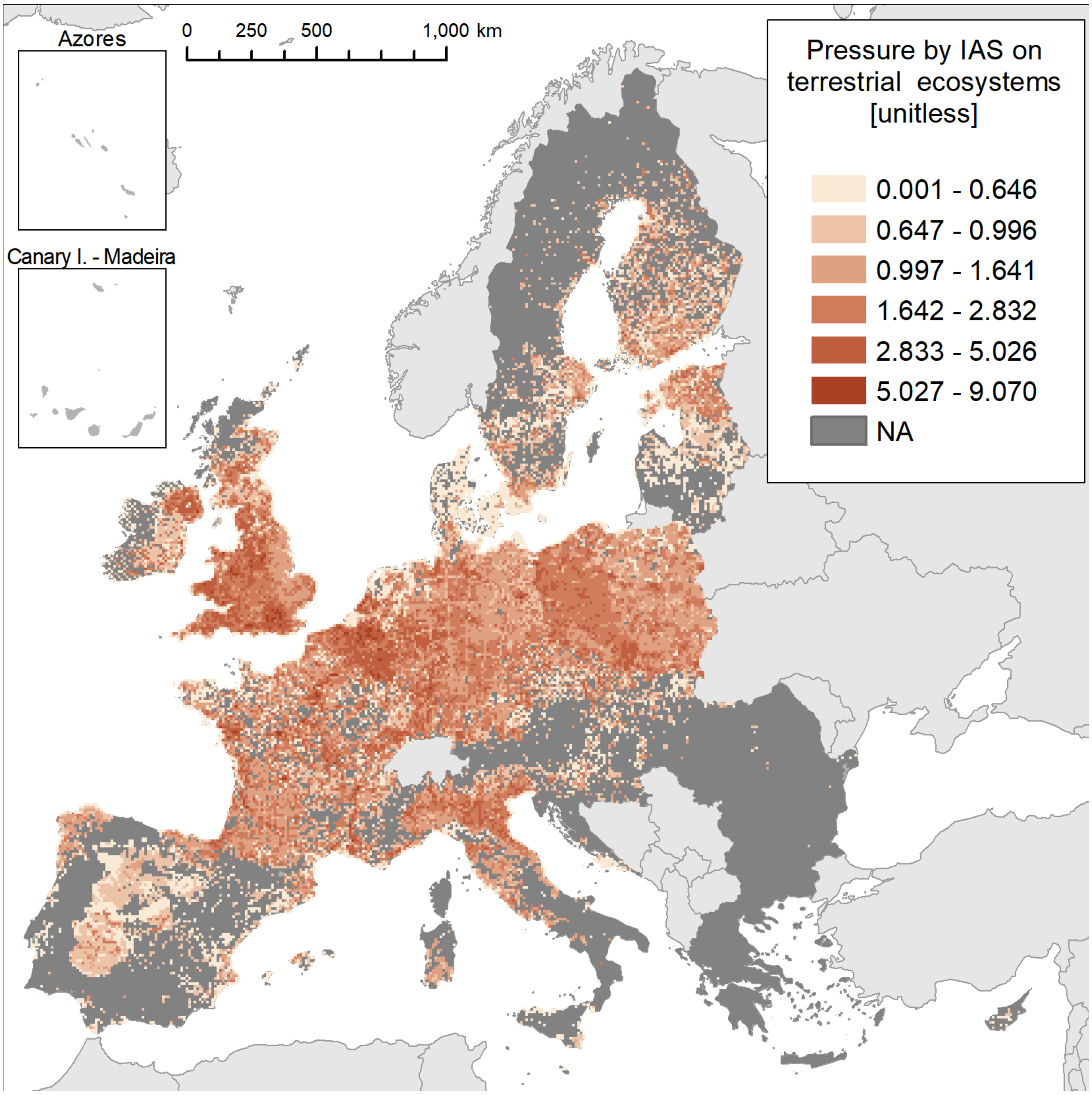

Figure 4.2.1. Cumulative pressure by the 49 invasive alien species of Union concern on terrestrial ecosystems. Dark grey indicate areas where presence of IAS is not reported. Values are grouped in geometric intervals.

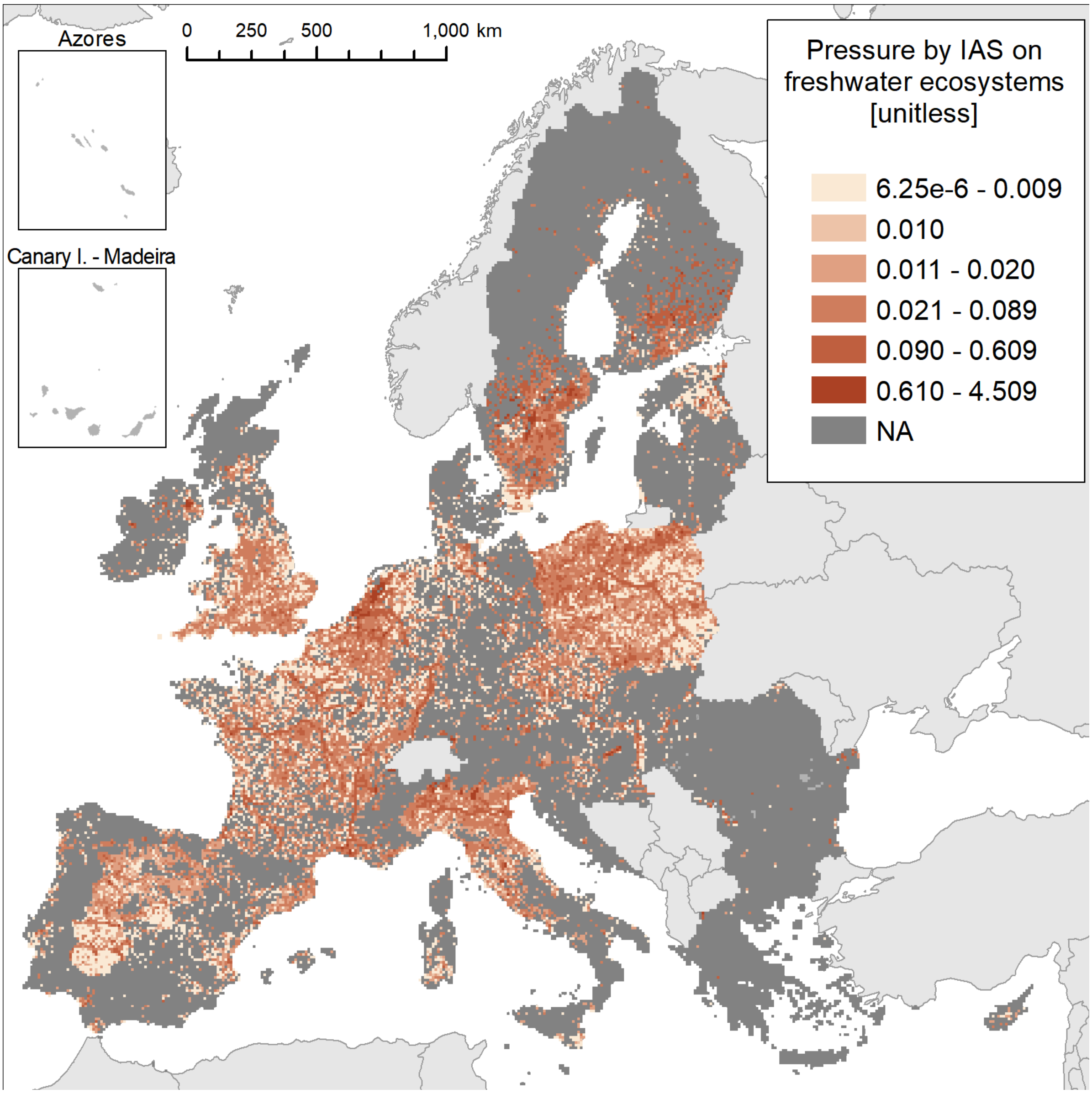

Figure 4.2.2. Cumulative pressure by the 49 invasive alien species of Union concern on freshwater ecosystems. Dark grey indicate freshwater ecosystems where presence of IAS is not reported. Values are grouped in geometric intervals. The minimum value reflects the minimum mappable area of the input data of freshwater ecosystems.

4.2.2.3 In depth assessment

This section shows, for each ecosystem type:

- A map of cumulative pressure by IAS, to show its spatial pattern;
- A histogram of the pressure values, their arithmetic mean and standard deviation, to recognize their frequency within given ranges;
- A chart with the biogeographical composition of each ecosystem type and the biogeographical characterisation of areas invaded by IAS, to show their proportional differences.

4.2.2.3.1 Urban ecosystems

Urban ecosystems include a variety of (land) features, which can act as habitats to many species, including aliens. Despite the maximum pressure recorded is greater than 7.75, the shape of the histogram (Figure 4.2.3 right) as well as the median (0.06, Table 4.2.1) indicate that most of the pressure is in the lowest range of values.

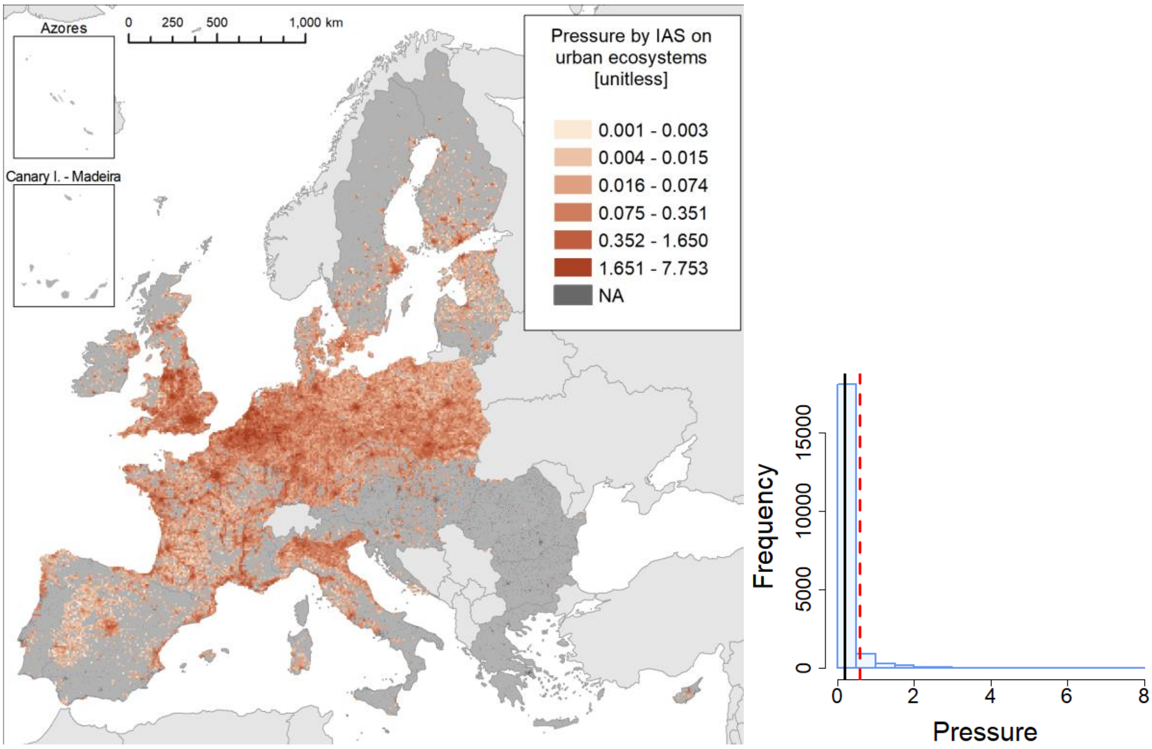

Figure 4.2.3. Pressure by the 49 invasive alien species of Union concern on urban ecosystems, in areas where presence of IAS is reported: spatial distribution (on the map) and frequency (histogram on the right). On the map, dark grey indicates urban ecosystems where IAS are not reported. On the histogram, black solid line indicates the arithmetic mean; red dashed line indicates the standard deviation.

The analysis across biogeographic regions reveals that the pressure is proportionally more widespread across Atlantic and Continental regions than across other regions (Figure 4.2.4).

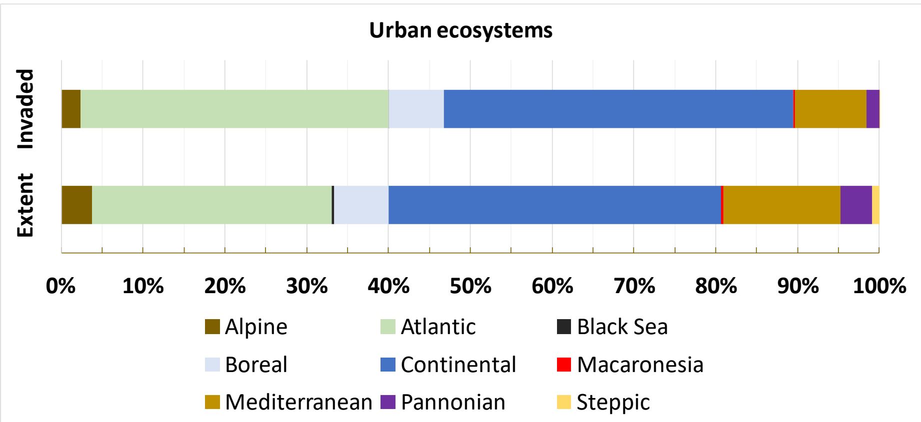

Figure 4.2.4. Biogeographic characterisation of urban ecosystems: biogeography of extent versus biogeography of invasion.

4.2.2.3.2 Cropland

The pressure across croplands reaches a maximum just above 4.4, with the median value set at 0.55, the highest value recorded across ecosystem types (Table 4.2.1).

The pressure is noticeable in the northern and central part of Italy, while continental Europe is characterised by areas of lower but widespread pressure (Figure 4.2.5 left).

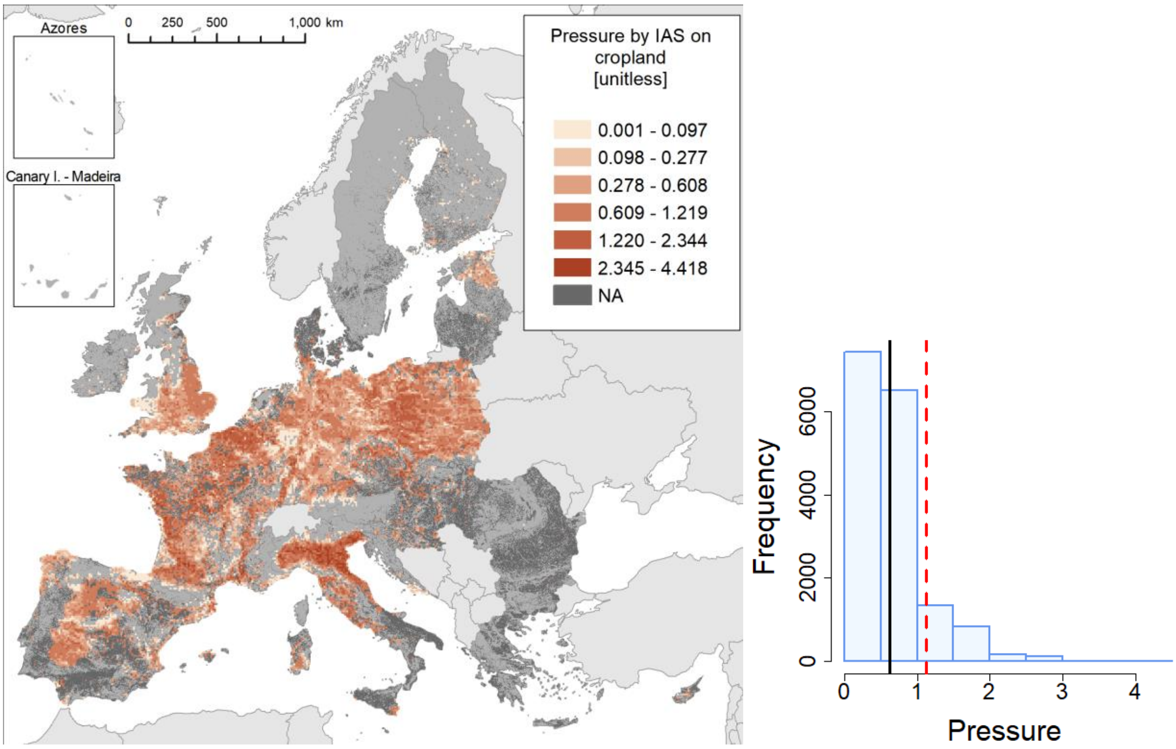

Figure 4.2.5. Pressure by the 49 invasive alien species of Union concern on cropland, in areas where presence of IAS is reported: spatial distribution (on the map) and frequency (histogram on the right). On the map, dark grey indicates croplands where IAS are not reported. On the histogram, black solid line indicates the arithmetic mean; red dashed line indicates the standard deviation.

Looking at the pressure across the different biogeographic regions confirms this pattern and shows similar features to urban ecosystems (Figure 4.2.6): the affected area is proportionally greater in Atlantic and Continental regions than in other regions.

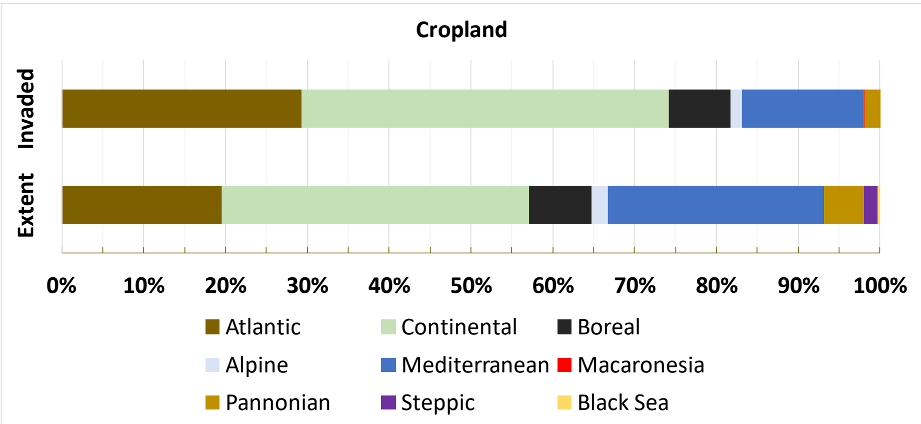

Figure 4.2.6. Biogeographic characterisation of cropland: biogeography of extent versus biogeography of invasion.

4.2.2.3.3 Grassland

The pressure across grasslands reaches 5.65, the second highest value after urban ecosystems; the median, however, is set at 0.17 (Table 4.2.1), with most of the pressure recorded within the range of 0.001 and 1 (Figure 4.2.7 right).

The pressure is noticeable across the United Kingdom and Ireland (Figure 4.2.7 left).

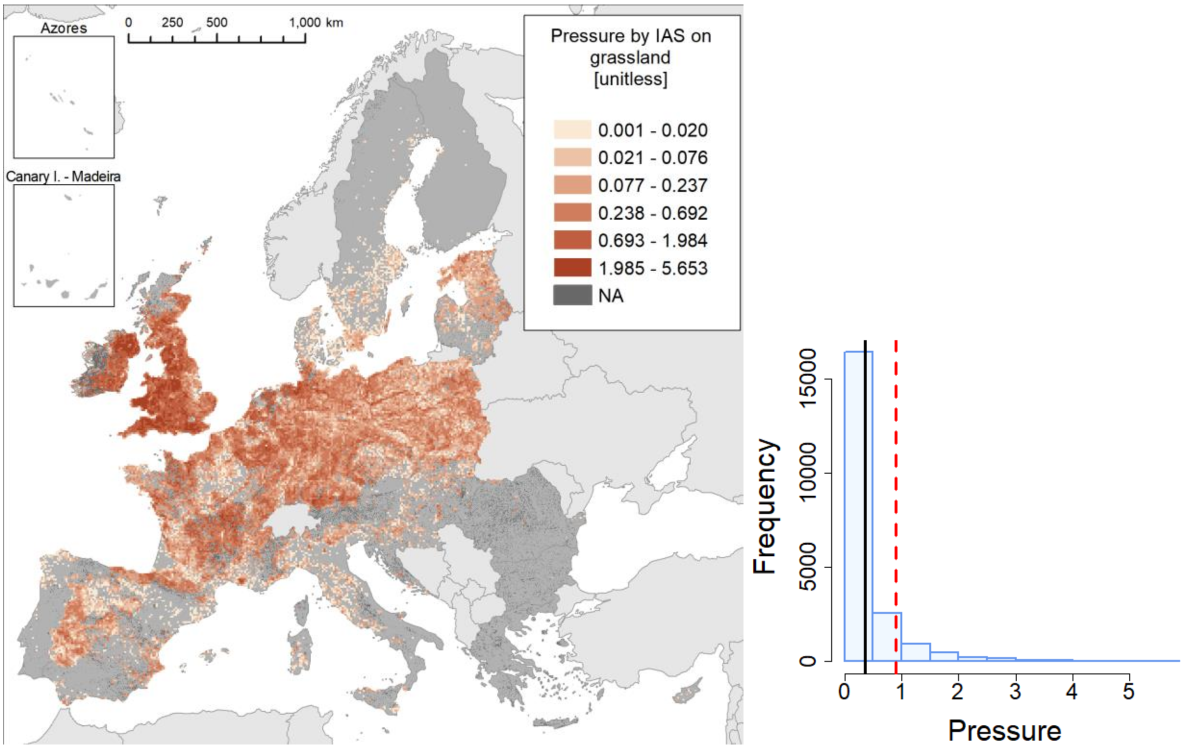

Figure 4.2.7. Pressure by the 49 invasive alien species of Union concern on grassland, in areas where presence of IAS is reported: spatial distribution (on the map) and frequency (histogram on the right). On the map, dark grey indicates grassland where IAS are not reported. On the histogram, black solid line indicates the arithmetic mean; red dashed line indicates the standard deviation.

The pattern across biogeographic regions shows that the extent of affected areas is proportionally greater across Atlantic and Continental regions, whilst it is proportionally lower across Alpine and Mediterranean regions (Figure 4.2.8).

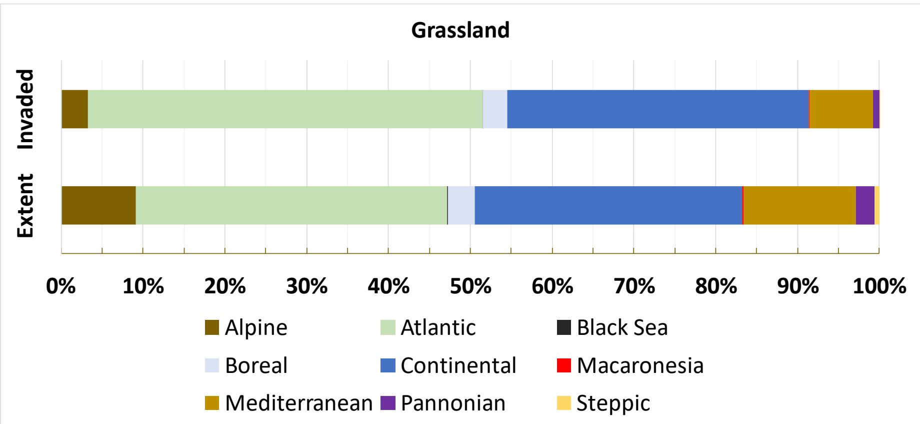

Figure 4.2.8. Biogeographic characterisation of grassland: biogeography of extent versus biogeography of invasion.

4.2.2.3.4 Forests

The pressure across forests reaches 5.03, the third highest value after urban and grassland ecosystems (Table 4.2.1). The median and the mean are the second highest after cropland, but the magnitude of the standard deviation suggests that local conditions might sensibly affect the average pattern of invasion (Table 4.2.1, and Figure 4.2.9 right).

The pressure is high across the Scandinavian countries and continental Europe (Figure 4.2.9 left).

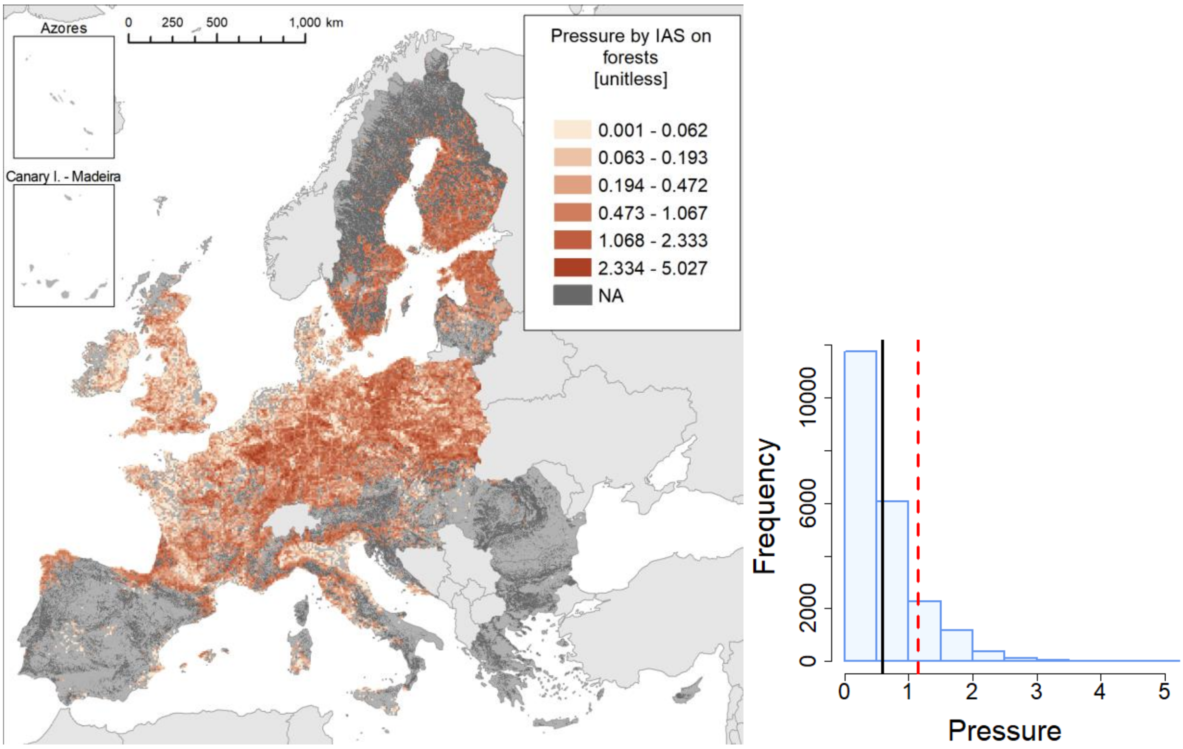

Figure 4.2.9. Pressure by the 49 invasive alien species of Union concern on forests, in areas where presence of IAS is reported: spatial distribution (on the map) and frequency (histogram on the right). On the map, dark grey indicates forests where IAS are not reported. On the histogram, black solid line indicates the arithmetic mean; red dashed line indicates the standard deviation.

As observed for other ecosystems, Atlantic and Continental regions show a proportionally greater affected area than other biogeographic regions (Figure 4.2.10).

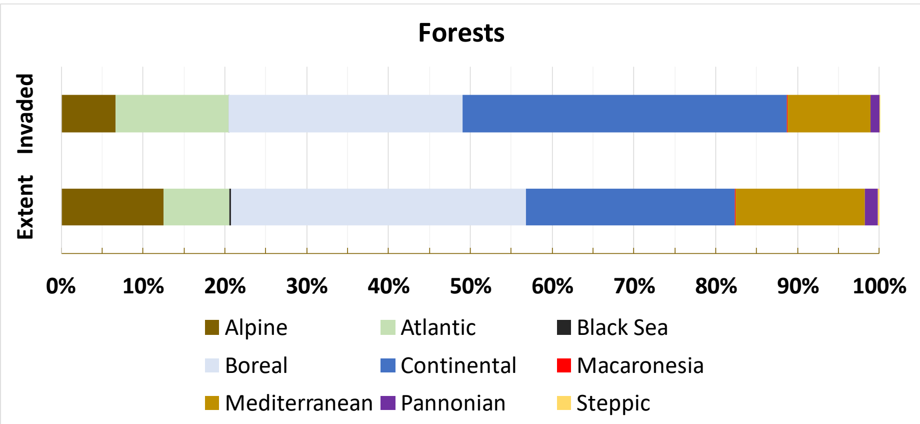

Figure 4.2.10. Biogeographic characterisation of forests: biogeography of extent versus biogeography of invasion.

4.2.2.3.5 Heathland and shrub

The pressure across heathland and shrub reaches at the most 2.31, while the median 0.04, placing this ecosystem among the ones with the lowest estimated pressure (second after sparsely vegetated land). Pressure is below 0.2 in most of the area (Figure 4.2.11 right), with the highest values recorded across the United Kingdom, the northern part of Spain and the southern coast of France (Figure 4.2.11 left).

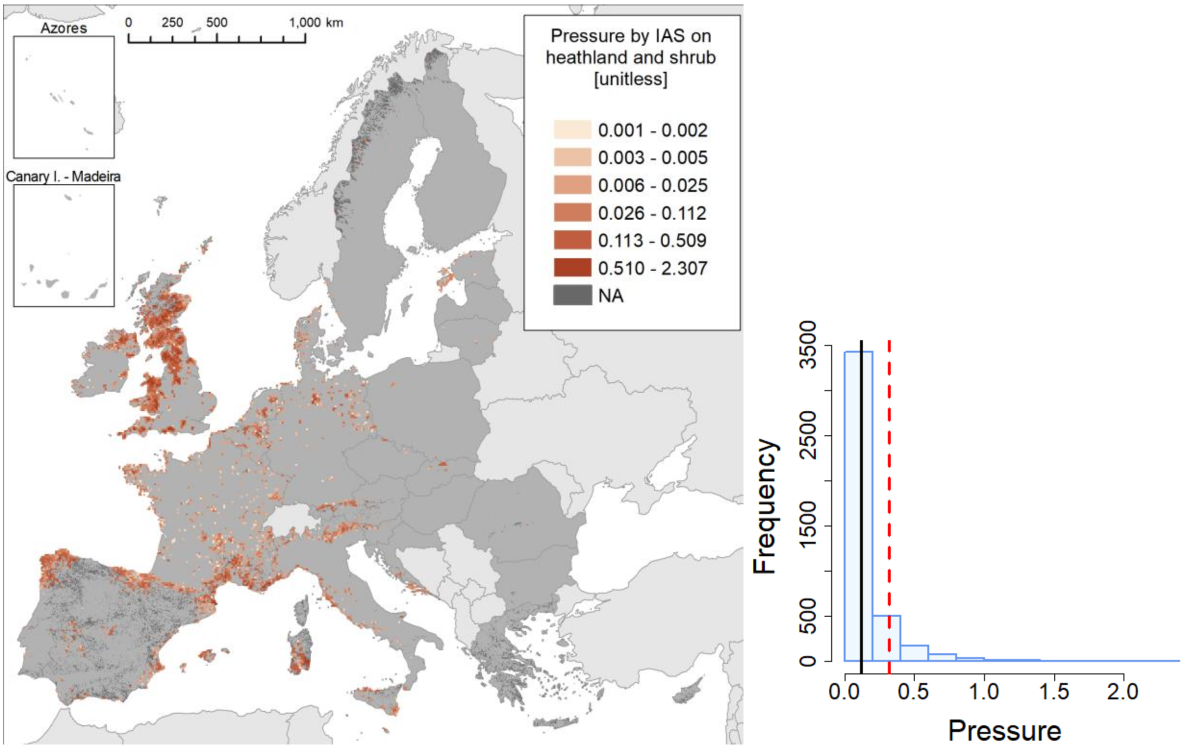

Figure 4.2.11. Pressure by the 49 invasive alien species of Union concern on heathland and shrub, in areas where presence of IAS is reported: spatial distribution (on the map) and frequency (histogram on the right). On the map, dark grey indicates heathland and shrub where IAS are not reported. On the histogram, black solid line indicates the arithmetic mean; red dashed line indicates the standard deviation.

The biogeographical analysis mirrors this pattern: proportionally greater affected areas are found across Atlantic (and Continental) regions; while a proportionally lower area is affected across Alpine regions (Figure 4.2.12).

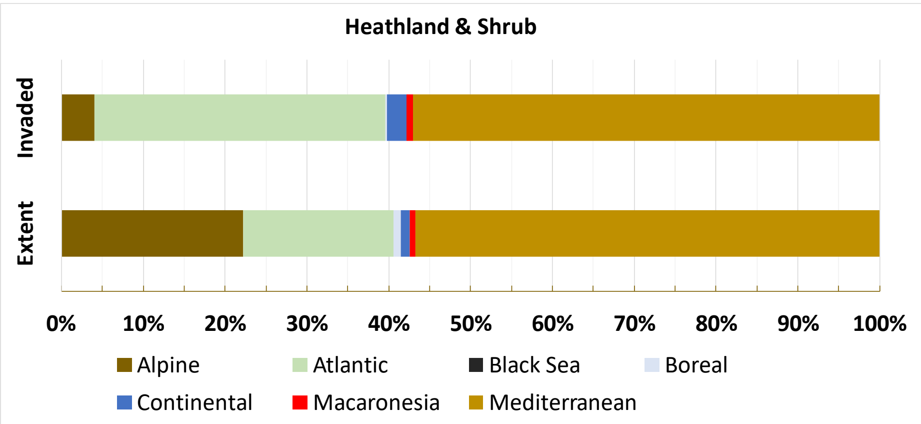

Figure 4.2.12. Biogeographic characterisation of heathland and shrub: biogeography of extent versus biogeography of invasion.

4.2.2.3.6 Sparsely vegetated land

The pressure across sparsely vegetated land reaches at the most 1.51, with a mean and median of 0.06 and 0.02 respectively, placing this ecosystem at the lowest end of the estimated pressure gradient (Table 4.2.1). Pressure values are below 0.1 across most areas (Figure 4.2.13 right), with the highest values recorded in the Alpine areas (Figure 4.2.13 left).

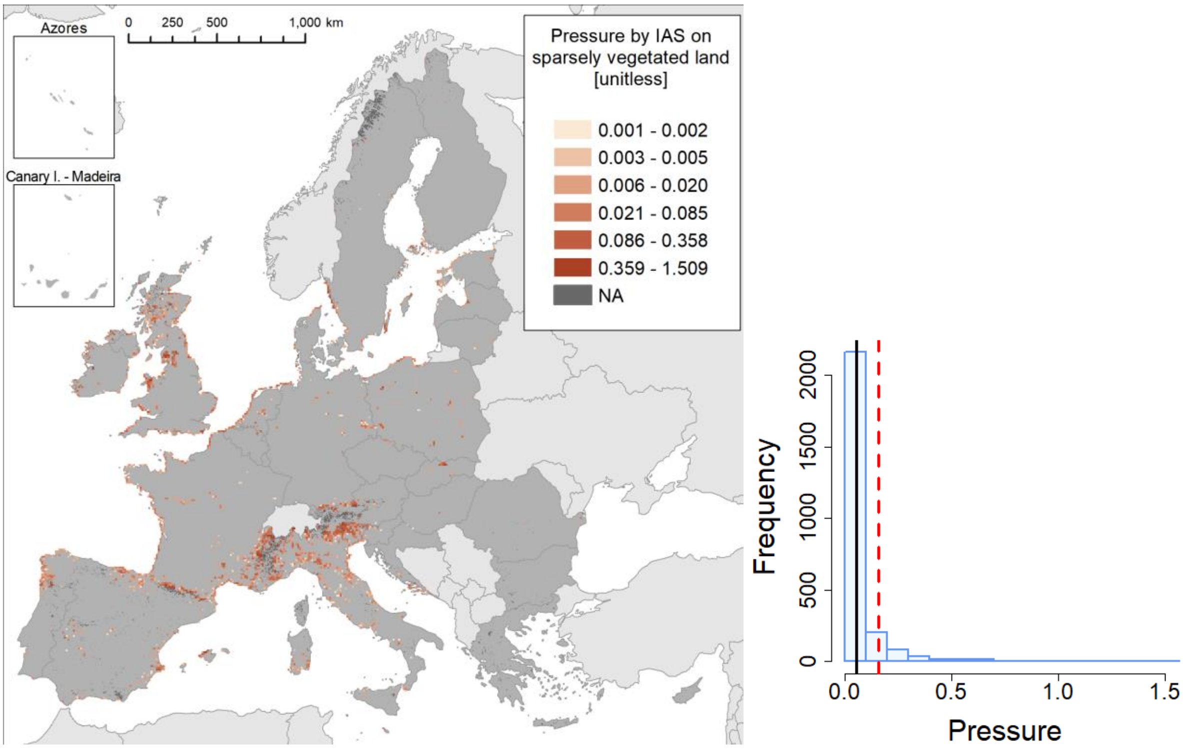

Figure 4.2.13. Pressure by the 49 invasive alien species of Union concern on sparsely vegetated land, in areas where presence of IAS is reported: spatial distribution (on the map) and frequency (histogram on the right). On the map, dark grey indicates sparsely vegetated land where IAS are not reported. On the histogram, black solid line indicates the arithmetic mean; red dashed line indicates the standard deviation.

The biogeographical analysis, on the other hand, shows that the affected area is proportionally larger across Atlantic, Continental, and to some extent Mediterranean regions, while it is proportionally lower across Alpine regions (Figure 4.2.14). Taken together with the estimated pressure values, these results suggest that invasion and pressure across Alpine regions are less widespread but characterised by hot spots of relatively high pressure.

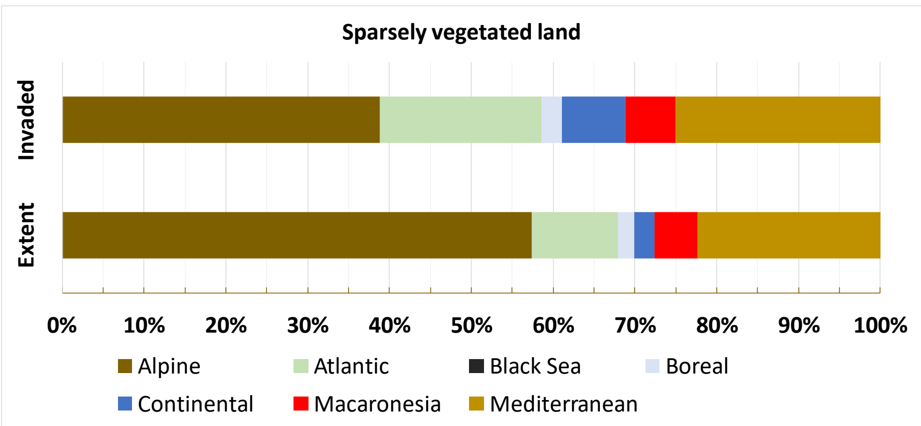

Figure 4.2.14. Biogeographic characterisation of sparsely vegetated land: biogeography of extent versus biogeography of invasion.

4.2.2.3.7 Freshwater ecosystems

The pressure across freshwater ecosystems reaches 4.51, although the distribution of values suggests that the majority of the area is characterised by pressure lower than 0.1 (Table 4.2.1 and Figure 4.2.15 right).

Areas of high pressure are found across the entire EU-28 (Figure 4.2.15 left).

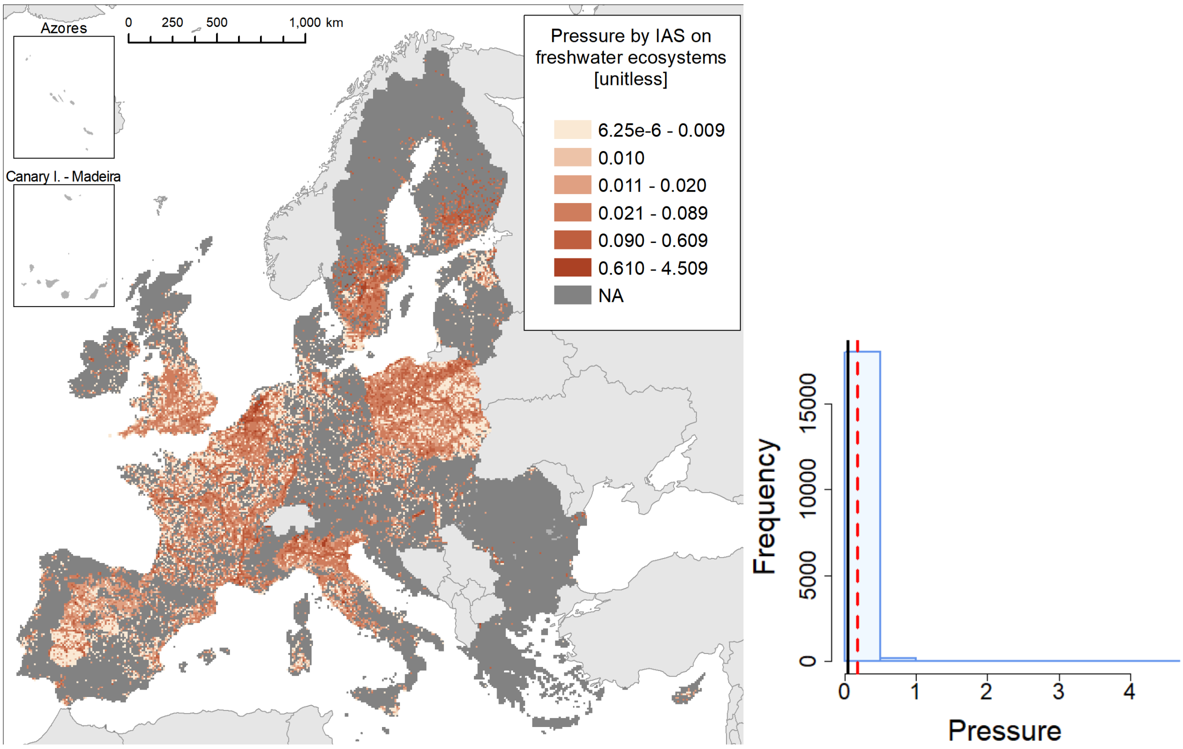

Figure 4.2.15. Pressure by the 49 invasive alien species of Union concern on freshwater ecosystems, in areas where presence of IAS is reported: spatial distribution (on the map) and frequency (histogram on the right). On the map, dark grey indicates freshwater ecosystems where IAS are not reported. On the histogram, black solid line indicates the arithmetic mean; red dashed line indicates the standard deviation.

Atlantic and Continental regions have a proportionally greater affected area, while Alpine, Boreal and to some extent Mediterranean regions have a proportionally lower affected area (Figure 4.2.16).

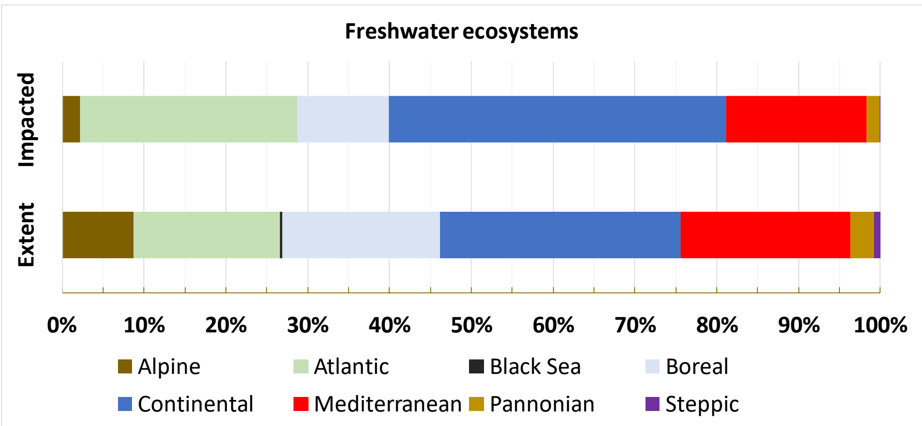

Figure 4.2.16. Biogeographic characterisation of freshwater ecosystems: biogeography of extent versus biogeography of invasion.

4.2.3 Knowledge gaps and future research challenges

The results outlined here can be used as a baseline of cumulative pressure for terrestrial and freshwater ecosystems against which future reporting and assessment can be compared: to allow monitoring and trend estimates, therefore, it is essential that reporting of IAS of Union concerns distributions be done over time and throughout all Member States of the European Union.

The impacts of IAS on biodiversity and ecosystem services are complex and often take substantial time to become evident: the effects of presence of an IAS cannot be predicted straightforwardly by looking at the ecology of the species in its native range (Hawkins et al., 2015; Blackburn et al., 2014). Moreover, the consequences caused by the presence of several IAS in the same area, could be more severe than the sum of each species impact (Magliozzi et al., 2020). The negative impacts of an IAS might be different from area to area, influenced by local environmental conditions, susceptibility of the ecosystem, and socio-economic aspects. Also negative impact can be attributed mainly to specific species: for instance, Coypu (*Myocastor coypus*) burrows and damages the banks of rivers and dykes causing instability; its feeding habits include rhizomes and young shoots of marsh plants, leading to plant community breakdown and erosion in coastal areas, but also crops such as sugar cane and alfa-alfa (Global Invasive Species Database, 2020). Similar impacts have been reported by the invasion of Muskrat (*Ondatra zibethicus*) (Skyriene and Paulauskas, 2012; Vermaat et al., 2016).

Hence, currently, we cannot translate the presence of an IAS into a level of ecosystem degradation. In general, understanding and quantifying the magnitude of impacts, not only from the research-based evidence perspective, but also from the methodological point of view of achieving standardised practices remains still a challenge (González-Moreno et al., 2019)

It is crucial to advance on these aspects to produce more realistic assessments for management support, prioritisation and implementation/adoption of adequate of measures.

Since the distribution of IAS is available at the spatial resolution of 10 km, the actual presence of the species at local level cannot be evaluated. While the 10 km spatial resolution might be acceptable for national or supra-national analyses, a finer spatial resolution (i.e. information at the local level) would allow us to distinguish areas of more or widespread presence, and therefore identify areas where intervention measures should be prioritised. Furthermore, species abundance or relative abundance could be preferable as predictor of impact than species presence, but data on this variable are currently sparse.

Most IAS of Union concern have been introduced and spread across north-western EU countries, while their presence is more limited in southern EU countries. This could be related to historical reasons: the majority of first introduction events of the IAS of Union concern, in fact, took place in France and in the United Kingdom (Tsiamis et al., 2017; Tsiamis et al., 2019). In addition, lack of data and limited monitoring efforts could explain the fact that in some countries only a limited presence and spread of the listed species has been recorded up to now: hence, absence of data in areas considered for this assessment does not necessarily mean absence of the species. This difference in the IAS distribution should be taken into account when interpreting the observed results at the EU-scale.

In addition, our assessment has not included many IAS that, while also causing severe negative impacts, have not been included yet in the Union list. The results of our assessment, therefore, might support actions towards the IAS considered, but these patterns might not necessarily reflect what expected when adding also IAS that are not on the Union list.

In light of the considerations outlined above, research areas that could benefit from the support of Horizon Europe are:

- Strengthening citizens' involvement, to aid the reporting and monitoring of IAS: this field would also require developing and distributing training and reporting material, in various formats (e.g. papers as well as digital).
- Advancing research areas to achieve standardised tools for understanding and quantifying the magnitude of environmental, social and economic impacts caused by IAS (risk assessment protocols). Standardised protocols (in particular rapid assessment tools) to quantify the impacts of IAS on ecosystems and their functioning, for instance, could help us also assess thresholds of ecosystem degradation and hence identify priority areas of intervention.

4.2.4 Conclusions

We assessed the pressure that IAS of Union concern cause on the ecosystems they invade, looking simultaneously and the distribution of IAS and at the extent of the ecosystems they can affect.

This approach allowed us to assess both the distribution and the magnitude of pressure across the EU-28. We assigned the same weight to the pressure of different IAS, because all the IAS of Union concern considered pose significant threat to the ecosystems they invade. We are aware, however, that their actual impacts are not necessarily similar, which can certainly influence priorities and type of measures to be adopted. As highlighted above, standardised protocols to quantify their impacts are a crucial aspect for developing tools for policy and management support.

In general, Atlantic and Continental regions showed a proportionally larger impacted area. Hotspots of high potential impacts, however, were recorded across all ecosystems, independently of the biogeographical region; this can indicate the presence of several alien species in the same area, the invasion of a large portion of ecosystem by one or more species, or both.

Despite the knowledge gaps highlighted above, the results obtained so far suggest that large portions of European ecosystems are under the pressure posed by several of the invasive alien species on the Union list. As per other examples of pressures, the consequences on ecosystems can be cumulative or interactive (Trochine et al., 2018; Teichert et al., 2016), and can reach a point beyond which ecosystem functioning can be severely compromised (if not irreversibly compromised).

The results of this assessment can provide a baseline for the estimated pressure by IAS of Union concern on terrestrial and freshwater ecosystems across EU-28. The assessment can be updated as additional information on IAS presence becomes available and also used to assess changes in relation to future species' distributions. Assuming that the same grid and ecosystem categories are used, future changes in estimated pressure can be attributed to one or more of these main causes:

- Changes in IAS distribution;
- Changes in the evidence of species-ecosystem negative impact;
- Changes in the number of IAS considered in the assessment if the Union list is further revised;
- Changes in the distribution and / or extent of the ecosystems.

These aspects need to considered when interpreting changes in future assessments, for instance to evaluate policy effectiveness.

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Annex 1. List of the 49 Invasive Alien Species of Union Concern, and pressure caused to macro-categories of ecosystems. 1 = evidence of pressure; 0 = absence of evidence.

Species Name	Artificial	Agriculture	Forests & Semi-natural	Freshwater
Alopochen aegyptiacus	0	1	1	1
Alternanthera philoxeroides	1	1	1	1
Asclepias syriaca	1	1	1	0
Baccharis halimifolia	1	0	1	0
Cabomba caroliniana	0	1	0	1
Callosciurus erythraeus	0	0	1	0
Corvus splendens	1	1	1	0
Eichhornia crassipes	1	0	0	1
Elodea nuttallii	1	0	0	1
Eriocheir sinensis	0	0	0	1
Gunnera tinctoria	0	0	1	0
Heracleum mantegazzianum	1	0	1	0
Heracleum persicum	1	0	1	0
Heracleum sosnowskyi	1	0	1	0
Herpestes javanicus	1	1	1	0
Hydrocotyle ranunculoides	1	0	0	1
Impatiens glandulifera	0	0	1	0
Lagarosiphon major	1	0	0	1
Lithobates catesbeianus	0	0	0	1
Ludwigia grandiflora	1	0	0	1
Ludwigia peploides	1	0	0	1
Lysichiton americanus	0	0	1	0
Microstegium vimineum	1	0	1	0
Muntiacus reevesi	0	1	1	0
Myocastor coypus	1	1	1	1
Myriophyllum aquaticum	1	0	0	1
Myriophyllum heterophyllum	1	0	0	1
Nasua nasua	0	0	1	0
Nyctereutes procyonoides	1	0	1	0
Ondatra zibethicus	1	1	1	1
Orconectes limosus	0	0	0	1
Orconectes virilis	0	0	0	1
Oxyura jamaicensis	0	0	1	1
Pacifastacus leniusculus	0	0	0	1
Parthenium hysterophorus	1	1	1	0
Pennisetum setaceum	0	0	1	0
Perccottus glenii	0	0	0	1
Persicaria perfoliata	0	1	1	0
Procambarus clarkii	1	1	0	1
Procambarus fallax f. virginalis	0	0	0	1
Procyon lotor	1	1	1	0
Pseudorasbora parva	0	0	0	1
Pueraria montana var. lobata	1	1	1	0
Sciurus carolinensis	0	0	1	0
Sciurus niger	1	0	1	0
Tamias sibiricus	0	1	1	0
Threskiornis aethiopicus	0	0	1	1
Trachemys scripta	0	0	0	1
Vespa velutina nigrithorax	1	1	1	0

Annex 2. Correspondence between CORINE LC classes' level 3, MAES ecosystem types' level 2, and macro-category of ecosystems adopted to identify the presence of pressure.

CORINE LC level 3	MAES level 2 ecosystem type	Macro-category of ecosystems
Continuous urban fabric	Urban	Artificial
Discontinuous urban fabric		
Industrial or commercial units		
Road and rail networks and associated land		
Port areas		
Airports		
Mineral extraction sites		
Dump sites		
Construction sites		
Green urban areas		
Sport and leisure facilities		
Non-irrigated arable land	Cropland	Agriculture
Permanently irrigated land		
Rice fields		
Vineyards		
Fruit trees and berry plantations		
Olive groves		
Pastures	Grassland	
Annual crops associated with permanent crops	Cropland	
Complex cultivation patterns		
Land principally occupied by agriculture with significant areas of natural vegetation		
Agro-forestry areas		
Broad-leaved forest	Woodland and forest ('Forest')	Forest & Semi-natural
Coniferous forest		
Mixed forest		
Natural grasslands	Grassland	
Moors and heathland	Heathland and shrub	
Sclerophyllous vegetation		
Transitional woodland-shrub	Woodland and forest ('Forest')	
Beaches dunes sands	Sparsely vegetated land	
Bare rocks		
Sparsely vegetated areas		
Burnt areas		
Glaciers and perpetual snow		
Inland marshes	Wetlands	Freshwater
Peat bogs		
Salt marshes	Marine inlets and transitional waters	Excluded
Salines		
Intertidal flats		
Water courses	Rivers and lakes	Freshwater
Water bodies		
Coastal lagoons	Excluded	Excluded
Estuaries		
Sea and ocean		

4.3 Landscape mosaic

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Summary: The Landscape Mosaic provides a comprehensive view of the spatial arrangement, composition and interactions of land cover classes. It measures the degree of land use intermix between agricultural, urban and natural areas. The five Landscape Mosaic stratification layers described in this report highlight the interactions between land cover at continental scale. Whereas the statistical summary suggests a very stable situation within the EU-28 between 2000 and 2018, the Landscape Mosaic map clearly highlights regional variability, thus providing an important information source for policy design:

- Increase in urban/industrial land cover in central Europe, southern UK and Madrid.
- Increase of agriculture in the south-western part of the Iberian Peninsula and Wales.
- Decrease of naturalness in the south-western part of the Iberian Peninsula.

As a cross-cutting indicator, the Landscape Mosaic provides a synergetic analysis of our environment resulting in dedicated information for landscape state and trend assessments, studies in biodiversity and green infrastructure networks, including delineating areas that would most benefit from conservation and restoration measures, and showing where landscape connectivity has changed in the EU.

4.3.1 Introduction

The focus of the Landscape Mosaic (LM) is to describe the juxtaposition of anthropogenic land cover (artificial or developed land and agricultural land) in relation to natural land. The analysis of these three dominant land cover types simultaneously addresses landscape composition, connectivity and the degree of landscape heterogeneity. In this way, it provides a synthetic measure of the human impact on the landscape. The indicator classifies a given location according to the relative proportions of the three land cover types Agriculture, Natural, and Developed in a neighbourhood surrounding that location (Riitters et al. 2000, 2009; Vogt 2019). This information is required to quantify and map the capacities of landscapes to sustainably provide ecosystem services. It promotes integrated landscape management by enabling common usage of the same information across disciplines and locations, and it permits rigorous evaluations of the trade-offs or synergies involved in land cover management. The Landscape Mosaic concept provides a holistic view of the spatial arrangement, composition and interactions of landscape feature classes. The synthesis allows for the assessment and monitoring of the status and trends in sustainability, ecosystem diversity, connectivity and heterogeneity of the European landscape. The cross-cutting and quantitative results of the Landscape Mosaic directly contribute to key cornerstones of the EU Bioeconomy Strategy, the EU Forest Strategy and Biodiversity Strategy (Natura 2000). The Landscape Mosaic forms a framework contributing to measure the condition, pressures and trends of European landscapes, the degree of land use intensity in agricultural, urban and natural ecosystems and their complex interactions in a changing world. The Landscape Mosaic may also contribute to the Aichi targets of the Convention of Biodiversity and the EU Biodiversity Strategy aimed to halt the loss of biodiversity and the degradation of ecosystem services in the EU.

The Landscape Mosaic captures issues that cross ecosystem-type boundaries. This is a unique feature of the approach used that cannot be achieved by simply aggregating indicators across the specific ecosystems. As a cross-cutting indicator, the information from the Landscape Mosaic may add value to the understanding of other specific indicators. For example, why the index of air quality is particularly low at a given location; or within the urban context, which city provides the most intact green infrastructure.

4.3.2 Assessment

The Landscape Mosaic (LM) provides detailed information on land cover composition within a local neighbourhood of approximately 500 hectares over each point in Europe. The LM analysis is conducted on CORINE land cover (CLC) maps for the years 2000, 2006, 2012, 2018 and summarised in spatially explicit maps as well as in tabular summary statistics. The full LM-information is then summarised into the following five stratification layers with specific focus on dedicated thematic topics (see Figure 4.3.1):

1. **LM-Background:** LM summary into 4 classes: Natural, Agriculture, Developed and Mixed.
2. **LM-Diversity:** LM summary into 4 classes showing increasing degree of land cover diversity from Uniform, Dual, Triple, to Intermixed land cover.
3. **LM-Agriculture:** LM interface summary into 3 classes showing areas where agricultural land cover is dominant (>= 60%), subdominant, or minor (<10%).
4. **LM-Natural:** LM interface summary into 3 classes showing areas where natural land cover is dominant (>= 60%), subdominant, or minor (<10%).
5. **LM-Developed:** LM interface summary into 3 classes showing areas where developed land cover is dominant (>= 60%), subdominant, or minor (<10%).

The scope of the LM-Background layer is to facilitate the reporting on land cover composition by focusing on the dominant presence (>= 60%) of each of the three land cover types. The second stratification layer, LM-Diversity, reports on the degree of spatial land cover heterogeneity. Because land cover dynamics are mainly driven by human activities it is of interest to investigate the interface zones for each of the 3 land cover types with their surrounding neighbourhood. Hence, the purpose of the stratification layer 4 (LM-Natural) is to delineate areas with prevalent natural land cover from those impacted by anthropogenic activities. The purpose of the stratification layers 3 (LM-Agriculture) and 5 (LM-Developed) is to locate and show the intensity of the human footprint on the landscape originating from Agriculture and Developed pressure, respectively. The mapping of the three interface zones (stratification layer 3-5) is an essential prerequisite for policy planning, monitoring and assessment, and towards understanding potential impacts of anthropogenic activities on the environment.

Methodology: The principle processing steps are summarised in Figure 4.3.1, exemplified for the area southwest of Berlin, Germany. The original CORINE land cover map (top left) is aggregated into the 3 base land cover types *Agriculture*, *Natural* and *Developed* (Step 1). In Step 2, the relative proportion of the 3 base types is calculated within a local neighbourhood of 500 hectares over each point resulting in the actual Landscape Mosaic. In Step 3, the Landscape Mosaic is stratified into the five thematic layers outlined above. Additional technical details can be found in the LM fact sheet (4.3.201).

4.3.2.1 Assessment of trends at EU-28 level

Within the context of the Conversion of Evidence mapping exercise, the original 100 m resolution assessment was aggregated into the lower but common 1 km resolution grid map. Each pixel in the aggregated map (Figure 4.3.2) shows the percentage in Naturalness, i.e. pixels of the NAT-Dominant and NAT-subdominant layers in the original 100 m resolution map. The change map is then derived from the two aggregated maps for the longest compatible time frame in CLC (2000 and 2018) by building the per-pixel difference: degradation (decrease of at least 5% per decade), improvement (increase of at least 5% per decade), stable or no change (change in naturalness within ± 5% per decade).

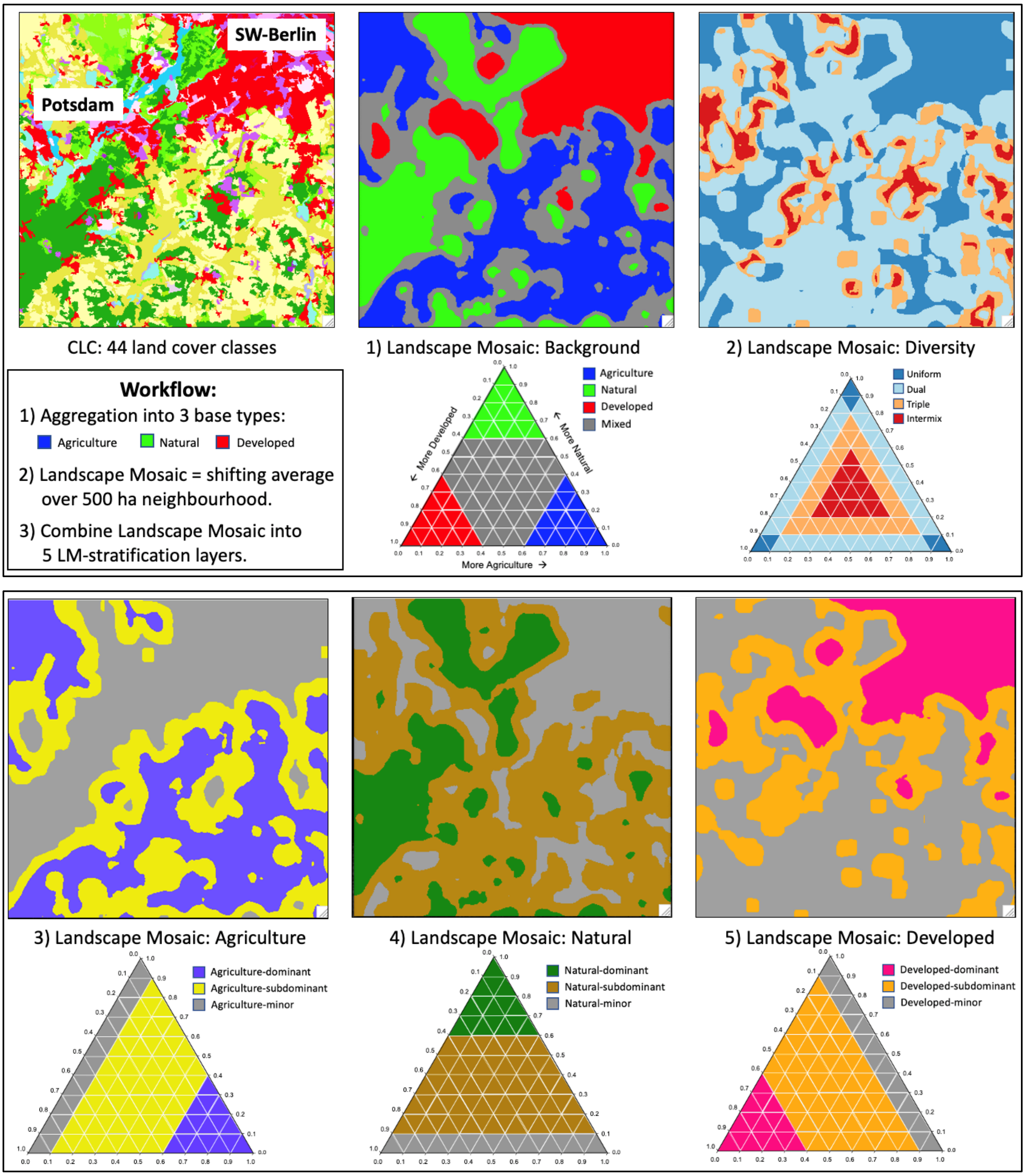

Figure 4.3.1. Example of the Landscape Mosaic product over the region of Potsdam/SW-Berlin, Germany. Top panel: Original landcover data, **LM-Background** (showing predominant land cover type), **LM-Diversity** (showing degree of heterogeneity). Bottom panel: **LM-Agriculture** (showing dominance of agricultural land cover), **LM-Natural** (showing dominance of natural land cover), **LM-Developed** (showing dominance of developed land cover).

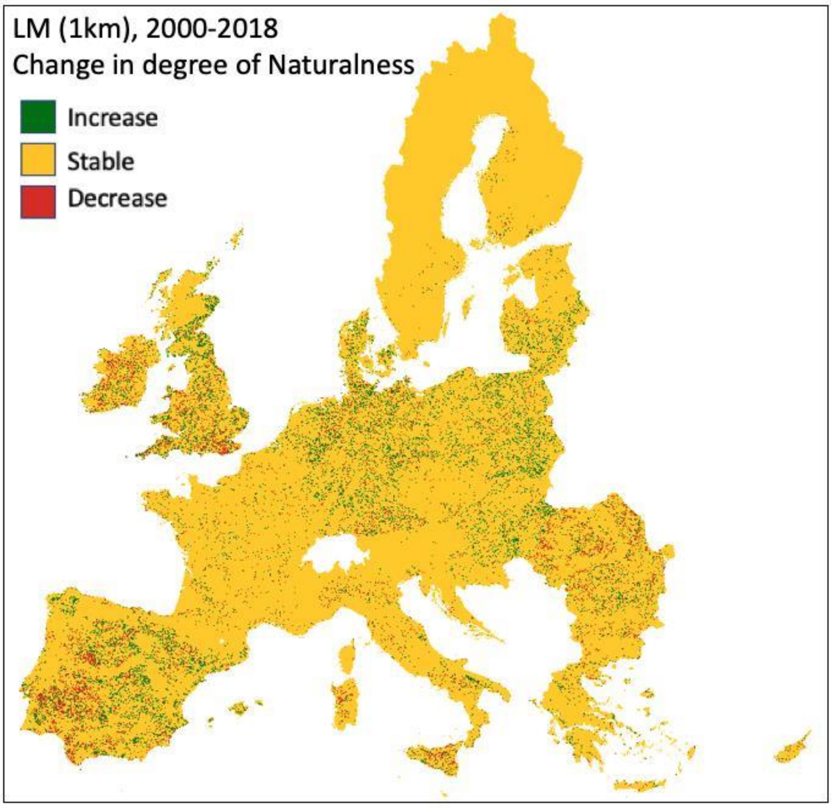

Figure 4.3.2. Change map of Naturalness at the aggregated scale of 1 km (Conversion of Evidence mapping). The labels 'Increase' and 'Decrease' refer to areas where naturalness has changed by at least 5% from 2000 to 2018.

The purpose of the downscaled change product shown in Figure 4.3.2 is to provide Landscape Mosaic derived information at a spatial scale that is directly compatible with other MAES indicators. For the Conversion of Evidence mapping, and to maintain the focus on biodiversity, we selected "natural" land cover (e.g., forest, grassland, shrubland, wetland, and other freshwater components), which is equivalent to the stratification layer 4, LM-Natural. The focus on natural land cover is of interest because it allows to map and assess key areas for policy planning and intervention: a) the current status, b) prioritise areas for conservation, c) locate areas for efficient restoration, d) map and quantify temporal changes in policy implementation and progress evaluation.

In general, however, any Landscape Mosaic-specific information should be taken from the original 100 m-based data. The interpretation of the original information content is mandatory to understand the interaction and cross-sectorial information content within the various Landscape Mosaic layers describing the key-components of land cover types.

Table 4.3.1 summarises the proportions for each of the five Landscape Mosaic layers aggregated at EU level, their status for each CLC assessment year as well as short-term and long-term trends using the original 100 m resolution data. The overall situation appears to be stable.

Table 4.3.1. Summary statistics for the five Landscape Mosaic layers, status and trends at EU-28 level.

	2000	2006	Baseline value (2010)	2012	2018	Short-term trend (% per decade)	Short-term trend (change)	Long-term trend (% per decade)	Long-term trend (change)
LM-Background									
Agriculture [%]	42.57	41.58	41.22	41.04	40.97	-0.31	→	-0.89	→
Natural [%]	42.53	43.09	43.12	43.13	43.14	0.02	→	0.34	→
Developed [%]	1.19	1.32	1.38	1.41	1.44	0.07	→	0.14	→
Mixed [%]	13.71	14.01	14.28	14.41	14.45	0.22	→	0.41	→
LM-Diversity									
Uniform [%]	47.73	47.19	46.85	46.68	46.65	-0.25	→	-0.60	→
Dual [%]	47.23	47.34	47.31	47.30	47.27	-0.05	→	0.03	→
Triple [%]	4.05	4.40	4.69	4.83	4.87	0.23	→	0.46	→
Intermix [%]	0.99	1.07	1.15	1.19	1.21	0.07	→	0.12	→
LM-Agriculture									
Dominant [%]	42.57	41.58	41.22	41.04	40.97	-0.31	→	-0.89	→
Subdominant [%]	29.28	29.73	29.98	30.10	30.09	0.14	→	0.45	→
Minor [%]	28.15	28.69	28.80	28.86	28.94	0.17	→	0.44	→
LM-Natural									
Dominant [%]	42.53	43.09	43.12	43.13	43.14	0.02	→	0.34	→
Subdominant [%]	30.71	30.65	30.78	30.84	30.85	0.09	→	0.08	→
Minor [%]	26.76	26.25	26.10	26.02	26.01	-0.11	→	-0.42	→
LM-Developed									
Dominant [%]	1.19	1.32	1.38	1.41	1.44	0.07	→	0.14	→
Subdominant [%]	11.02	11.91	12.52	12.82	12.95	0.54	→	1.07	→
Minor [%]	87.79	86.77	86.10	85.77	85.61	-0.61	→	-1.21	→

4.3.2.2 In depth assessment

Trends from aggregated statistical data (Table 4.3.1) can only provide a simple summary message. They hide important trends because they are averaged out into a single value. While statistics can always be derived from a map, only the map contains and provides spatially explicit information. This implies that any question addressing hotspots or regional variability in general cannot be answered from statistics but requires spatially disaggregated data. The discrepancy in information content from tabular statistics versus spatially explicit maps becomes evident when comparing Table 4.3.1 with the following figures. While Table 4.3.1 suggests a very stable situation for all Landscape Mosaic layers, Figure 4.3.3 shows the large variability of status and trends on a spatial map. The map also allows locating hotspots and key change areas, here exemplified for LM-Developed (Figure 4.3.3): The status map (left panel) shows locations where developed land is dominant and sub-dominant, usually within and around the most densely populated areas. The change mask (right panel) provides an overview of increase and decrease in urban and industrial land cover from 2000 to 2018. From this map one can find a decrease of developed land use in Romania and Bulgaria compared to an increase of urban land use, which is most pronounced in central Europe (Poland, Germany, southern UK) and Madrid. Those findings are clearly evident in the map but they cannot be derived from the aggregated tabular statistics (Table 4.3.1). Figure 4.3.4 and Figure 4.3.5 show the status map and the change mask for the LM stratification layers LM-Agriculture and LM-Developed.

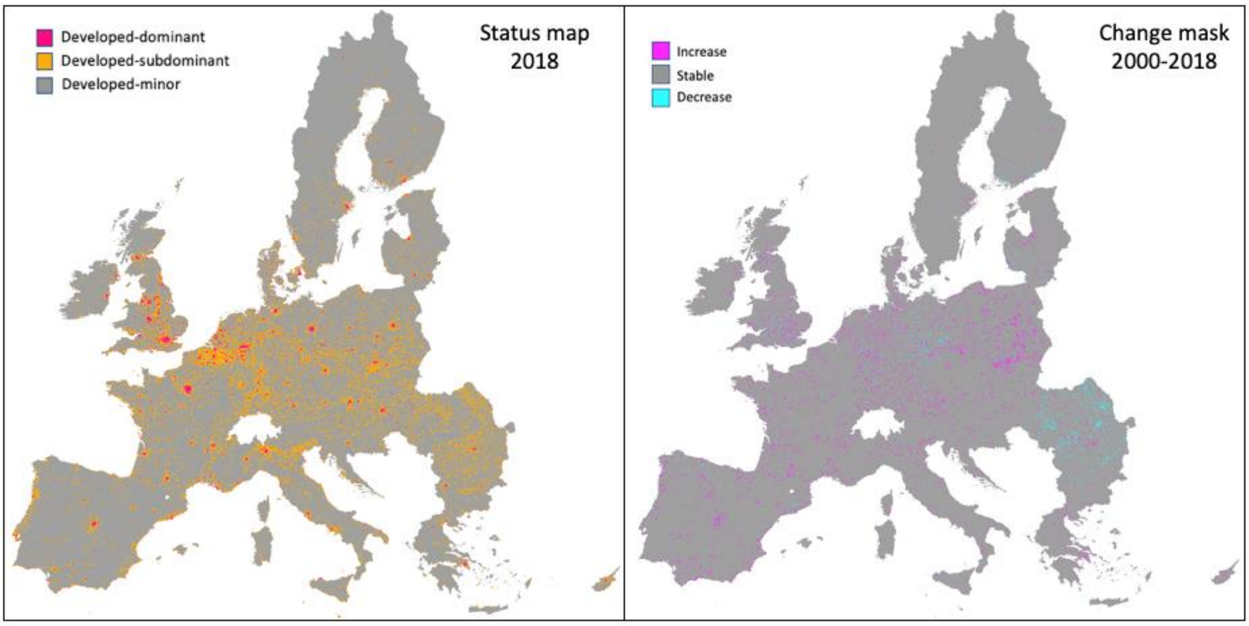

Figure 4.3.3. LM-Developed: Status map of dominance in 2018 (left panel) and changes in dominance for the EU-28 from 2000 to 2018 (right panel).

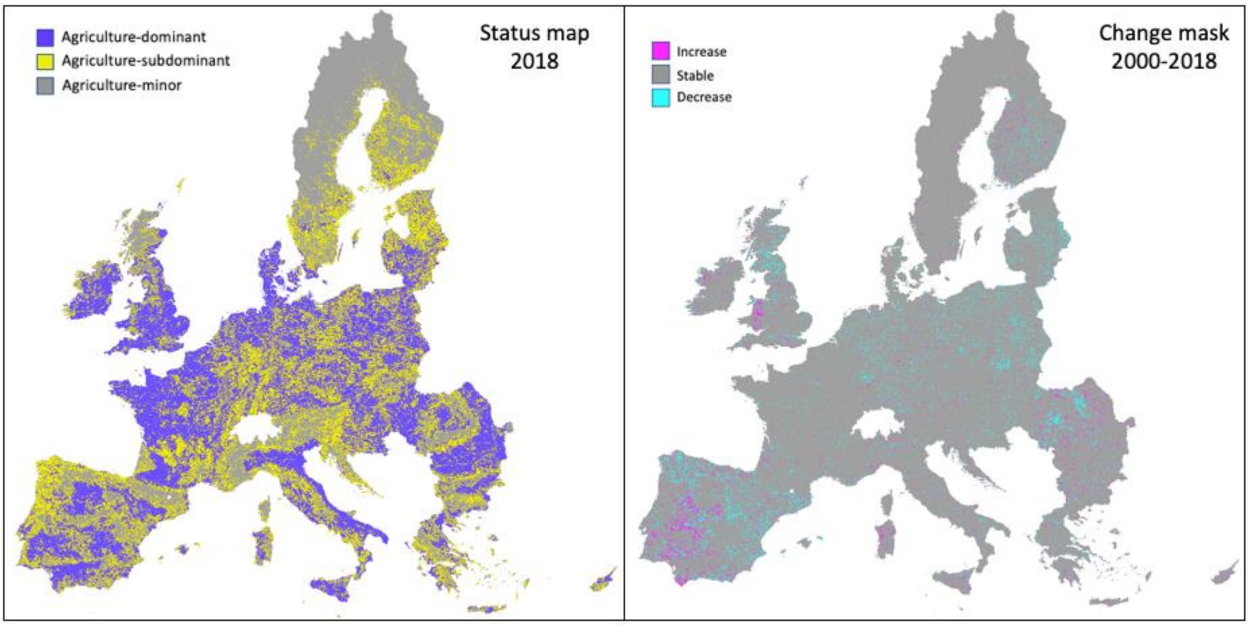

Figure 4.3.4. LM-Agriculture; Status map of dominance in 2018 (left panel) and changes in dominance for the EU-28 from 2000 to 2018 (right panel).

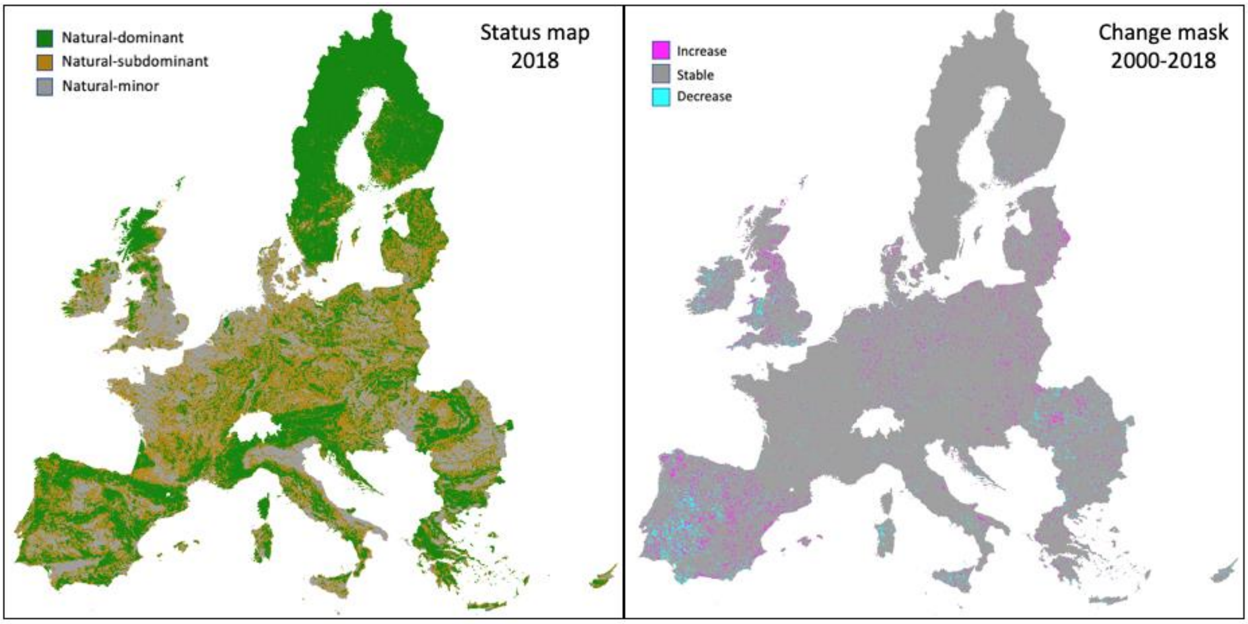

Figure 4.3.5. LM-Natural: Status map of dominance in 2018 (left panel) and changes in dominance for the EU-28 from 2000 to 2018 (right panel).

Comparing Figure 4.3.4 and Figure 4.3.5 reveals a clear inverse relationship between agricultural and natural land cover: While the majority of changes in natural land cover show an increasing tendency, a clear pattern of areas with decreasing natural land cover can be found on the Iberian Peninsula, Wales and Romania. Those areas coincide with an increase in agricultural land cover.

4.3.3 Options for policy

The different layers of the Landscape Mosaic provide summary statistics and spatially explicit information on three dominant land cover types: agriculture, natural land and developed land. By accounting for the land cover information in the local neighbourhood, the Landscape Mosaic simultaneously addresses and detects land cover diversity, location and extent of natural land and hotspots for efficient conservation as well as restoration. With its focus on the dominant land cover types, the Landscape Mosaic provides a generic framework, which can be equally applied to policy question in agriculture, biodiversity, sustainable development and green infrastructure planning in the urban context. The Landscape Mosaic is an indicator of the 'landscape context' at any given location. It is mapped according to the 'contents' of a neighbourhood, but is interpreted as the 'context' of the situation at the middle of the neighbourhood. This feature may be of interest when intersecting the information from the Landscape Mosaic map with other environmental data layers. For example, when overlaid on other features (for example forest plot locations, air quality sensors, stream monitoring stations), the Landscape Mosaic then describes the landscape context of each plot/sensor/station.

The assessment of information across different but interrelated ecosystem types contributes to the evaluation and the understanding of the complex interactions of the human footprint on our environment. The various stratification layers of the Landscape Mosaic locate and quantitatively assess key ecosystem components. Such monitoring is essential to identify areas in need of policy intervention as well as to evaluate the impacts of existing legislation. The cross-sectorial assessment of the Landscape Mosaic may aid to the development of an EU-wide, coherent monitoring system to track economic, social and environmental progress towards a circular and sustainable bioeconomy (EC, 2018). Furthermore, the European Green Deal (EC,2019) and the new Biodiversity Strategy for 2030 (EC, 2020), places the protection of our planet and of the shared environment among the top priorities of the new Commission (2019-2024), a priority that is also clearly shared in the EU Bioeconomy Strategy and Action Plan.

Preserving Europe's natural capital for future generations, restoring our ecosystems and enhancing their functions while conserving biodiversity are core pillars of the EU bioeconomy strategy. Within this context, the Landscape Mosaic may provide new insights into the interactions and interdependencies of the various ecosystem components of our environment. Specifically, the Landscape Mosaic stratification layers may be used to map and quantify ecosystem changes, localise hotspots for conservation as well as prioritise areas for efficient restoration of green infrastructure and habitat connectivity. Additional data and analyses are often needed to address the most specific questions at particular locations. Here, the Landscape Mosaic and its stratification layers may provide a top-down approach for identifying where the additional work/expense is justified.

4.3.4 Conclusions

The Landscape Mosaic analysis outlined in this report is designed to describe the ecosystem condition through a synergetic analysis of its key land cover components. This integrated assessment provides additional insights into the state and functioning of our environment. The additional information from this cross-cutting analysis may help to improve our understanding of other ecosystem condition and ecosystem pressure indicators. By analysing the local neighbourhood, the Landscape Mosaic can address questions on spatial heterogeneity, intactness of dominant land cover types and landscape configuration, including proximity and connectivity. These features have already been applied in MAES for the assessment of green infrastructure in urban ecosystems.

A key finding of this report is to stress the importance of spatial information, which is a generic issue: Aggregated tabular summary statistics may be short and succinct but they provide only a summary of the information. For example, this report clearly shows the limitations of aggregated tabular statistics. From the tabular summary (Table 4.3.1) alone it would not even be possible to identify where a specific land cover actually is or how it is distributed in the country, nor could one infer hotspots of substantial changes, locate areas for conservation and/or restoration. Yet, this information is essential in policy design, progress monitoring and final program evaluation. Mapping the spatial variability of an environmental indicator is crucial for any question addressing distance, connectivity and flux through the landscape. Tabular statistics lose this information, an effect which becomes worse with increasing size of the area assessed.

The Landscape Mosaic - and its stratification layers - are by design and on purpose spatially explicit assessments. Here, it is the spatial analysis that provides explicit information on a) geographic locations of interest (hotspots), b) connectivity within the spatial neighbourhood of a given location, and c) the land cover context, that allow for a holistic assessment across all ecosystem types. For these reasons, an integrated assessment such as the Landscape Mosaic provides additional value and deeper understanding in the endeavour to meeting the biodiversity targets.

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4.4 Soil

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Summary: Soil, arguably the largest terrestrial habitat in the EU, is a unique and complex ecosystem. Largely contiguous, soil forms a highly heterogeneous base for all other terrestrial ecosystems, and is an important component of aquatic systems. Organic soils, more commonly referred to as peatlands, are a distinctive soil ecosystem in their own right.

Soil, and the organisms living within it, provides an array of ecosystem goods and services that are vital for life on the planet. The mapping of many soil-based ecosystem services is still largely in the research domain.

Soils are under pressure from a range of drivers, reflecting diverse competition for land. These include urban expansion (resulting in soil sealing and loss of soil functions), intensive agriculture (resulting in compaction, loss of organic matter, loss of biodiversity, contamination, and increased soil erosion) and industrial pollution (from both local and diffuse sources).

At present, the assessment of soil is inconclusive as many key indicators at EU level and in most Member States are not available or are incomplete.

Data to characterize the overall suite of pressures on soil are largely lacking (e.g. diffuse soil pollution, compaction), making it impossible to quantify the geographical extent of the pressure or establish quantitative trend assessments of overall soil health.

More effort (and supporting resources) is required to develop a harmonized and comprehensive soil monitoring system for the EU that integrates pan-European initiatives such as LUCAS SOIL and national programmes.

Soil erosion rates in agricultural ecosystems do not show a significant decrease between 2010 and 2016. The estimated soil erosion rates in 2016 (2.45 t ha^{-1} yr^{-1}) show a limited decrease of 0.4% in all lands and 0.8% in arable lands compared to 2010. Long-term trends (2000-2010) report a stronger decrease in soil erosion by water, falling by 9% in all lands and 19% on arable land (driven largely by the implementation of erosion reduction measures under the CAP). Regions with high levels of erosion (e.g. the Mediterranean) show limited improvements, probably reflecting a combination of limited soil cover, limited implementation of control measures, increasingly erosive rainfall patterns and terrain conditions.

While the previous decade saw a significant reduction in soil erosion by water in agricultural soils, the current assessment shows that erosion by water on arable land is 10% greater than the mean for the EU while permanent crops show the highest soil erosion rates. In addition, there are notable erosion rates on shrublands and sparse vegetation with mean soil loss rate of 2.69 t ha^{-1} yr^{-1} and 40 t ha^{-1} yr^{-1}, respectively.

Soil erosion by water across the EU is above accepted soil formation rates, which means that the soil ecosystem will continue to degrade. In this context, efforts to reduce soil erosion should be reinforced with more agro-environmental friendly measures and a better targeting of areas that are vulnerable to erosion.

Soil nitrogen (N) and phosphorus (P) are assessed for the first time in the EU using measured data from 22 000 locations that were sampled through the LUCAS Soil Programme – however, trend data are not currently available.

Ecosystem condition is assessed through soil organic carbon fluxes. It is worth reflecting that mineral cropland soils exhibit the lowest soil carbon stocks of all land cover types apart from artificial areas and may already have reached a minimum equilibrium.

In overall terms, croplands and grassland soils exhibit a slight decrease in soil organic carbon stocks between 2009 and 2015 of about 0.06% and 0.04% respectively, but with marked regional differences. In the context of the MAES analytical framework, this reflects no change in condition. The majority of points used in the assessment of soil organic carbon do not record significant changes in land cover.

Long-term assessments, derived through biogeochemical modelling that incorporates LUCAS Soil data, denote slightly higher reductions in soil organic carbon stocks for agricultural land (see Chapter 3.2) but changes are not significant.

While peat (peatlands) cover 6.5% of the EU land area, half of which is estimated to have been drained, the assessment of changes on organic soils is inconclusive due to insufficient sampling sites to assess statistical significance. It should be stressed that from a soil perspective, peatland soils (i.e. the organic soil ecosystem) are more extensive than the inland wetlands ecosystem described in Chapter 3.4.

It should be noted that organic carbon concentrations in LUCAS sampling points that changed from grassland to cropland over six years decreased by -11%. This demonstrates the loss of soil carbon associated with land cover change and suggests that cropland soils are not working as carbon sinks as cultivation results in increased mineralization.

Short-term changes in soil carbon stocks for most Member States reflect a six year interval (2009-2015). The findings are thus derived from observations of a relatively short time window, while the effect of land management on soil is very dynamic: it takes time until stable trends relative to specific practices and environmental conditions can be observed and explained with clear causal reference.

Detailed land use data (e.g. tillage type, rotational practices, use of cover crops) are not available on a EU basis, which makes it difficult to identify specific drivers of change.

The analysis presented in this report does not account for the potential effect of climate change, which will likely increase soil erosion rates in the EU as a result of more extreme weather patterns.

While the data and methodology used in the assessment indicate a stable ecosystem, this outcome does not fully capture the continued loss of soil through sealing and related infrastructure development nor that a reduction in the level of degradational processes still means that the ecosystem is under pressure.

Closer synergies should be sought between the MAES framework and the methodology being developed to assess land degradation and progress towards land degradation neutrality.

Unlike aboveground habitats, soil is not explicitly covered the Habitats Directive, the Natura 2000 network and national network of designated areas. This should be addressed through targeted policy instruments.

It is expected that the development and support of extensive farming systems and the introduction of soil health targets in to the CAP should lessen pressures on cropland and managed grassland soils. Industrial emissions on natural systems should be assessed and necessary policy response formulated.

4.4.1 Introduction and description of soil ecosystems

Soil is at the same time a habitat and a unique ecosystem, a blend of living (organic) and non-living matter (essentially minerals and rock fragments). The soil ecosystems displays the effects of genetic and environmental factors such as climate, living organisms and relief acting on parent material over a period of time. Soil plays a vital role in all terrestrial ecosystems and particularly so in natural ecological cycles (carbon, nitrogen, oxygen, water and nutrient). They also provide a range of ecosystem services including the provision of nutrients from decomposition of organic residues, water filtration and buffering of contaminants.

Soils are generally classified as being either mineral or organic, which is based on the percentage of organic matter present. In simple terms, organic soils, commonly referred to as peat, are characterized by the presence of a relatively thick horizons containing high levels of organic matter[92] (technically more than 20% carbon, which can rise to as high as 90%). Organic soils are found in wet or very cold landscapes where the decomposition of vegetation remains is reduced. They are found in peatlands, bogs, ferns and mires. Soils with organic carbon levels below 20% are referred to as mineral soils. It should be noted that mineral soils can also contain organic-rich horizons (usually sitting on top of a mineral subsoil). These are usually referred to as organic-rich mineral soils, although the thickness of the organic layer needs to be assessed carefully. More detailed guidelines on how to define organic soils can be found in the World Reference Base for Soil Resources (IUSS 2015), the International Union of Soil Sciences' international standard for soil classification.

Uniquely, soil contains a greater diversity and abundance of life than any other ecosystem. A handful of soil contains billions of different organisms, many of them still to be studied or identified. Some estimates place at least a quarter of the world's biodiversity in soil, the majority of which still needs to be identified. The diversity of organisms living within soils is critical to all terrestrial ecosystems. In addition to being a habitat for biodiversity, soil provides a physical support system for plants, facilitates organic decomposition, regulates water purification and quantity, and nutrient cycling (including organic carbon). In good condition, soils can naturally control biological antagonists thus prevent pests from outbreaks. All this, in turn, provides humans

[92] See Histosols in http://www.fao.org/soils-portal/soil-survey/soil-classification/world-reference-base/en/

and other animals with a secure source of food as well as resources for potential medicinal or other goods. In addition, soil can both hold and release water, thereby providing resilience in times of drought, flood control, together with water filtration and purification services. Soils can buffer the effects of pollutants and transform or degrade harmful substances. In addition to being conditioned by climatic factors, soils are a key element in climate regulation and are increasingly recognized for their emission mitigation potential. Finally, soil preserves our history and has extensive cultural connotations.

Simply put, the ecosystem processes in soil maintain life on the planet.

Perhaps a concept not well recognized by society and policy makers is that all soils perform all of the functions described above simultaneously, but at different magnitudes reflecting interactions between soil attributes (physical, chemical and biological), environment (e.g. climate, weather, slope and geology) and land management.

There have been several attempts to map soil-related ecosystem services. Toth et al. (2013b) assessed soil biomass productivity for grasslands, croplands and of forest areas of the EU Makó, et al. (2017) mapped the storing and filtering capacity of European soils; Kibblewhite et al (2015), predicted the preservation of cultural artefacts and buried materials in soil; Lugato et al (2014) defined that soil organic carbon saturation Capacity in Europe (these datasets –Figure 4.4.0 - together with maps indicating the availability of raw material from soils, soil hydraulic properties, and soil as a platform for human activities are available from the JRC's European Soil Data Centre[93]). In parallel, the LANDMARK H2020 Project[94] (e.g. Schröder, 2016) assessed the supply of interaction key soil functions in response land management practices reflecting societal demands.

4.4.2 Ecosystem extent and change

Soil is arguably the largest terrestrial ecosystem in the EU. In extent, soil in one form or other covers 4,398,178 km^2 (i.e. the total EU land area; Chapter 6, Table 6.1; Fact sheet 3.0.100). Excluding rivers and lakes, and marine inlets and transitional waters and minus a nominal 50% of the urban area, soil extends over 4,153,047 km^2 of the EU's terrestrial ecosystems (or 94.4%).

Largely contiguous, soil forms a highly heterogeneous base for all other terrestrial habitats (it is even pertinent to aquatic systems when nutrient flows from soil are considered). At its lower boundary, soil grades to hard rock or secondary unconsolidated materials, generally devoid of any evidence of biological activity. Conventionally, the lower boundary of soil is set to 200 cm, although they can be shallower (e.g. in mountainous regions) or deeper (e.g. in peatlands or in tropical regions).

Organic soils, more commonly referred to as peatlands, are a distinctive soil ecosystem in their own right (see chapter 3.4 on inland wetlands) and account for around 6.5% of the soil area. The remaining 93.5% are mineral soils.

In summary, we can consider that

- Agricultural soils cover almost half (47.8%) of the EU land area (c. 2 096 617 km^2).
- Cultivated or arable soils occupy about 36.4% (c. 1 596 051 km^2), of which 5.5% (115 000 km^2) are under permanent crops.
- Artificial areas occupy just over 5% of the EU. If one can assume that approximately 50% of the urban fabric is not covered by buildings or infrastructure, this would imply that there are around 110,000 km^2 of urban soils.
- Organic soils (peatlands) cover around 6.3% of the EU (i.e. 270 000 km^2), although the figures for some countries are still approximations. From a soil perspective, peatland soils (i.e. the organic soil ecosystem) are more extensive than the inland wetlands ecosystem described in Chapter 3.4.
- Natural soils (i.e. without intensive management regimes) cover 54% of the EU land surface. However, it should be stressed that these areas are not without pressures.

During the period 2010-2020, the reduction in the extent of soil as an ecosystem is difficult to assess. Land cover change statistics show that the loss of soil is mainly due to land take associated with urban extension and infrastructure development.

[93] https://esdac.jrc.ec.europa.eu/resource-type/soil-functions-data
[94] http://landmark2020.eu/work-package/work-package-4/

During the period 2012-2018, the rate of net land take was estimated to be around 539 km² per year (EEA 2019). Between 2000 and 2018, 78% of land take in the EU-28 affected agricultural areas (EEA 2018). As the rate of recycling of urban land for development is currently only 13% (EEA 2020), this effectively means that every ten years an area the size of Cyprus (9,300 km2) is paved over and lost from agricultural, forestry and conservation land.

Between 2000 and 2006, the average increase in artificial areas in the EU was 3%, however, this masks local issues, exceeding 14% in Cyprus, Ireland and Spain. In many cases, sealing generally consumes high quality agricultural soil.

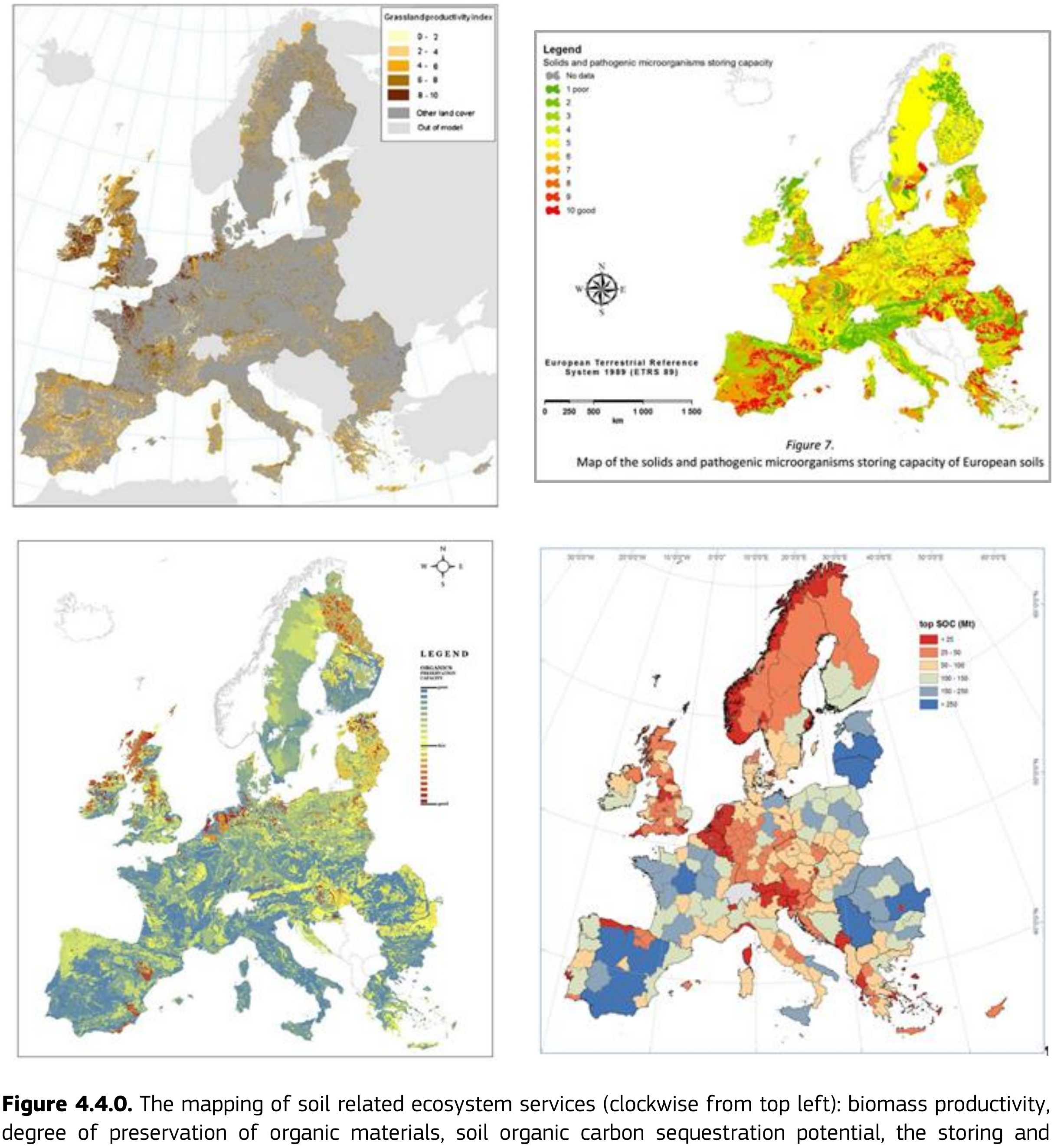

Figure 4.4.0. The mapping of soil related ecosystem services (clockwise from top left): biomass productivity, degree of preservation of organic materials, soil organic carbon sequestration potential, the storing and filtering potential of soil.

4.4.3 Drivers and pressures

The most important pressures influencing the condition of soil are increasing competition for land (often associated with a loss of soil as an ecosystem), land use change, inappropriate or unsustainable land management practices and climate change (as climate is a key factor in soil processes)[95].

4.4.3.1 Assessment at the level of EU-28

Soils are subject to a range of direct or indirect pressures. Separating natural processes from human actions is often complicated and interlinked (e.g. soil erosion is a natural process but can be amplified by how land is used). Some human activities have clear impacts (e.g. pollution).

The EU Soil Thematic Strategy identified a series of pressures that affect soil condition. These include erosion, compaction, sealing, salinization, landslides and pollution (both in a local and diffuse sense), which in turn affects soil organic matter levels and soil biodiversity. Pressures acting on the soils of the EU, together with their impacts, are described in more detail by Jones et al (2012), FAO & ITPS (2015) and Montanarella et al. (2016). The reader is also directed to Chapter 3 for additional information on soil sealing and acidification.

One can hypothesize that all soils are under pressure, even if only considering indirect pressure, from air pollution and climate change. While it can be proposed with some confidence that 25-30% of EU agricultural soils are currently either losing organic carbon, receiving more nutrients than they need, are eroding or are compacted or suffer secondary salinization, or have some combination, the recent proposal for a Horizon Europe Mission (Caring for soils is caring for life[96]) set a goal that 75% of soils in the EU should be healthy by 2030 for healthy food, people, nature and climate. An additional 30% of non-agricultural soils (i.e. forest, shrub and sparse vegetation) are also eroding at an unsustainable level.

Soil pollution, compaction and secondary salinisation are probably the biggest unknowns. Soil pollution includes both local hotspots (e.g. ex-industrial land, landfills, etc.) and more widespread contamination reflecting inputs from air pollution legacy, agricultural land use (pesticides, metals, sewage sludge) as well as from unquantified emerging pollutants (e.g. microplastics).

In this assessment, two indicators are used to show pressure: soil erosion by water and concentrations of nitrogen and phosphorous (Table 4.4.1).

With regards to soil erosion, the following conclusions can be stated in relation to state and trends:

- Following a decline in the previous decade in the EU, the soil erosion rate does not show a significant decrease between 2010 and 2016. The 'picture' is heterogeneous as most of the regions perform well applying increased conservation measurements; however, soil erosion rates are still above soil formation rates and the most erosive regions (e.g. Mediterranean areas) show little progress in combating the issue. This means that the efforts to reduce soil erosion need to be reinforced with more agro-environmental friendly measures and better targeting areas with high erosion risk.
- Taking into account the current trends, a stronger sets of soil conservation practices (e.g. cover crops, plant residues, reduced tillage, contouring, stone walls, agro-forestry) is needed to face soil erosion in hot spots. This indicator does not yet take account the effect of climate change, which will likely have a negative impact in increasing soil erosion rates in the EU.
- The current agro-environmental policies need to focus more on hot spot areas, especially on agricultural lands where current rates are higher than sustainable ones. In addition, an important step would be to set a policy target of halting severe and very severe/extreme erosion on agricultural land by 2030

With regards to soil nutrient, the following conclusions can be stated in relation to state and trends:

- Indicators clearly show (e.g. EUROSTAT 2020) that there is currently an excess of fertilizer applications in the EU.

[95] An overview of pressures from agricultural land use is provided by EEA (2020): Chapter 13_SOER2020. Environmental pressures and sectors https://www.eea.europa.eu/publications/soer-2020/chapter-13_soer2020-environmental-pressures-and-sectors/view

[96] Proposed Soil Health and Food Mission: https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/32d5d312-b689-11ea-bb7a-01aa75ed71a1

- Excessive fertilizer levels can detrimental impacts on ecosystems, which include the mineralization of soil organic carbon, algae blooms (that causing the depletion of oxygen in aquatic systems), the leaching of nitrates to drinking water, and the emission of greenhouse gases into the atmosphere.
- Nutrients from manure and fertilizers enter lakes and streams through runoff (i.e. washed off the land by rainfall) or by soil erosion (highly relevant for phosphorous).

LUCAS data from 2009 have been used to establish observed baselines for N and P. Data for 2015 are currently being processed but unfortunately are not available in time for this report, which means that trend information is not available.

Box 4.4.1. LUCAS SOIL

Many of the data reported in this chapter are derived from the LUCAS Soil Module.

The Land Use/Land Cover Area Frame Survey (LUCAS) is a EUROSTAT project to monitor land use and land cover changes across the EU. The LUCAS survey is performed every three years and includes field observations at more than 273 000 points. Since 2009, soil samples have been taken from about 10% of the surveyed locations. The first LUCAS soil survey, in 2009 collected 19 969 topsoil samples (0-20 cm) from 25 EU countries (excluding Romania, Bulgaria and Croatia). In 2012, a further 2 034 topsoil samples were collected from Bulgaria and Romania following the protocols of 2009. The overall sampling density of this pan-European soil survey is nearly one soil sample every 196 km^2 (Panagos et al., 2013), which means one sample about every 14 km x 14 km.

The LUCAS topsoil dataset is the most comprehensive and harmonised soil dataset covering the EU, supporting studies on the distribution of physical properties (clay, silt and sand) (Ballabio et al., 2016), soil erodibility (Panagos et al., 2014), soil organic carbon (de Brogniez et al., 2015) and the modelling of metal pollution (Ballabio et al., 2018). The number of points selected is based on a stratification reflecting main land cover types (based on CORINE land cover classes) and country surface (Carre et al., 2013). Orgiazzi et al. (2018) described in detail the soil sampling procedure. The samples were analysed by a single laboratory to reduce uncertainties due to analysis based on different methods or different calibrations in case of multiple laboratories. Parameters reported include: percentage of coarse fragments, particle size distribution (silt, clay, sand), pH, organic carbon, calcium carbonate, soluble phosphorous, total nitrogen, extractable potassium, cation exchange capacity (CEC), heavy metals and multispectral properties (Tóth et al., 2013).

Box 4.4.2. Soil erosion modelling

Soil erosion data presented in this report are derived from a modified version of the Revised Universal Loss Equation (RUSLE) model that has been adapted for European conditions (Panagos et al., 2015). RUSLE2015 improves the quality of calculating soil erosion by sheet and rill erosion by using the most current high-resolution (100m) input layers.

Annual soil loss rates by water erosion (measure in t ha^{-1} yr^{-1}) is based on the following equation:

$E = R \times K \times C \times LS \times P$ where:

- R: Rainfall Erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1})
- K: Soil Erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}),
- C: Cover-Management factor (dimensionless),
- LS: Slope Length and Slope Steepness factor (dimensionless),
- P: Support practices factor (dimensionless).

Table 1. EU aggregated pressure data for soil (source JRC)

Pressure class	Indicator	Unit	Baseline value (erosion: 2010) (nutrients: 2009)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3 to 9]	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score [3 to 9]
Soil degradation	**Soil health**				unresolved			unresolved	
Soil erosion	Soil erosion by water	t ha^{-1} yr^{-1}	2.46 (2010)	-0.67	→	5	-9	↑	5
Soil nutrients	Topsoil nitrogen content croplands	g kg^{-1}	1.84	NA	unresolved	4	NA	unresolved	
	Topsoil nitrogen content grasslands	g kg^{-1}	2.87	NA	unresolved	4	NA	unresolved	
	Topsoil nitrogen content forests	g kg^{-1}	2.11	NA	unresolved	4	NA	unresolved	
	Topsoil phosphorous content croplands	mg kg^{-1}	32.35	NA	unresolved	4	NA	unresolved	
	Topsoil phosphorous content grasslands	mg kg^{-1}	33.68	NA	unresolved	4	NA	unresolved	
	Topsoil phosphorous content forests	mg kg^{-1}	20.22	NA	unresolved	4	NA	unresolved	

↑: Significant improvement (significant downward trend of pressure indicator); →: No change (the change is not significantly different from 0% per decade); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment.

4.4.3.2 In depth assessment

The following section, partly developed with the Soil Health and Food Mission Board[97], outlines the main pressures on soil.

4.4.3.2.1 Erosion

Erosion by water

Panagos et al. (2015) reported that 24% of the EU-28 exhibits unsustainable soil water erosion rates (>2 t ha^{-1}). Mean soil erosion by water for EU-28 in 2010 was 2.46 t ha^{-1} yr^{-1}, resulting in a total annual soil loss of 970 Mt. This covers a wide range of land use types, with around 70% occurring on land in agricultural systems.

The potentially erosive area of the EU-28 is about 3,912 x 103 km^2, which is 89.6% of the land area (Figure 4.4.1). The erosive areas are defined from CORINE Land Cover classes and includes all the agricultural areas (Classes 2x), forests (classes 3.1.x), scrub and herbaceous areas (classes 3.2.x), sparsely vegetated areas (class 3.3.3) and burnt areas (class 3.3.4).

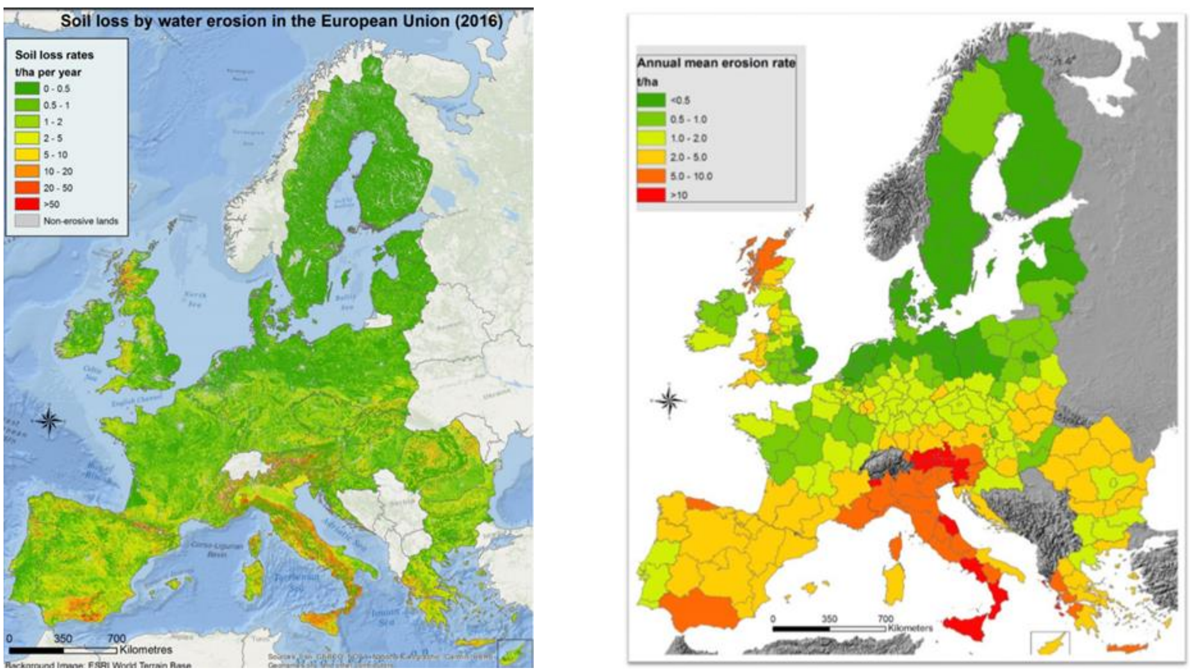

Figure 4.4.1. a) Soil loss by water erosion assessment for 2016; b) aggregated for NUTS2

The non-erosive includes land covers not prone to soil erosion (cities, urban areas, bare rocks, glaciers, wetlands, lakes, rivers and marine waters). In practice, artificial surfaces (class 1.x), beaches and dunes (3.3.1), bare rocks (3.3.2), glaciers (3.3.5), wetlands (class 4.x) and water bodies (class 5.x) are not considered. The non-erosive area has slightly increased compared to 2010, mainly due to urbanisation.

The mean soil erosion rate in EU-28 for 2016 is estimated to 2.45 t ha^{-1} yr^{-1}, which is close to the 2010 mean erosion rate of 2.46 t ha^{-1} yr^{-1} (Panagos et al 2020). This decline of 0.4% in 6 years is much smaller than the reduction observed during the period 2000-2010 (where the reduction in erosion was 9% per decade).

The spatial patterns of the 2016 EU soil erosion map (Figure 1a) are similar to that of 2010. The differences between the two datasets are more obvious when comparing aggregated data at regional level (Figure 1b). The estimated total erosion is about 960 million tonnes (Panagos et al 2020), a slight decrease of about 10 million

[97] Pers. Comm. Prof. Bridget Emmett, Centre for Ecology & Hydrology, Bangor, UK. May 2020

tonnes compared to 2010 (Panagos et al., 2015a). This Indicator 'Estimated soil erosion by water' aggregates the detailed dataset of 100 x 100m resolution (Figure 4.4.1) in different NUTS levels. The geographical distribution of the mean erosion rates show an increase of in eight countries and a decrease in 20 countries (Table 4.4.2).

Table 4.4.2. Detailed assessment of soil erosion by water (after Panagos et al 2020).

Member State	Baseline value 2010 $(t\ ha^{-1}\ yr^{-1})$	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score [3-9]
Austria	7.19	-0.17	→	5
Belgium	1.22	0.17	→	5
Bulgaria	2.05	9.83	↓	5
Cyprus	2.89	5.50	↓	5
Czechia	1.65	-1.17	→	5
Germany	1.25	-3.17	→	5
Denmark	0.50	-9.50	↑	5
Estonia	0.21	-11.33	↑	5
Greece	4.13	2.67	→	5
Spain	3.94	2.50	→	5
Finland	0.06	-0.67	→	5
France	2.25	-4.00	→	5
Croatia	3.16	-39.50	↑	5
Hungary	1.62	-1.33	→	5
Ireland	0.96	-1.83	→	5
Italy	8.46	2.50	→	5
Lithuania	0.52	-0.83	→	5
Luxembourg	2.07	-0.33	→	5
Latvia	0.32	3.67	→	5
Malta	6.02	-42.83	↑	5
Netherlands	0.27	-4.17	→	5
Poland	0.96	3.83	→	5
Portugal	2.31	-10.00	↑	5
Romania	2.84	-2.67	→	5
Sweden	0.41	-2.67	→	5
Slovenia	7.43	0.50	→	5
Slovakia	2.18	-1.50	→	5
United Kingdom	2.38	-0.33	→	5

↑: Significant improvement (significant downward trend of pressure indicator); →: No change (the change is not significantly different from 0% per decade); ↓: Significant degradation (significant upward trend of pressure indicator);

There are significant positive signs of conservation practices increase in Austria, Estonia, France, Germany and Portugal. Bulgaria shows a decrease in management practices to reduce soil erosion which has an effect in increasing the mean soil erosion rate to 2.18 t ha-1 yr-1 (+5.9%). Three Mediterranean countries with high erosion rates, Italy (8.59 t ha-1 yr-1), Spain (4.0 t ha-1 yr-1) and Greece (4.19 t ha-1 yr-1) show an increase of mean rates in 2016 by at least 1.5% compared to 2010. If those four countries have maintained the same level of management practices as in 2010, then the mean soil erosion rate in EU-28 could have been reduced to 2.43 t ha-1 yr-1 (-1.3%).

The changes of soil erosion for the period 2010-2016 at regional level show a heterogeneous picture. There is a decrease in mean erosion rates for northwestern regions while the Mediterranean indicates a worsening situation.

Agricultural area under severe erosion

Looking specifically at agricultural areas (based on CORINE Land Cover classes for arable and permanent crop area (CORINE raster codes: 12-17, 19-22) and permanent meadows and pasture (CORINE raster codes: 18, 26), a threshold of 11 tonnes ha-1 yr-1 has been applied to Figure 4.4.1 to determine the agricultural areas under severe erosion. Table 4.4.3 aggregates the area under severe erosion both in terms of area (1 000 ha) and as a percentage of total agricultural land.

Table 4.4.3. CAP context indicator: agricultural area (%) under severe erosion, 2016 (Panagos et al 2020).

Soil erosion by water		Agricultural areas at risk of soil erosion by water					
Member State	Tonnes ha^{-1} yr^{-1}	Estimated agricultural area (1,000 ha) affected by moderate to severe water erosion (> 11 t ha^{-1} yr^{-1})			Estimated agricultural area (%) affected by moderate to severe water erosion (> 11 t ha^{-1} yr^{-1})		
		Total agricultural area	Arable and permanent crop area	Permanent meadows and pasture	Total agricultural area	Arable and permanent crop area	Permanent meadows and pasture
		1 000 ha			% of total area in each category		
EU-28	**2.45**	**14 119.2**	**11 979.9**	**2 139.2**	**6.6**	**7.2**	**4.5**
AT	7.19	660.9	211.9	449.1	19.9	10.8	33.3
BE	1.22	7.2	6.7	0.4	0.4	0.5	0.1
BG	2.18	246.0	231.6	14.4	4.0	4.4	1.8
CY	2.99	34.5	34.4	0.1	7.4	7.9	0.3
CZ	1.63	68.1	65.6	2.5	1.5	1.8	0.3
DE	1.23	301.6	267.3	34.2	1.4	1.6	0.8
DK	0.47	0.1	0.1	0.0	0.0	0.0	0.0
EE	0.19	0.0	0.0	0.0	0.0	0.0	0.0
EL	4.19	652.8	599.9	53.0	10.2	11.6	4.3
ES	4.00	2 714.8	2 478.5	236.3	9.8	10.1	7.2
FI	0.06	0.1	0.1	0.0	0.0	0.0	0.0
FR	2.20	937.2	639.9	297.3	2.8	2.7	3.0
HR	2.41	162.3	131.2	31.1	6.4	6.6	5.7
HU	1.61	177.1	173.3	3.8	2.8	3.2	0.4
IE	0.95	16.8	7.3	9.5	0.4	0.7	0.3
IT	8.59	5 610.0	5 081.0	528.9	32.8	33.3	28.1
LT	0.51	0.8	0.8	0.0	0.0	0.0	0.0
LU	2.07	4.6	4.4	0.2	3.3	4.3	0.5
LV	0.33	0.3	0.3	0.0	0.0	0.0	0.0
MT	4.47	1.4	1.4	0.0	8.9	8.9	0.0
NL	0.26	0.1	0.1	0.0	0.0	0.0	0.0
PL	0.99	278.4	277.4	1.1	1.4	1.7	0.0
PT	2.17	225.6	222.9	2.7	5.2	5.4	1.3
RO	2.80	1 264.2	1 103.7	160.6	9.1	10.1	5.6
SE	0.40	12.8	11.7	1.1	0.3	0.3	0.2
SI	7.46	307.4	242.7	64.7	42.2	41.1	47.2
SK	2.16	160.5	153.1	7.4	6.7	7.3	2.5
UK	2.37	273.7	32.7	241.0	1.7	0.5	2.7

Note: Data calculated using RUSLE model. EU, national and regional data: 2012 (CLC2012). Corine Land Cover classes: total agricultural area (12-22 and 26), arable and permanent crop area (12-17 and 19-22) and permanent meadows and pasture (18 and 26).

The assessment shows that around 12 million ha of agricultural land (including pastures) are under threat of severe erosion. This represents the 6.58% of the total agricultural area in EU. This is similar to the situation in 2010 as the share of severe erosion was 6.62%. The agricultural areas have a higher share of severe erosion compared to pastures and grasslands.

Slovenia and Italy have the highest proportion of severe soil erosion in agricultural areas (42% and 32.8%, respectively). In addition, some Mediterranean countries (e.g. Greece, Spain, Cyprus and Malta) together with

Austria[98] and Romania, display relatively high percentages of agricultural land in severe erosion (i.e. higher than the mean EU-value). Nine northern countries (DK, EE, LV, LT, FI, SE, BE and IE) have less than 0.5% of their agricultural areas in severe erosion (Figure 4.4.2).

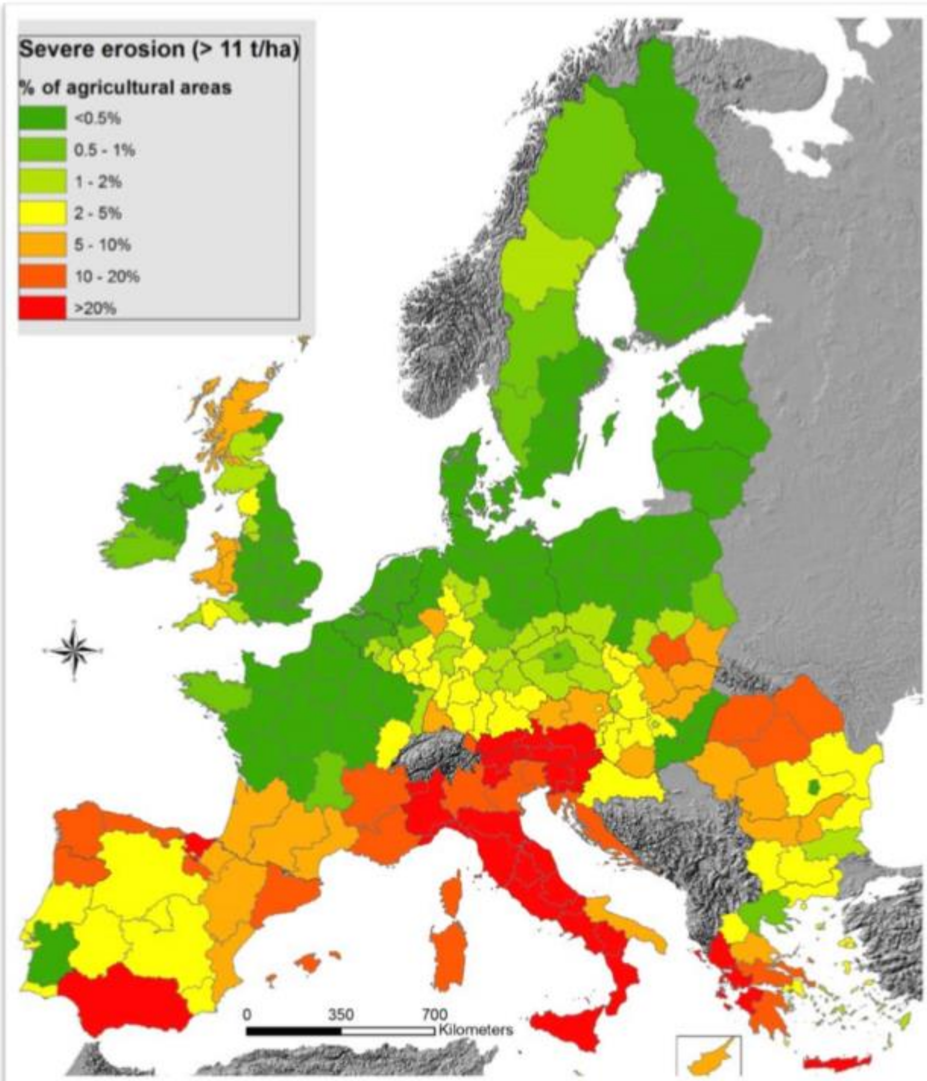

Figure 4.4.2. Percentage of agricultural area affected by severe erosion (%) – CAP Context Indicator 42 (Panagos et al 2020)

Soil erosion rates per land cover

The mean rate of soil loss for the 110 million ha of arable land of the EU (2.67 t ha^{-1} yr^{-1}) is 10% higher than the overall soil loss rate (2.45 t ha^{-1} yr^{-1}). Permanent crops have a high mean soil loss rate (9.45 t ha^{-1} yr^{-1}), as most vineyards and olive trees are located in hilly Mediterranean areas with high rainfall erosivity. Conversely, the mean annual soil loss rate in grassland is 2 t ha^{-1} yr^{-1}, mainly due to higher vegetation densities and, as a consequence, lower soil disturbing activities (known as C-Factor, reflecting the protective effects of plants on soil cover, etc.). Heterogeneous agricultural areas have a higher overall mean rate of soil loss (4.2 t ha^{-1} yr^{-1}) than arable land areas, despite the fact that their C-Factor is lower. This is due to differences in topography (which influence the slope length factor), as the arable lands are typically found in flat or gently sloping terrain.

[98] Discussions are ongoing to resolve discrepancies in the results for Austria in certain conditions.

Woodlands and semi-natural ecosystems are very heterogeneous in terms of soil loss estimates. Despite the fact that they occupy more around 34% of the EU erosive land, woodlands have by far the lowest rate of soil loss (0.07 t ha^{-1} yr^{-1}), contributing less than 1% of the total soil loss in Europe (Figure 4.4.3). Areas covered with shrub and herbaceous vegetation have a mean soil loss rate of 2.69 t ha^{-1} yr^{-1}. Very high soil loss rates (40 t ha^{-1} yr^{-1}) have been estimated for sparsely vegetated areas, which are mainly bad-lands in high attitudes with scattered vegetation. Those sparsely vegetated areas explain the high rates of soil loss in southern Spain and Italy. However, this is the most uncertain land-cover group due to the uncertainty of the C-Factor and the ambiguity in CORINE Land Cover classification.

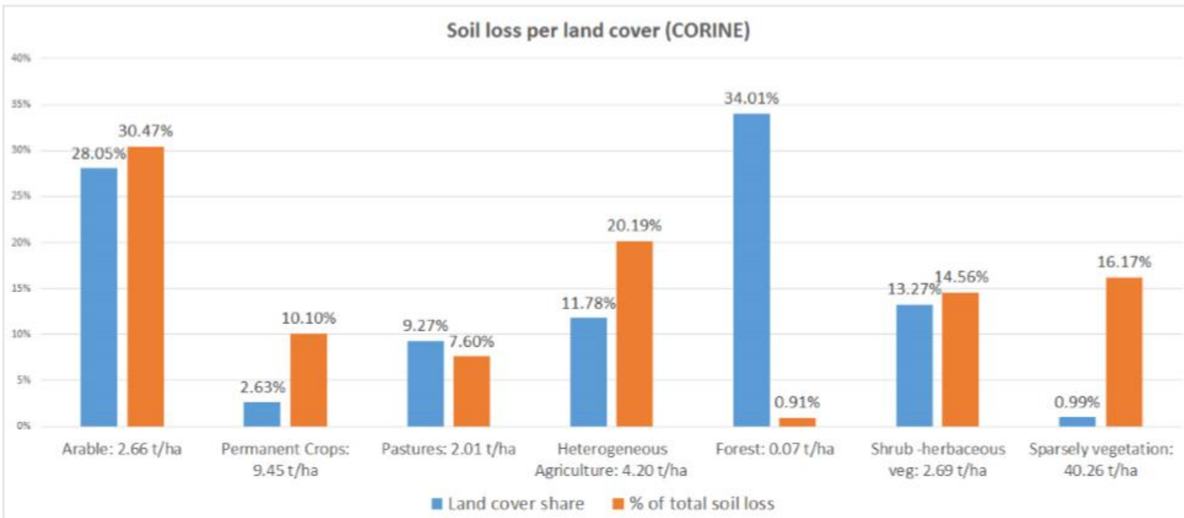

Figure 4.4.3. Rates of mean soil loss per land cover group and corresponding shares of soil loss (Reference: 2016).

Wind erosion

A JRC model (Borelli et al. 2017) shows wind erosion in EU is 0.53 Mg ha−1 y−1. It is estimated that·7% of arable land has problems with wind erosion, with 5·3% and 4·4% displaying moderate and high rates of wind erosion, respectively. However, trend information is currently lacking.

Soil nutrients assessment

The Gross Nutrient Balance Indicator (EUROSTAT 2020) shows that there is currently an excess of fertilizer applications in the EU. There is a surplus of 50 kg ha-1 for nitrogen and 2 kg ha-1 for phosphorous for agricultural land. The European Commission (EC 2018) reports that Nitrates Vulnerable Zones (NVZ) cover 2,175,861 km^2 of the EU (latest figures for 2015 and includes MS that apply a whole-territory approach). NVZ therefore represent approximately 61% of agricultural soils. This means that there are obligations to reach a balanced fertilisation for 61% of agricultural soils (arable and grasslands). SOER 2020 (EEA) reports that for 65-75% of agricultural soils, nitrogen values exceed critical values beyond which eutrophication can be expected (De Vries et al., in prep).

There are also issues from atmospheric deposition of nutrient nitrogen in non-agricultural systems. CIAM/IIASA (2018) reported that critical loads for eutrophication were exceeded for 67% of the area of ecosystems in Europe 2017 (See also point 6 on Contamination).

Nitrogen

Among all the essential nutrients, nitrogen (N) is required by plants in the largest quantity and is important for soil fertility and soil quality (Reeves, 1997). Nitrogen is the most frequent limiting factor in crop productivity (Smil, 1999). The spatial distribution of nitrogen in the soil is affected not only by natural ecological processes but also by intensive human activities (Wang et al., 2013). This is an important challenge for accurate predictive mapping at regional scales.

The distribution of topsoil nitrogen (Figure 4.4.4) is highly correlated with soil organic carbon (SOC), given that nitrogen is a major component of organic matter. While the ratio between carbon and nitrogen (C/N) can vary, some carbon-rich soils are also nitrogen rich, at least in terms of absolute quantities. Given this relation, it is quite clear that vegetation cover and climate are the main drivers in the distribution of nitrogen. As shown by Figure 4, forests and grassland areas tend to have higher nitrogen content (Table 1). Forests in Scandinavia and in mountain areas are clearly delimited. Climate also acts as a main driving force influencing nitrogen content along the Atlantic area; in particular, Ireland and the United Kingdom show higher N concentrations due to a fresh and humid climate, which favours organic matter accumulation. Soil texture also plays a role in stabilising organic matter and thus nitrogen. Areas with coarser soils, such as most of Poland, tend to have less nitrogen even if other conditions are favourable (e.g. vegetation, climate).

While the nitrogen concentration is relevant to assessing stocks and potential N2O emissions, the C/N ratio between may better represent the differences in the organic matter composition. Where higher rates correspond to more oligotrophic soils, typical of coniferous forests, or to peatland soils, lower rates are typical of more balanced nutrient-rich soils.

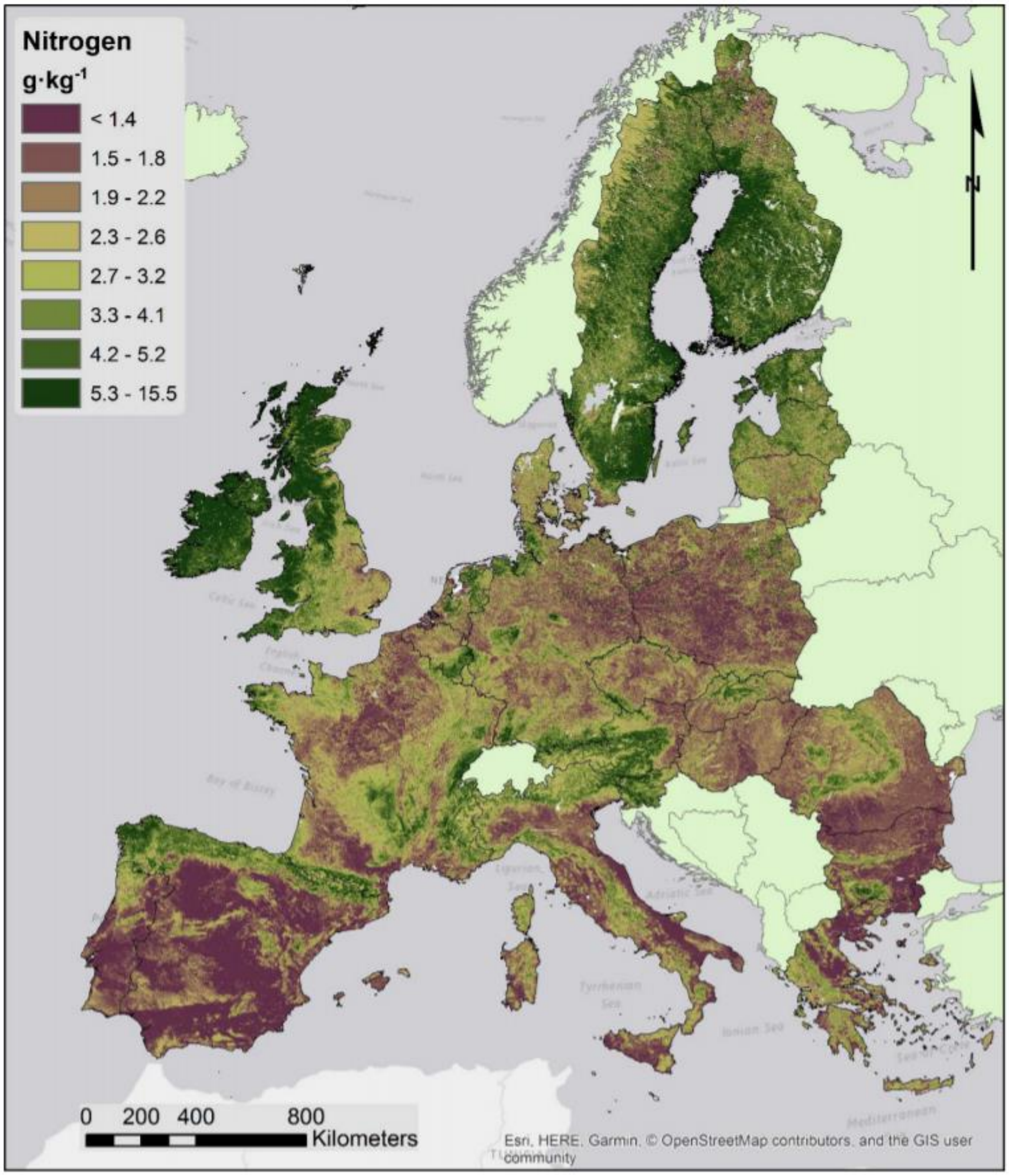

Figure 4.4.4. Topsoil nitrogen concentrations (Ballabio et al., 2019).

Phosphorus

Phosphorus (P) can be naturally derived from the weathering of minerals in parent rock material. It is usually the second most limiting nutrient for terrestrial primary production (Cordell et al., 2009). In agricultural areas fertilisation can result in higher levels of P, especially in highly productive areas where high input of P fertilisers is reported (Tóth et al., 2014). Modern agriculture is highly dependent on P fertilisers, the supply of which is strategically critical at global level.

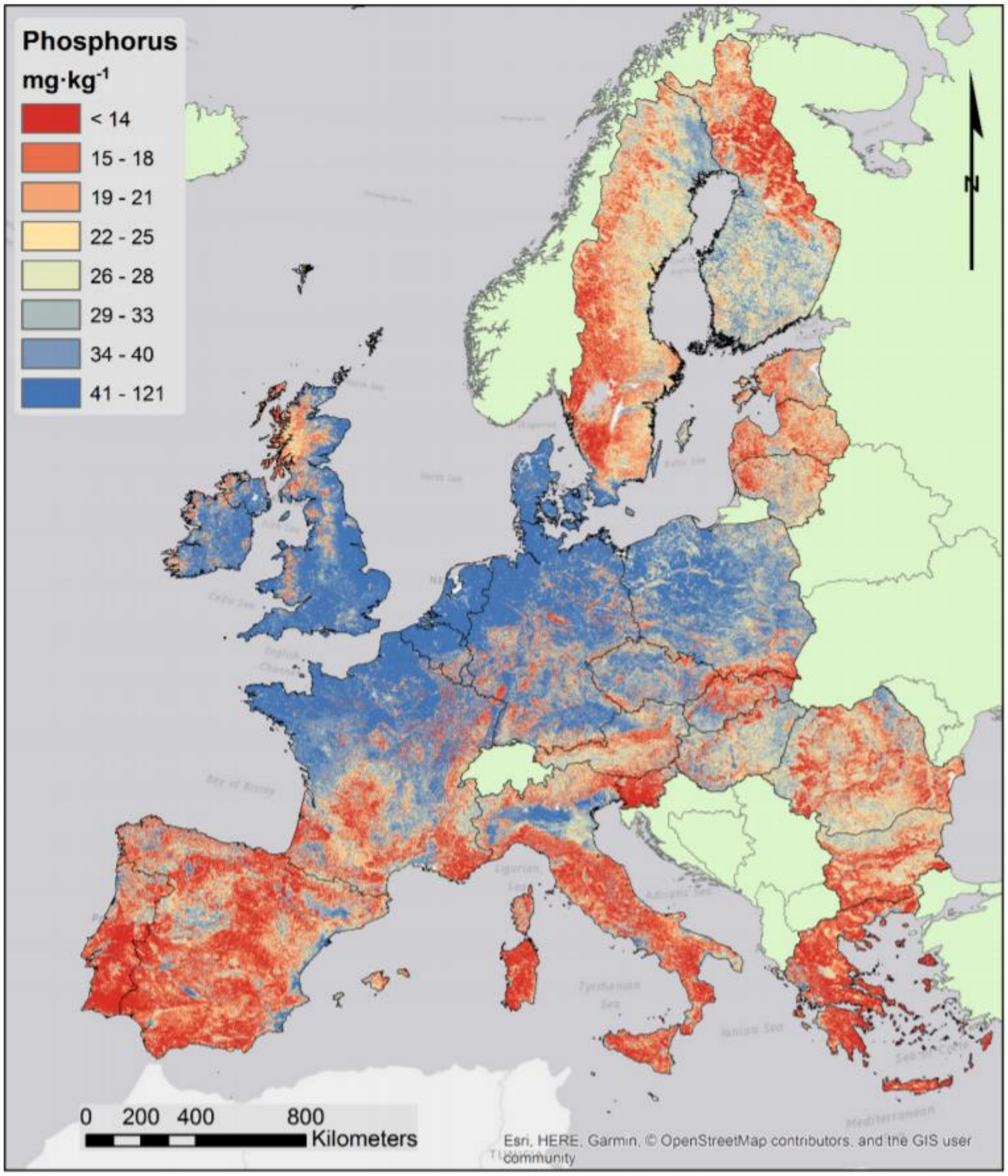

Figure 4.4.5. Topsoil phosphorus concentrations (Ballabio et al., 2019).

The map of soil phosphorus (Figure 4.4.5) shows a clear trend in which land use appears to have a strong influence. In particular, most of the agricultural areas have higher levels of P. This is quite evident in areas such as the River Po plain (Italy) where levels of P diverge from the national average. In general, areas with natural land cover and those with a prevalence of permanent crops correspond to lower levels of P.

The geological background seems to have a quite small influence, whereas climate is much more relevant; this is probably because of higher fertilisation rates in wetter climates. The P map produced in this study also confirms models of P fertilisation load (Potter et al., 2010).

In should be noted that phosphorus is a limited resource with significant reserves in just a few countries (China, Morocco, Russia, South Africa, etc.). There is a just one phosphorus mine in the EU, which is located in Finland. Therefore, optimising the use and application of phosphorus as a fertiliser is beneficial to both the environment and the economy of the EU. Mapping phosphorus concentration in soils is crucial for designing long-term agri-environmental policies that do not harm our environment and health, and at the same time guarantee optimal fertilisation rates in agriculture. The reforms of the CAP, with a shift to decoupled payments and away from direct support linked to production of specific crops, have already led to a strong reduction in fertiliser use.

Therefore, the data sets reported here can be regarded as the most up-to-date baseline to study the impact of CAP measurements and development programmes in Member States in reducing nutrient pollution (nitrogen, phosphorus) from agriculture in order to meet the commitments of the Water Framework Directive.

Organic soils

Special attention should be given to peatlands (organic soils). Byrne et al. (2004) reported an area of 340,000 km2 of peat soils in the EU Member States and Candidate Countries. Tanneberger et al. (2017) has updated figures on extent per country, which indicates that the extent of peatlands in the EU is closer to 270,000 km2, although the figures for some countries are still approximations. On this basis, peat soils would cover around 6.3% of the EU land area, at least half of which are estimated to have been drained. The extent of peatland soils is significantly larger than the extent of inland wetlands mapped by CLC2018 (probably as a result of the mapping of surface vegetation characteristics that mask the soil type). This will result in the oxidising of the peat and loss carbon to the atmosphere (JRC 2016).

Results from hydrological reconstructions indicated 60% of European peatlands are drier than they were 1000 years ago due to these direct human impacts and climatic drying (Swindles et al. 2019). Not all peat being degraded is under agriculture. Schils et al., 2008 estimates about 20,000 km2 of drained peat (ca. 6% of peatland) is not in agricultural use as cropland or grassland (about 0.5% of EU).

Compaction

Detailed assessment for compaction is very uncertain. Partial estimates for the EU based on the modelling of representative soil profiles suggest that 23% of the territory assessed had critically high densities (JRC 2016). In a separate study the JRC estimated that 33% of soils are susceptible to compaction, of which 20% were moderately susceptible (JRC 2009). The issue is more likely in agricultural soils but it is also found in organic-rich forest soils. Data on trends information are lacking.

Pollution

Assessing the extent and impact of soil pollution is highly problematic, very challenging, and with many unknowns, especially in relation to diffuse soil pollution of natural landscapes that cover more than half of the EU land territory. In addition, more than 700 recognised soil pollutants have been identified (Norman, 2014), the majority of which have not been assessed in a systematic manner.

In terms of local soil pollution, Paya Perezet al. (2018) reported 2.8 million potentially contaminated sites for EEA-39. However, the total area covered by such sites is not known. Additionally, there are differences between countries regarding which polluting activity they count in or exclude. The EEA indicator "Progress on the remediation of contaminated sites" is based on several consecutive Eionet assessments. Based on the latest Eionet questionnaire, Paya Perez et al. (2018) counted 650,000 registered sites where polluting activities took/are taking place, referring to countries where national and/or regional inventories exist; 65,500 sites have been remediated. The Cocoom InterReg Project estimated that there are more than 500,000 landfills in EU-28. 90% are regarded as non-sanitary landfills (i.e. predating the Landfill Directive (1999). No actual figures exist of the total numbers of landfills in the EU.

The situation is even more complex for the assessment of diffuse soil pollution. Numerous experimental and laboratory studies clearly demonstrate the impact of pollution on soil dwelling organisms and the potential to human health. However, it is difficult to assess the area or extent of pollutants. For example, there are no data on the extent of pesticide contamination, persistent organic pollutants (POPs), microplastics, veterinary products or pharmaceuticals, as well as emerging pollutants such as PFAS. Pimentel & Levitan (1986) reported that around 3,000 types of pesticides have been applied in EU agricultural environment during the past 50 years. They estimated that less than 0.1% of the pesticide applied to crops actually affects the target pest.

Analysis of LUCAS soil samples have established base lines for several metals (e.g. Toth et al, 2014; Ballabio et al 2018) while Silva et al. (2019) showed that 83% of samples tested contained one or more residue of pesticides and 58% contained mixtures. For the heavy metal cadmium, De Vries et al. (In prep and cited in EEA 2020) states that 21% of agricultural soils have concentrations in the topsoils which exceed groundwater limits used for drinking waters.

Critical loads are defined where inputs of a pollutant may impact on ecosystem structure and function. (CIAM IIASA 2018) defined the critical loads for eutropication and acidification on 2.93 and 2.65 million km2 of European ecosystems, respectively. In 2005, deposition exceeded the critical loads for eutrophication in 67% of the analysed ecosystem area. For acidication this was the case for 11% of the ecosystem area. Slootweg et al. (2007) reported that the EU ecosystem soils at risk from deposition of heavy metals such as mercury and lead in 2000 were as high as 51% and 29% respectively. Lema & Martinez (2017) reported 10 million tons of sewage sludge production for EU (excluding Croatia), 37% of the sludge produced in the EU is being utilized in agriculture.

Plastics Europe (2016) reported that 3.3% of total EU plastic demand (49 million tonnes) was used in agriculture. Agriculture produced 5% of plastic waste of EU (EC, 2018).

Organic farming covered 13.4 million hectares of agricultural land in the EU-28 in 2018. This corresponds to 7.5% of the total utilised agricultural area of the EU-28 (EUROSTAT 2020b). We can assume that pesticides are applied in most of the remaining 92.5% of arable area (21% of EU).

Soil sealing and net land take

Artificial areas cover 5.2% of the EU (see Chapter 6) of which it can be assumed that about 50% is sealed. This would imply that 2.5% of urban land is exposed to pressures (e.g. low inputs, compaction, pollution) The rate of net land take was estimated to be around 539 km² per year during the period 2012-2018, with (EEA 2019). Between 2000 and 2018, 78% of land take in the EU-28 affected agricultural areas (EEA 2018). As the rate of recycling of urban land for development is currently only 13% (EEA 2020), this effectively means that every ten years an area the size of Cyprus is paved over (9,300 km2) from agricultural, forestry and conservation land. Between 2000 and 2006, the average increase in artificial areas in the EU was 3%, however, this masks local issues. Figures exceed 14% in Cyprus, Ireland and Spain. However, sealing generally consumes high quality agricultural soil. See also Chapter 3.1 for imperviousness in urban ecosystems and land take and soil sealing in other ecosystem types (Chapter 3).

Salinisation

In addition to naturally saline soils (reflecting parent material or groundwater movements), salts can accumulate in soils due to increased temperatures, decreasing precipitation and unsustainable irrigation, cultivation and drainage on cultivated land. This processes is referred to as secondary salinization. The extent of secondary salinisation in EU is still uncertain. Ranges estimate from 1 - 4 million hectares (for the enlarged EU), predominantly occurring in the Mediterranean Region and Central European countries (JRC 2008). The higher end of the range would means that 0.95% of land is estimated to be affected in the EU.

In 2016, 10.2 million hectares were actually irrigated (5.9% of EU). 25% of this area is at risk of secondary salinization (i.e. 1.5% of EU). Spain (15.7%) and Italy (32.6%) had the largest shares of irrigable areas in the agricultural areas of the EU (JRC 2016). Major areas of salt affected soils within the EU are located in parts of Spain, Portugal, Italy, Greece, Cyprus, France, Bulgaria, Romania and Hungary, where salinization is most severe, but can also occur in rather temperate countries such as Denmark, Poland, the Netherlands, Latvia and Estonia. Several studies carried out in various European countries indicate an increase of soil salinization (Beek & Toth, 2012; Paz et al 2006; Tsanis et al, 2016).

Finally, the area at risk of saline intrusions in coastal areas due to sea-level rise is unknown. However, salinization due to sea water intrusion may not only occur with rising sea-level, but also with inappropriate management of land in coastal areas (such as irrigation).

Desertification

The most recent estimate of sensitivity to desertification in Southern, Central and Eastern Europe in 2017 suggested that 25% of the study area (411 000 km2 out of 1.7 million km^2) was at High or Very High Risk (Prăvălie et al. 2017). Due to improved data quality, the extent of land under these high risks was 75% more than the previous estimation done in 2008. Almost half of the land area of Spain (~ 240,000 km2) is deemed highly or very highly susceptible to degradation while large parts of Greece (34%), Bulgaria (29%) and Portugal

(28%) are at high risk. There are also concerns for Italy and Romania, where around 10% of their territories are highlighted.

Summary

Based on the convergence of evidence presented in the previous section, we can conclude that soil degradation is prevalent and extensive in the context of all EU territorial ecosystems. It is likely that all of the above drivers are singly, or in combination, resulting in a decline in soil condition and biodiversity (but there are no actual EU data demonstrating soil biodiversity change). It is also important to reflect that a simple reduction in the level of degradational processes still means that the ecosystem is under pressure (e.g. a reduction in the rate of sealing from urbanization and infrastructure development or soil erosion that is greater than the rate of soil formation, will still result in damage to the ecosystem). Soil as a natural resource and habitat for many important species (nutrient cycle, greenhouse gases) and ecosystem services (nutrient storage, water storage, pollutant filter) is negatively impacted. Ecosystem monitoring should include soils, and different threats and the links between them as joint effects must be observed and taken care of.

4.4.4 Ecosystem condition

4.4.4.1 Assessment at the level of EU-28

Under the MAES framework, the soil ecosystem condition is assessed by soil organic carbon (SOC) stocks. Most people are unaware that soil is an enormous store of organic carbon, which is a form or carbon associated with living matter as opposed to inorganic carbon such as diamonds, graphite and carbonate minerals in limestone. Organic carbon is made up of soil dwelling flora and fauna, together with plant and animal remains at various stages of decomposition, and humus (which is a stable form of decomposed matter).

After the oceans, soil is the largest store of organic carbon on the planet, holding about twice as much as that found in vegetation or the atmosphere (alternatively, more than all the vegetation on Earth and the atmosphere combined). Through photosynthesis, plants take carbon dioxide out of the atmosphere, where upon the carbon becomes incorporated in the soil through roots or eventually as litter fall. In this manner, soils have the capacity to regulate climate by offsetting carbon dioxide emissions elsewhere. However, this capacity is heavily dependent on how the land is used. Natural habitats tend to act as carbon sinks while land cover change (e.g. deforestation) and some agricultural practices can lead to a loss of carbon from the soil. In addition, organic carbon is a major component of several key ecosystem services, which include soil fertility, nutrient cycling, water retention and purification and pollution control. Soils with low levels of organic carbon will have lower resilience to pressures such as drought, compaction and flood prevention.

The loss of organic matter was highlighted as a major threat in the EU Soil Thematic Strategy (COM(2006)232) and has been proposed as an indicator to assess the impact of the EU's post-2020 Common Agricultural Policy. In addition, Member States are obliged to consider the impact of changes in soil carbon stocks on greenhouse gas emissions and removals from land use, land use change and forestry under the LULUCF Regulation. In this policy context, a loss of soil organic carbon is considered as environmental degradation.

The concentration of carbon in a soil sample is expressed as a (mass) percentage (e.g. g kg^{-1} or %) relative to the mass of the sample. The concentration of organic carbon in most soils is generally around 3 - 5% (but can be lower than < 1% in deserts).

The amount of organic carbon stored in soil is referred as it stock. It is calculated from the amount of carbon in a sample of known bulk density for a nominated depth. Soil organic carbon stocks are generally expressed in tonnes or Mg per hectare.

Assessment

Data from the LUCAS Soil Module (Hiederer 2018) shows that cultivated and permanent crops have the lowest soil organic carbon levels of all major land cover classes (around 17 g kg^{-1} C). By comparison, average levels for permanent grasslands in the EU are 2.4 times higher. Most croplands in EU are most likely to be already at sub-optimal levels – 1.5% of all land use have SOC levels below 1% C. This rises to 2.6% of arable soils (JRC LUCAS).

Analysis of short-term changes in soil organic carbon concentration from 2009-2015 for LUCAS points where land cover was the same in both dates show a decrease of about 0.5% per year on croplands which was statistically significant on the most carbon poor soils (Hiederer 2018). Subsequent, analysis suggests that changes in organic-rich and organic cropland soils may reflect sampling inconstancies.

Modelled estimates by the JRC of overall SOC stock changes (all soils) indicate that the total SOC change between LUCAS 2009/12 and 2015 show that about 60% of EU agricultural areas only experienced changes below 0.2% of the average stock (in tonnes). The results show a reduction in carbon stocks in grassland of about 0.04% while in arable land, the loss was about 0.06% (Panagos et al 2020). Around 10% of the area is predicted to have changes larger than ± 12 g kg^{-1} over the 6 year interval.

Changes in Soil Organic Carbon (SOC) content and stocks are not significant in the time interval of six-years between the two Lucas Surveys (2009-2015). This may raise the issue if soil organic carbon should be estimated in longer intervals (e.g. 10 years) and include higher number of samples representing better areas with low density of points and higher uncertainties.

The long-term assessment, derived through the Century biogeochemical modelling incorporating LUCAS Soil data (see Soil organic carbon Fact Sheet), indicates a slightly higher reduction in soil organic carbon stocks for agricultural land but changes are not significant.

The impact of management practices to increase soil organic carbon may take longer than 10 years in order to show significant changes. Overall the total SOC change between LUCAS 2009/12 and 2015 are minimal and account for less than 0.05% of the total stock in croplands and grasslands.

The impact of climate change should be further investigated as first signs show carbon change in cooler areas which become warmer and dryer. A new model framework integrating Machine-Learning and biogeochemical modelling is under developing at the JRC to investigate climate and management interactions on C cycling.

Table 4.4.4. EU aggregated condition data soil organic carbon in croplands and grasslands (Panagos et al 2020)

<table>
<tr><th>Indicator</th><th>Unit</th><th>Baseline value (2009)</th><th>Short-term trend (% per decade)</th><th>Short-term trend (change)</th><th>Short-term trend confidence score [3 to 9]</th><th>Long-term trend (% per decade)</th><th>Long-term trend (change)</th><th>Long-term trend confidence score [3 to 9]</th></tr>
<tr><td>SOC Stock Grasslands</td><td>10^6 t</td><td>4,352.4</td><td>-0.07%</td><td>→</td><td>7</td><td rowspan="2">-0.65</td><td rowspan="2">→</td><td rowspan="2">4</td></tr>
<tr><td>SOC Stock Croplands</td><td>10^6 t</td><td>7,819.3</td><td>-0.1%</td><td>→</td><td>7</td></tr>
</table>

→: No change (the change is not significantly different from 0% per decade)

4.4.4.2 In depth assessment

Soil organic carbon stocks assessment

Changes in soil organic carbon (SOC) stocks were assessed by fitting a boosted trees machine-learning model on the measured SOC concentrations of the samples taken in the 2009/2012 and 2015 LUCAS survey (Panagos et al 2020).

SOC stock changes between 2009/2012 and 2015

The results presented here should be considered as preliminary modelling comparative analysis between the two main LUCAS surveys. As such, besides the uncertainties due to sampling strategy, surveyors' accessibility and possible laboratory biases, the spatial maps include the uncertainties of modelling and the problems inherited from covariates data (land cover, climate data and terrain data). There are additional studies which are performed based only on the point data or the soil organic carbon content (%). However, this study focuses exclusively in the carbon stocks based a spatial interpolation model and not on simple statistical aggregation. The map presented in Figure 4.4.6 shows the changes in SOC concentration as predicted by the GMB model. The map depicts the changes as colour classes divided as quantiles of the predicted difference between SOC measured in 2009/2012 and 2015 (i.e. 2015 - 2009 values).

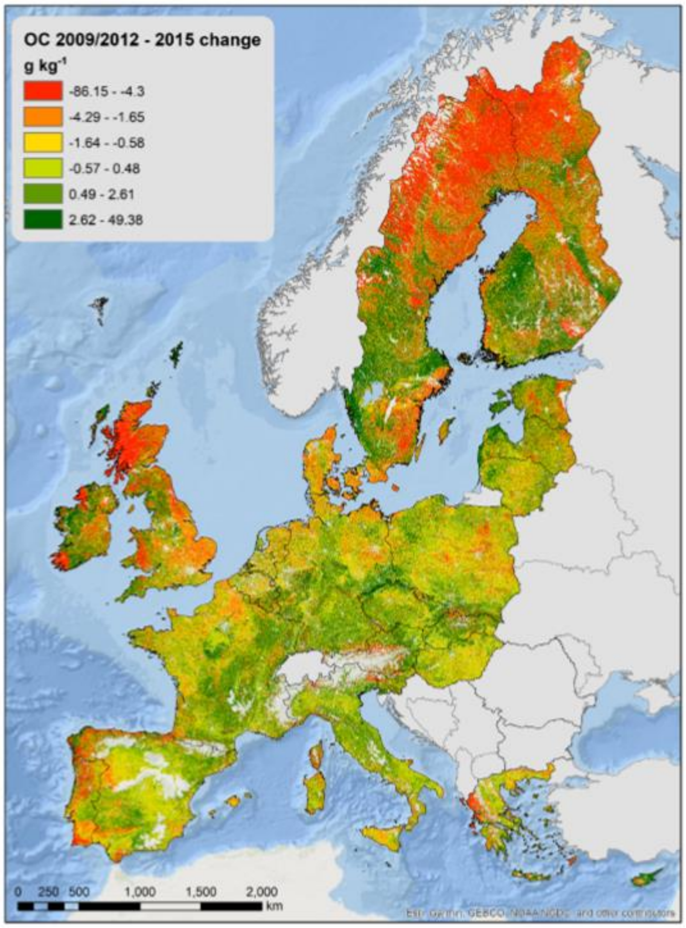

Figure 4.4.6. SOC concentration change between 2009/12 and 2015 (2015-2009 values) as modelled by GMB

It should be noted that changes in SOC levels are quite small given the short time interval. Most (~70%) of the changes fall below the limit of ±4 $g{\cdot}kg^{-1}$ while only 10% of the area is predicted as having changes greater than ±12 $g{\cdot}kg^{-1}$. Moreover, many of the areas where large changes are predicted reflect high model uncertainty due to a lack of samples (northern portion of Scandinavia and Scotland).

Variations in SOC concentration seem to reflect climate and increases in vegetation cover, generally related to the presence of forest or permanent grassland. Decreases seem to be related to areas more affected by climate change with warmer and drier conditions that favour organic matter mineralization.

Soil organic carbon stocks were calculated using a pedo-transfer function (PTF) using soil texture and SOC as inputs. The actual volume to the fine earth fraction was calculated by subtracting the volume of the coarse fragments from the soil volume. The resulting stocks, in $kg{\cdot}ha^{-1}$, were aggregated at NUTS2 level is shown by Figure 4.4.7. As for the concentrations, the values for the stock changes are quite small considering that, on average, the maximum change in stock represent about 2% of the average SOC stock. The changes in stocks are not significant as about 60% of the SOC changes are below 0.2% of the average stock.

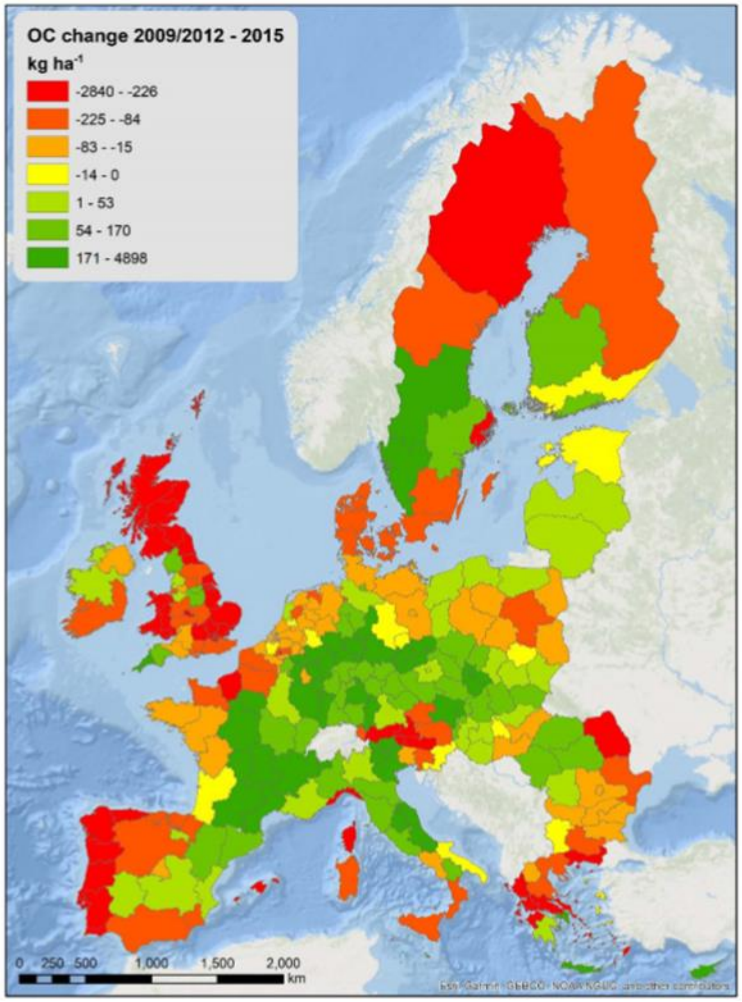

Figure 4.4.7. Changes in mean carbon stocks between 2009/12 and 2015 (20015 - 2009 values) at NUTS2 level.

Results of changes in SOC contents had uncertainties as the large values of standard error demonstrated in cropland, woodland and grassland (Figure 4.4.8). In most NUTS2 regions in UK and in northern Sweden and Finland, the large standard error values in cropland and grassland were mainly due to the reduced number of points per region. In Sweden and Finland, the problems with the removal of litter layer during sampling contributed to the large standard errors in woodland. The impact of these factors on the results of SOC and other soil properties should be reduced as more surveys are carried out.

Carbon stocks and changes 2009/12-2015 in croplands and grasslands

The soil organic carbon stocks in Figure 7 refer to all land cover types (cropland, pastures/grasslands, forests, semi-natural areas, wetlands, etc.). However, in the perspective of MAES Analytical Framework, only data for cropland and grasslands are assessed in detail. In total, the uppermost 20 cm of the EU agricultural land (excluding Croatia) stores about 12.17 Gt of SOC. Previously modelled results have estimated the SOC stock at about 17.63 Gt but the measured soil depth was 0-30 cm and the area was much larger - including all EU Member States plus Albania, Bosnia and Herzegovina, Croatia, Montenegro, North Macedonia, Norway and Serbia (Lugato et at al., 2014.)

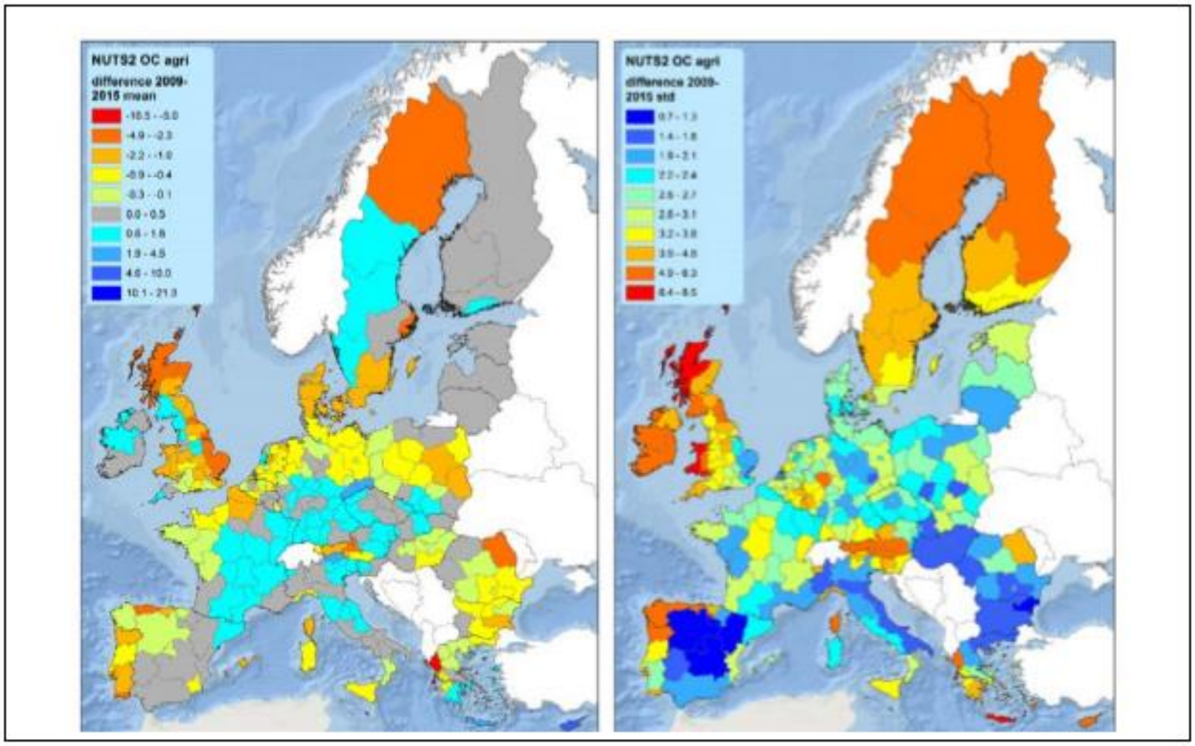

Figure 4.4.8. Changes in OC content and standard deviation between LUCAS 2019/2012 and 2015 surveys at NUTS 2 level in cropland

Cropland

Figure 4.4.9 depicts SOC stocks (in tonnes per hectare) in cropland (left figure) together with their estimated changes between the two LUCAS surveys of 2009/2012 and 2015 (right figure). The total SOC stocks for the uppermost 20 cm of cropland soil in the EU (estimates for Croatia are not included) is about 7.82 Gt. As expected, higher stocks are found in the wetter and cooler parts of the EU, in particular in the UK, Ireland and Scandinavia. Nevertheless, only a small part of the total EU SOC stock is actually accounted for by these areas as their relative area occupied by cropland is relatively small (for instance, UK cropland accounts for about one half of the soil carbon of France's) compared to central Europe (see Table 5).

Changes in SOC stocks in croplands are quite small and account for less than 1% of the stock. The spatial distribution of the stock changes evidences decreasing stocks in the cropland soils of the NUTS2 regions closer to the Atlantic Ocean, including Portugal, the north of Spain and NW France, Benelux, Northern Germany and Denmark. A decrease is present also in Poland, Romania and Bulgaria. The area surrounding the Alps show generally increasing stocks (except in parts of Austria). In particular, SOC stocks in cropland increase in Southern France, most parts of Germany, Czechia, part of Slovakia and Austria, plus most regions of north-central Italy. This distribution might be due to the effect of climate change where wetter and cooler areas are gradually becoming dryer and warmer, resulting in the mineralization of SOC.

However, it should be noted that cultivated and permanent crops have the lowest soil organic carbon levels of any vegetated land cover classes (Hiederer 2018). As a consequence, small changes in stocks may reflect minor fluctuations along a minimum, sub-optimal baseline.

Grasslands

Figure 4.4.10 depicts the stocks (in tonnes per hectare) of soil organic carbon in grassland (left figure) and their estimated changes between the two LUCAS surveys of 2009/2012 and 2015 (right figure). The total SOC stocks for the uppermost 20 cm of grassland soil in the EU (estimates for Croatia are not included) is about 4.35 Gt. The distribution of both stocks and stock changes is quite similar to the one of cropland (Figure 4.4.9), supporting the hypothesis that climate is the main driver of these changes.

The total amount of SOC in cropland, grassland and the changes for each Member State are given in Table 4.4.5 and Table 4.4.6 together with the trend assessments. In general the SOC stock depends on the size of the country and the percentage of area occupied by the specific land cover. As a result, SOC stocks can vary by several orders of magnitude, whereas SOC concentrations in soils have a more moderate variation among countries. For example, the UK has the largest stock of SOC in grassland among current and former EU Member States, while France has the largest stock in cropland. In addition, the changes in the stocks between 2009 and 2015 mostly depend on the size of the stock, so the UK has the largest change in grassland stocks, but France and Italy have the same change in cropland although Italy has a smaller cropland area.

The total SOC change between LUCAS 2009/12 and 2015 in grassland is about 1.8 million tons (Table 3), which is a decrease of about 0.04%. In the same line, the SOC change in cropland is estimated at about 4.8 million tons of SOC, which is a decrease of about 0.06%. Overall, the total SOC change between LUCAS 2009/12 and 2015, as shown in Table 3, is minimal and accounts for less than 0.05% of the total stock. Neither trend is significant, because the carbon stock changes are estimated over a very short period (6 years).

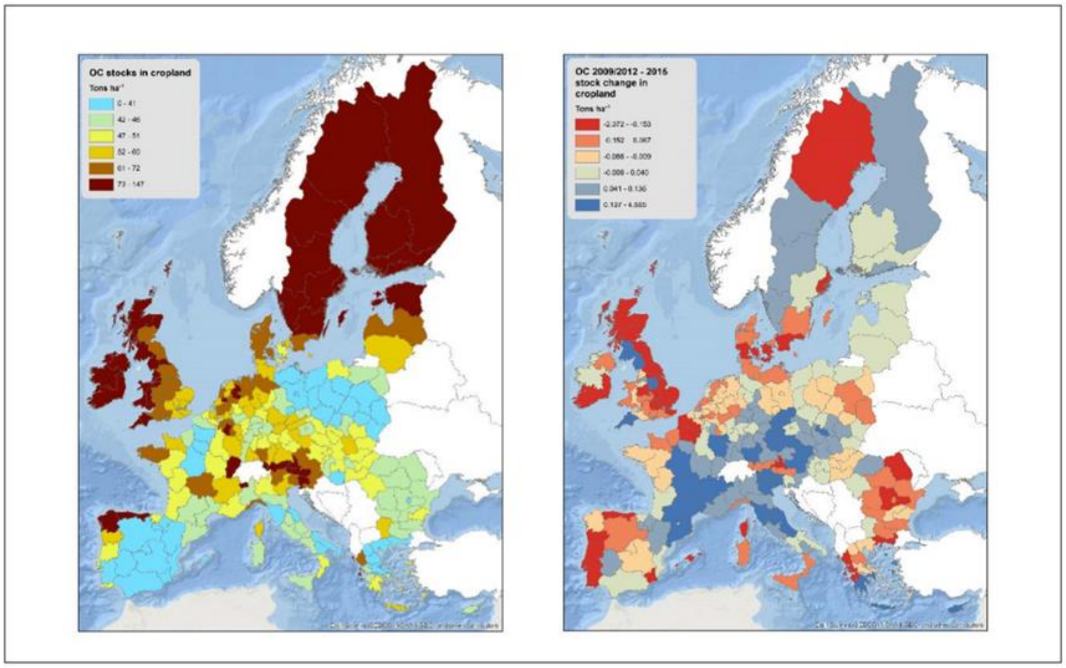

Figure 4.4.9. Soil organic carbon (SOC) stocks in croplands and changes in SOC between 2009/12 and 2015 (20015-2009 values) at NUTS2 level.

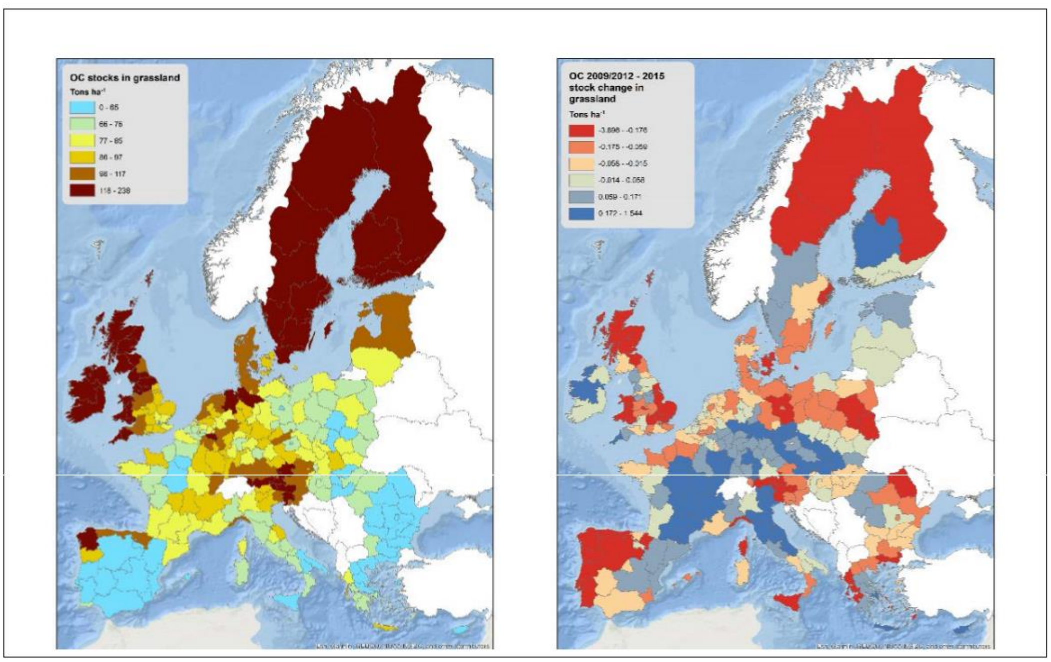

Figure 4.4.10. Soil organic carbon (SOC) stocks in grasslands and changes in SOC between 2009/12 and 2015 (20015-2009 values) at NUTS2 level.

Table 4.4.5. Detailed assessment of soil organic carbon (SOC) stocks for cropland for the period 2009 - 2015 (based on Panagos et al 2020).

Member State	**Baseline value** 10^6 t **(2009)**	**Short-term trend (% per decade)**	**Short-term trend (change)**	**Short-term trend confidence score**	**Long-term trend (% per decade)**	**Long-term trend (change)**	**Long-term trend confidence score**
Austria	115.40	0.405	➔	6		unresolved	
Belgium	80.50	-0.082	➔	6		unresolved	
Bulgaria	244.30	-0.473	➔	5		unresolved	
Cyprus	19.70	3.507	➔	6		unresolved	
Czechia	178.40	0.327	➔	6		unresolved	
Germany	705.50	0.069	➔	6		unresolved	
Denmark	202.20	-0.358	➔	6		unresolved	
Estonia	83.10	0.000	➔	6		unresolved	
Greece	207.60	-0.465	➔	6		unresolved	
Spain	804.80	-0.022	➔	6		unresolved	
Finland	335.60	0.057	➔	6		unresolved	
France	1180.00	0.121	➔	6		unresolved	
Hungary	252.80	-0.067	➔	6		unresolved	
Ireland	107.20	-0.100	➔	6		unresolved	
Italy	672.80	0.213	➔	6		unresolved	
Lithuania	191.90	0.009	➔	6		unresolved	
Luxembourg	7.10	-0.204	➔	6		unresolved	
Latvia	124.70	-0.004	➔	6		unresolved	
Malta	0.60		unresolved			unresolved	
Netherlands	86.60	-0.172	➔	6		unresolved	
Poland	632.00	-0.074	➔	6		unresolved	
Portugal	173.10	-1.616	➔	6		unresolved	
Romania	488.40	-1.921	➔	5		unresolved	
Sweden	325.60	-0.048	➔	6		unresolved	
Slovenia	43.40	0.152	➔	6		unresolved	
Slovakia	103.00	0.183	➔	6		unresolved	
United Kingdom	453.00	-0.601	➔	6		unresolved	

Short term trend for Bulgaria and Romania based on 2012-2015; Croatia was not included in 2009 or 2012 Survey; Results for Malta are not calculated due to low number of samples

➔: No change (the change is not significantly different from 0% per decade); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment.

Table 4.4.6. Detailed assessment of soil organic carbon (SOC) stocks for grassland for the period 2009 - 2015 (based on Panagos et al 2020).

Member State	**Baseline value** 10^6 t **(2009)**	**Short-term trend (% per decade)**	**Short-term trend (change)**	**Short-term trend confidence score**	**Long-term trend (% per decade)**	**Long-term trend (change)**	**Long-term trend confidence score**
Austria	64.20	-0.140	➔	6		unresolved	
Belgium	35.40	0.071	➔	6		unresolved	
Bulgaria	40.00	-0.162	➔	5		unresolved	
Cyprus	1.50	4.522	➔	6		unresolved	
Czechia	71.10	0.491	➔	6		unresolved	
Germany	629.50	0.090	➔	6		unresolved	
Denmark	6.90	-0.118	➔	6		unresolved	
Estonia	37.80	0.101	➔	6		unresolved	
Greece	57.00	-0.795	➔	6		unresolved	
Spain	190.60	-0.267	➔	6		unresolved	
Finland	3.00	-2.067	➔	6		unresolved	
France	717.20	0.246	➔	6		unresolved	
Hungary	61.30	-0.089	➔	6		unresolved	
Ireland	528.60	0.114	➔	6		unresolved	
Italy	55.90	0.077	➔	6		unresolved	
Lithuania	30.60	0.025	➔	6		unresolved	
Luxembourg	3.50	-0.081	➔	6		unresolved	
Latvia	75.20	0.009	➔	6		unresolved	
Malta	NA	NA	unresolved			unresolved	
Netherlands	102.20	-0.054	➔	6		unresolved	
Poland	197.30	-0.184	➔	6		unresolved	
Portugal	10.80	-1.898	➔	6		unresolved	
Romania	173.80	-1.182	➔	5		unresolved	
Sweden	60.20	-0.574	➔	6		unresolved	
Slovenia	14.90	-0.088	➔	6		unresolved	
Slovakia	23.80	0.291	➔	6		unresolved	
United Kingdom	1160.10	-0.282	➔	6		unresolved	

Short term trend for Bulgaria and Romania based on 2012-2015; Croatia was not included in 2009 or 2012 Survey; Results for Malta are not calculated due to low number of samples

➔: No change (the change is not significantly different from 0% per decade); Unresolved: The direction of the trend is unclear or unknown; data are not available; data are available but still need to be adapted to the ecosystem typology used in this assessment.

4.4.5 Convergence of evidence

4.4.5.1 Assessment conclusion based on the pressure indicators

It is not possible to provide a positive message about the condition of soil.

Data on soil pressures are incomplete (e.g. nutrients) or insufficient (e.g. soil pollution). This means that a baseline and overall the direction of the trend in pressures for soil cannot not be defined with certainty.

Some pressures (e.g. erosion) can be assessed by modelling. However, pan-EU datasets often lack the necessary biogeochemical detail or spatial resolution.

However, the material presented in assessment of pressures is a clear demonstration that the soil ecosystem across the European Union is subject to an enormous range of degradational processes, arguably greater in scale and diversity than other ecosystems. These pressures are widespread and vary in geographical extent and intensity.

Broadly, soil pressures are the result of poor land management, unsustainable land use, or the emissions of pollutants. This situation reflects the diverse competition for land in the EU, which includes a loss of ecosystem to urban expansion and a decline in condition due to intensive agriculture (as a result of compaction, reduction in organic inputs, contamination, soil erosion) and industrial pollution (from both local and diffuse sources).

In summary, the assessment has shown that:

The estimated soil erosion rates in 2016 show a limited decrease of 0.4% in all lands and 0.8% in arable lands compared to 2010. The long-term assessment (2000-2010) shows a corresponding significant decrease of 9% in all lands and 19% in arable ones (Figure 4.4.10).

Soil formation rates found in the literature are about to 1.4 - 2 t ha^{-1} yr^{-1} (Verheijen et al., 2009). As reported above, almost 25% of the EU territory has erosion rates higher than the threshold of 2 t ha-1 yr^{-1}.

In addition, 6.6% of EU agricultural land suffers from severe erosion. It is evident that a stronger package of soil conservation practices (e.g. cover crops, plant residues, reduced tillage, contouring, stone walls, agro-forestry) is need to face soil erosion in hot spots. All this does not encounter yet the effect of climate change which will have a negative impact in increasing soil erosion. Recent research studies show that extreme intense rainfall will show a mean increase by 18% in EU by 2050 (Panagos et al., 2017).

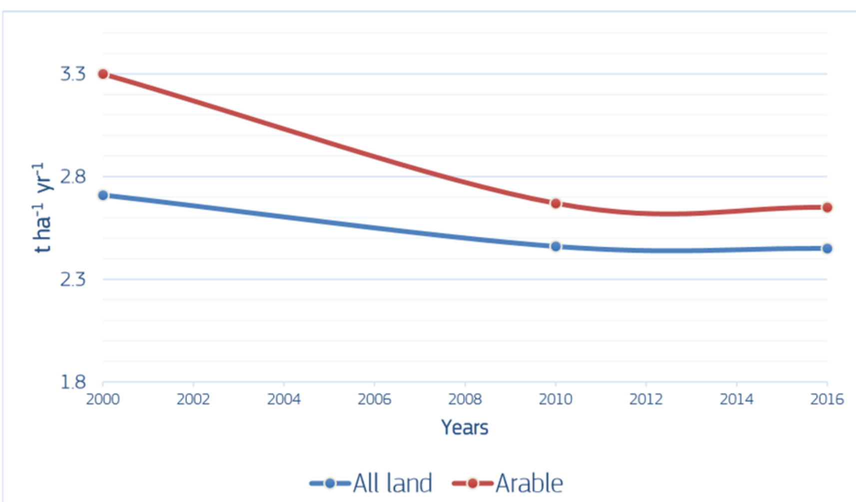

Figure 4.4.10. Trends of soil erosion in all lands and arable lands (from Panagos et al 2020).

In relation to soil nutrients, soil phosphorus shows the strong influence of land use. In particular the agricultural land has higher levels of P than natural areas or forests. This is also quite evident in the most intensive agricultural regions in the EU, such as the River Po plain in Italy, where the levels of P are much higher than the national mean value. The fertilisation rates in agricultural land influence the P concentration especially in the wetter climates of north-west Europe. Topsoil nitrogen is highly correlated with SOC (Ballabio et al., 2019). In addition to this, vegetation (higher values in forests and grassland), climate (higher values in humid climates) and soil texture play an important role in nitrogen distribution.

4.4.5.2 Assessment conclusion: condition indicators

It is not possible to provide a clear message about the condition of soil.

The conclusion related to the assessment of the conditions of soil using soil organic carbon shows that under current climatic and agri-environmental conditions, SOC does not change significantly in the reporting period. This undoubtedly reflects the short interval between LUCAS Surveys and the timeframe required for soil to show changes in properties. Comparison of LUCAS 2009 and 2018 or 2022 should be more illuminating.

Most LUCAS sampling points (~70%) report SOC changes below the limit of ± 4 g kg^{-1} while only 10% of the area is predicted to have changes greater than ± 12 g kg^{-1}. Moreover, many of the areas where the change is predicted to be higher reflect model uncertainty due to the lack of samples (e.g. northern portions of Scandinavia and of Scotland). The changes in SOC stocks are not significant, as about 60% of EU agricultural areas experienced SOC stock changes below 0.2% between 2009/12 and 2015.

The estimation of SOC content has uncertainties such as the large standard errors in Finland and Sweden, reflecting the issue of litter removal during sampling in woodlands. The total change in carbon stocks in grassland was about 0.04% and in arable land about 0.06%. Carbon stocks show a decrease in cropland in regions close to the Atlantic Ocean, such as Benelux, Denmark, northern Germany, north-west France and Portugal, and in Bulgaria and Romania. In contrast, an increase in carbon stocks is found in areas surrounding the Alps, such as Czechia, southern Germany, southern France, northern and central Italy, and parts of Austria and Slovakia. This distribution might be due to the effect of climate change, whereby wetter and cooler areas are gradually becoming dryer and warmer, resulting in the mineralisation of SOC (Lugato et al., 2018). In a nutshell, the changes in SOC content and SOC stocks are not significant in such a short period as 6 years.

The long-term assessment (2000-2010), derived through biogeochemical modelling incorporating LUCAS Soil data indicates a slightly higher reduction of -0.65% in soil organic carbon stocks for agricultural land (not significant). More accurate assessments will be possible following the release of the LUCAS Soil 2018 survey.

4.4.6 Options for policy

Quantifying and monitoring soil condition is challenging. While the results of the soil chapter are inconclusive, in reality, the convergence of evidence indicates that action is needed to protect and restore soil ecosystems across the EU.

The lack of a legal requirement to monitor soil condition means that harmonised data to assess pressures are generally lacking. While most Member States have mapped the soils on their territory that are used for agriculture, many of these surveys are now several decades old, are not updated and do not contain the data required to answer current policy questions (such as the impacts of pollutants and the capacity to provide ecosystem services).

A few countries have detailed and wide-ranging soil monitoring networks that measure a number of parameters relating to ecosystem condition. However, many of these networks reflect national or regional priorities and standards, which makes comparison of their results with those of other countries is difficult.

The LUCAS Soil Module attempts to overcome many of these issues through the use of standardized sampling and analytical protocols. However, the approaches used in the 2009 and 2015 surveys do not address many of the key pressure indicators or their trends (e.g. pollution, compaction, salinsation, etc.). This is increasingly addressed in more recent LUCAS surveys (e.g. soil genetic analysis, pesticide residues, changes in metal concentrations).

Efforts are underway under the umbrella of the EU Soil Observatory (incorporating LUCAS SOILS), the European Joint Programme Initiative on Agricultural Soils (EJP Soils) and the EEA's EIONET-Soil, to integrate pan-EU and national soil data collection programmes in order to develop a comprehensive soil monitoring system and populate relevant soil indicators. This should be a priority to support future MAES assessments.

Closer synergies should be sought between the MAES framework and the methodology being developed to assess land degradation and progress towards land degradation neutrality. Indeed, the Commission has set commitment to achieve land degradation neutrality by 2030. As noted by the European Court of Auditors recent report on land degradation , land degradation is a current and growing threat in the EU that impacts on ecosystem condition. Currently, there is no clear picture of these degradational processes, and the steps taken to combat soil pressures often lack coherence. As stated previously, there is no EU-level strategy on land degradation and soil protection. Instead, a range of policy areas, such as the Common Agricultural Policy, the EU Forest Strategy, or the EU strategy on adaptation to climate change, note the importance of soil but do not focus on it.

In addition, there should be a harmonisation of terminology to aid a common understanding. A decrease in pressure intensity is not necessarily an overall improvement of ecosystem condition as degradational processes can be still ongoing and affecting soil health. While the data and methodology used in the assessment indicate a stable ecosystem, this outcome does not fully capture the continued loss of soil through pressures such as sealing and related infrastructure development, nor ongoing degradation through continued erosion, pollution or compaction. above critical thresholds means that the ecosystem in question is still under pressure.

Soil erosion estimates are of high importance for a number of EU policies such as the CAP, SDGs, Soil Thematic Strategy and Resource efficiency (Panagos and Katsoyiannis, 2019). Potentially, the soil erosion indicators may also be included in assessing ecosystem services, biodiversity loss (Biodiversity Strategy 2030) and sediments pollution (Water Framework Directive). Current agro-environmental policies in place need to focus in hot spots and reduce soil erosion rates in agricultural lands where current rates are higher than sustainable ones. This is well illustrated by the reduced applications of grass margins in the period 2010-2016 (8%) with respect to the previous decade. The application of conservation tillage also shows a very limited increase (0.8%) from 21.6% to 22.4%. Cover crops were applied to 8.9% of EU arable lands compared to 6.5% in 2010. On the contrary, the plant residues show a decrease from 10.6% in 2010 to 9.1% in 2016. The last figure is worrying as this decrease may be attributed to the increased use of plant residues for biomass production and their increased use for the renewable energy. An important step would be to set a policy target of halting severe and very severe/extreme erosion on agricultural land by 2030.

The funding of soil data collection across the EU is very low in comparison with other environmental media (reflecting policy drivers). Policy makers should be encouraged to orient funding towards supporting an increased number of points in under-represented areas and land cover types, while increasing the collection of data on key pressure indicators (predominantly pollutants).

Soil is the overarching element of the EU Green Deal. The various strategies set ambitious targets for the restoration and preservation of healthy soils. In parallel, the proposed Mission on Soil Health and Food (CARING FOR SOILS IS CARING FOR LIFE) has a main goal that by 2030, at least 75% of all soils in each EU Member State are healthy.

4.4.7 Knowledge gaps and future research challenges

A thorough overview of research needs in relation to soil and land management has been provided by the INSPIRATION H2020 Project (http://www.inspiration-h2020.eu/). The project has assessed critical knowledge gaps between the societal challenges for sustainable land-use and the current knowledge on land management and net impact of land-use and synthesizes the current state of research demands.

It is clear that harmonized data for the EU on several soil pressure indictors are lacking. In particular, soil pollution (both diffuse and local), soil compaction and secondary salinization all require reinforcement.

The focus in soil erosion to date has mainly been on in water erosion through sheetwash and rills as this is the most widespread processes across the EU. However, soil losses due to wind erosion (Borelli et al., 2017), harvest erosion (Panagos et al, 2019) and gully erosion (Vanmaercke et al., 2016) should not be ignored.

Given the relatively long-time frame (with regard to most policy cycles), there are challenges is assessing changes in soil carbon stocks. Improved spatial representativity and the integration of field data with biogeochemical models and machine learning algorithms show much promise.

Finally, an integrating Soil Health Indicator should be developed integrating field data collection, proximal soil sensing systems and earth observations. With this in mind the JRC is currently a harmonised DNA assessment of soils from across the EU. DNA sequences have been extract4ed from around 1000 locations that will be subjected to metagenomic barcoding analysis to identify key dwelling communities. This could form the basis of a baseline indicator for soil biodiversity (at least at microbial level). In parallel, relationships will be sought between the genetic data and land management practices (e.g. farm systems, pollutants). The outcomes will controibute to the development of global soil biodiversity observation systems, such as the Soil BON Network under the GEOS umbrella. This work is matched by a similar assessment of pesticide residues in agricultural soils of EU. The challenge is to implement corresponding activities in all Member States.

4.4.8 Conclusions

Life in the Earth's various ecosystems depends on healthy soils. However, these benefits for generally not recognized by society as a whole. Soils are fragile and non-renewable in term of human lifespans.

The increasing demand for land for urban development and infrastructures continues to consuming this critical ecosystem. In parallel, soils are under pressure from a range of drivers, including intensive agriculture, industrial pollution, and increasingly climate change. It is likely that all of the above drivers are probably singly or in combination resulting in a decline in soil condition.

At present, the assessment of soil is inconclusive as many key indicators at EU level and in most Member States are not available or are incomplete while that the interval between field data collection through LUCAS Soil Module is not yet sufficiently long enough for trends to be observed. More effort is required to develop a harmonized and comprehensive soil monitoring system for the EU that integrates pan-European initiatives such as LUCAS SOIL and national programmes.

Unlike aboveground habitats, soil is not explicitly covered the Habitats Directive, the Natura 2000 network and national network of designated areas. This should be addressed through targeted policy instruments.

It is expected that the development and support of extensive farming systems and the introduction of soil health targets in to the CAP should lessen pressures on cropland and managed grassland soils. Industrial emissions on natural systems should be assessed and necessary policy response formulated.

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5 Ecosystem services

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Summary: Ecosystems provide services to people contributing to human well-being; which is known as ecosystem services (ES). The EU initiative on Mapping and Assessment of Ecosystems and Services (MAES), in support to the EU Biodiversity Strategy to 2020, aims to improve ecosystem service knowledge at the EU and Member State level.

The Knowledge Innovation Project on an Integrated system for Natural Capital and ecosystem services Accounting (KIP INCA) builds on the first phase of MAES and provides an understanding of how the delivery of ecosystem services has changed in Europe. This chapter presents the EU-wide assessment for six ecosystem services between 2000 and 2012. Crop provision, timber provision, carbon sequestration, crop pollination, flood control and nature-based recreation are assessed using different indicators. When possible, four indicators are calculated: 1) Ecosystem service potential: amount of service that ecosystems can provide in a sustainable way. 2) Ecosystem service demand: the need for ecosystem services by society and economy. 3) Ecosystem service use: amount of service effectively used or mobilized from ecosystems to socio-economic systems to generate ultimately benefits. 4) Unmet demand: the need for a specific ecosystem service by society that is not fully satisfied by ecosystems.

The analysis of the ecosystem services indicators at EU level shows opposing trends between the ecosystem service potential and demand. While the amount of services that ecosystems can offer was decreasing or stable, society showed a growing demand for most ecosystem services. This demonstrates that there was an increase in the reliance of the EU society on ecosystems, whereas ecosystems at EU level were not enhanced to provide a higher quantity of the services assessed (pollination, flood control and recreation). Ultimately, the impact of changes in the ecosystem service potential on the benefits to the society depends on the way local needs for ecosystem services are met. For instance, the decrease of crop pollination potential, in general terms, did not have a very negative impact on covering the needs of pollinator-dependent crops at EU level. In the case of flood control, the downward trend of the potential water runoff retention by ecosystems led to an increase of areas not sufficiently protected by upstream ecosystems (unmet demand in settlements).

This assessment highlights the need to enhance regulating and cultural ecosystem services to cope with the increasing societal demand. This is also suggested by the large gap between the societal demand for ecosystem services and the amount of services effectively delivered by ecosystems: about 54% of the demand for regulating and cultural ecosystem services was not sufficiently covered by ecosystems (i.e. unmet demand). To narrow this gap, restoration actions using nature-based solutions should be prioritized in the proximity of areas where the demand for regulating and cultural services is not fully satisfied by ecosystems.

The understanding of knowledge gaps identified in this assessment can help target future research and monitoring priorities to improve knowledge on ecosystem service.

5.1 Introduction

Ecosystem services (ES) are the benefits we get from nature and which underpin our economies and our own well-being. **Ecosystems deliver a broad range of services** classified in different groups depending on the type of service provided. Provisioning services are those providing products such as food, fibber or timber. Ecosystems can also provide regulating services by buffering environmental pressures or reducing the impact of natural hazard contributing to safety of society. Examples of this type of ecosystem services are the carbon sequestration, water purification or flood control. Moreover, ecosystems generate non-material benefits to people such as spiritual enrichment and recreation, which are considered cultural ecosystem services[99].

The **EU Biodiversity Strategy to 2020** included as new focus the immense value of ecosystem services and the urgent need to maintain and restore these for the benefit of both nature and society. More concretely, Action 5 of Target 2 of the EU Biodiversity Strategy endorses the mapping and assessment of the state and economic value of ecosystem services in the entire EU territory, as well as their integration in accounting and reporting systems across Europe. For this last purpose, the European Commission set the **Knowledge Innovation Project on an Integrated Natural Capital Accounting system for ecosystems and their services (KIP INCA[100])**. KIP INCA builds on the first phase of the EU initiative on Mapping and Assessment of Ecosystems and Services (MAES) with the aim to develop ecosystem services accounts at EU level. These accounts are meant to test the implementation and development of the international standards on ecosystem accounts defined by United Nations et al. (2014). Creating accounts for ecosystem services requires quantification of the ecosystem service that is effectively used; this is, the amount of service mobilised from the ecosystem to the socio-economic system (Figure 5.1). The amount of service used is quantified in biophysical and monetary terms for all of them (Vallecillo et al., 2019a).

The **use of ecosystem services** is also called actual flow and it ultimately generates a benefit for the economy and the society. However, the quantification of the amount of a service actually used is a complex task hampered with conceptual issues especially for regulating and maintenance ecosystem services (Sutherland et al., 2018). KIP INCA has adopted a framework for a consistent quantification of the use of ecosystem services based on the assessment of key indicators driving their use (Vallecillo et al., 2019a): ecosystem service potential and ecosystem service demand[101] (Figure 5.1). The **ecosystem service potential** quantifies the natural contribution to the generation of an ecosystem service (also known as supply). It measures the amount of ES that can be provided or used in a sustainable way in a certain region. The potential is determined by the type and condition of ecosystems and can be considered as a measure of the quality of natural capital to provide a given service. The ecosystem service potential is especially relevant for the EU-wide ecosystem assessment since it refers to the ecological component: the ecosystem (Figure 5.1). **Ecosystem service demand** quantifies the need (or wish) for specific ecosystem services by society, particular social stakeholder groups or individuals. For provisioning services, the real demand could be considered as the desired amount of goods per unit space and time (Villamagna et al., 2013). However, given the direct link of provisioning services to agriculture and forestry sectors, the desired amount of goods is meant to be maximized to make economic activities more profitable, which entails conceptual and technical limitations for their assessment. Therefore, for provisioning services we have used the definition of demand provided by Wolff et al. (2015), where the use of provisioning services is considered to be equal to the demand at national level (no imports are considered).

[99] Based on the Common International Classification of Ecosystem Services (CICES): https://cices.eu/
[100] https://ec.europa.eu/environment/nature/capital_accounting/index_en.htm
[101] Definitions are partially based on Burkhard et al. (2017)

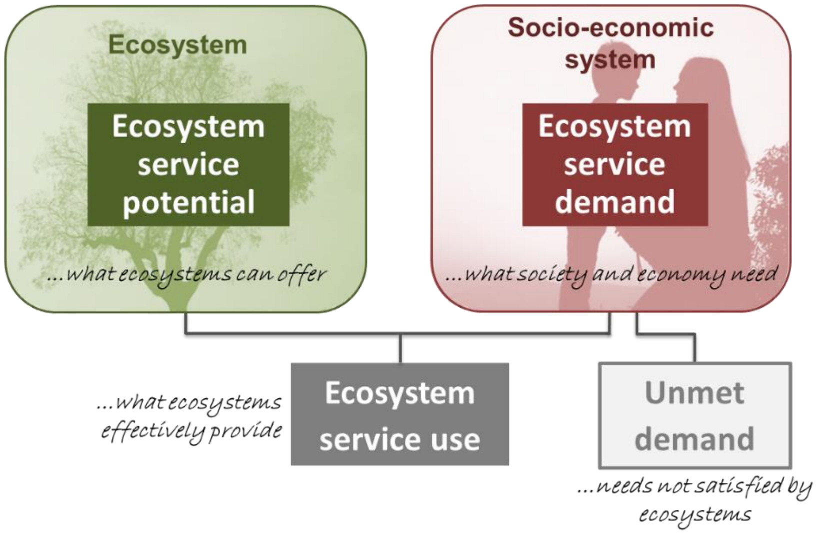

Figure 5.1. Scheme of the ecosystem services indicators.

Once the ecosystem service potential and demand are quantified, the ecosystem service use will be determined according to the spatial relationship between them. For instance, the proximity of natural sites for recreation to citizens (demand) is a key factor favouring the use of these sites.

The spatial modelling of different ecosystem service indicators enables assessment of another complementary indicator of ecosystem services: unmet demand (also termed 'ecosystem service deficit'). We considered as **unmet demand** the need for a specific ecosystem service by society that is not satisfied by ecosystems. The unmet demand is quantified as the difference between the ecosystem service demand and use and it provides valuable information to support the planning of ecosystem restoration measures to enhance the contribution of ecosystem services to human wellbeing.

Ecosystem services are of special relevance for the EU Biodiversity Strategy to 2020. However, they are also linked to several **other EU policies that are governing the ecosystem management and/or protection** in a direct or indirect way (Table 5.1). The section relevant for each ecosystem service also includes a discussion on the linkage between the results of the assessment and the associated EU policies.

This chapter aims at providing an overview on the main **changes over time for six ecosystem services taking place at the EU based on the best available indicators**. Changes are described for the different indicators including the ecosystem service potential, demand, use and unmet demand. Finally, we provide an integrated analysis, showing the convergence of evidence for ecosystem services and conclusions to be considered for policy support.

5.2 Methods and data overview

This chapter is partially based on the biophysical assessment carried out for the accounting of six ecosystem services at EU level developed so far under the KIP INCA project. We present results for two provisioning service, three regulating and maintenance services and one cultural ecosystem service. Providing a detailed explanation of the models used for each ecosystem service is beyond the scope of this report, since methods are already described in dedicated publications (Vallecillo et al., 2020; Vallecillo et al., 2019b; Vallecillo et al., 2018; Vallecillo et al., 2019c). Annex 1 shows the precise reference for each ecosystem service. Only the assessment of timber provision is original in this study. Timber provision accounts are currently being updated to better integrate the international standards on ecosystem accounts (United Nations et al., 2014; United Nations, 2017) and the key principles in ecology.

Quantifying the ecosystem contribution to the generation of an ecosystem service remains very challenging in a context where ecosystems are usually managed or affected by human interventions. However, in this study we present the novel approach of KIP INCA, in which the natural contribution to crop provision has been assessed, removing the role of human inputs in driving yield production (see section 5.3.1). Models to assess ecosystem potential for other services focus only on physical properties and conditions of different land cover types to offer a given service trying to assess as much as possible only the natural contribution. In this assessment the distribution of different land cover types is considered as a 'natural' factor, even when the landscape is shaped by the interaction with humans. For instance, the presence of green urban areas in a given location due to the land planning cannot be isolated in the modelling and it is considered as an ecosystem component.

KIP INCA indicators on ecosystem services were valuable for the purpose of this study because they were assessed following a systematic approach and making use of consistent datasets at EU level to make sound comparisons over time. KIP INCA indicators report changes over time based on the years in which the accounting layers of CORINE Land Cover (CLC) are available (2000, 20006 and 2012). The relatively recent release of CLC for the year 2018 was not timely to model ecosystem services for this last year, since the modelling of ecosystem services requires a considerable amount of time and resources.

Two different approaches were adopted for the assessment of ecosystem services depending on data availability and the peculiarities of each service (Table 5.1):

- **Official statistics**: when data (proxies) on the use of the ecosystem service are available. This includes sources like Eurostat and Food and Agriculture Organization of the United Nations (FAO);
- **Spatially explicit models**: in the absence of useful data to quantify ecosystem service use. Application of spatial models allows the calculation of different ecosystem services indicators (potential, demand, use and unmet demand) that are not available when making use of official statistics. These indicators provide complementary information relevant for different purposes (Figure 5.1).

The assessment of three ecosystem services is based on official statistics, and the other three is based on ecological modelling approaches (Table 5.1 and Annex 1). Depending on the approach adopted and the type of service different types of indicators become available (Table 5.1 and 5.2). Although we refer throughout the report to the EU, the precise extent covered by each ecosystem service is described in Table 5.2.

Data for the different ecosystem services components is described in Table 5.2. Many indicators of this assessment are derived from modelling exercises. Input data used to calculate the indicators and the reference where the method is described in detail are provided in Annex 1. Moreover, we provide for each ecosystem service a technical fact sheet provided as a separate annex of this report (reference to each fact sheet is provided in Table 5.2). These fact sheets include the description of the different indicators, data sources, maps of the indicators and the main statistics at EU level for the years considered in this assessment. As mentioned before, the assessment tries to cover as far as possible years 2000, 2006 and 2012; however, not always these exact years were available (Table 5.2).

Importantly, we base our conclusions on the best available indicators for more than one point in time at the EU level. Different conclusion might have been obtained when using other indicators, based on alternative models or making use of different statistics, but to the best of our knowledge, this is the more representative dataset for the purpose of the EU-wide ecosystem assessment.

Table 5.1. Ecosystem services assessed, key policy connections and approach adopted.

	EU policy	**Approach**	**Indicators**	**Description**
Provisioning				
Crop provision	Common Agriculture Policy, Climate policy, Renewable Energy Policy	Official statistics	Use and demand	Share of the total crop production derived only from the ecosystem contribution (human inputs are excluded)
Timber provision	Forest policies, Renewable Energy Policy, Bioeconomy Strategy	Official statistics	Potential	Net annual increments of growing stocks
			Use and demand	Annual standing volume of all trees, living or dead, that are felled during the given reference period
Regulating and maintenance				
Carbon sequestration	Climate policy	Official statistics	Demand	CO_2 concentration in the atmosphere
			Use	Net flow of CO_2 sequestered by ecosystems
Crop pollination	Pollinators initiative, Common Agriculture Policy	Spatially explicit model	Potential	Dimensionless indicator of environmental suitability to support wild insect pollinators
			Demand	Extent of pollinator-dependent crops
			Use	Area where high pollination potential (environmental suitability > 0.2) and demand overlap
			Unmet demand	Extent of pollinator-dependent crops not covered by high pollination potential
Flood control	Floods Directive, Climate change adaptation, Water framework Directive	Spatially explicit model	Potential	Dimensionless indicator of potential runoff retention
			Demand	Extent of artificial surfaces located in floodplains
			Use	Extent of artificial surfaces protected by upstream ecosystems
			Unmet demand	Extent of the demand (artificial areas) not protected by upstream ecosystems
Cultural				
Nature-based recreation	Natura2000, Green Infrastructure, Urban policies	Spatially explicit model	Potential	Dimensionless indicator of the availability of opportunities provided by nature
			Demand	Population (inhabitants)
			Use	Potential visits to suitable areas for daily recreation
			Unmet demand	People living beyond 4 km from suitable areas for daily recreation

Table 5.2. Data description for ecosystem services indicators. Fact sheets are provided in the separate supplement of this report.

Ecosystem service	Indicator	Unit per year	Years assessed	Spatial resolution	Spatial coverage	Fact sheet
Provisioning						
Crop provision	Use/demand	million tonne	2000-2006-2012	NUTS0	EU-25 (lack of data for Cyprus, Malta and Croatia)	5.0.100
		tonne/ha				
Timber provision	Potential	million m^3	2000-2005-2010	NUTS0	EU-27 (excluding Malta: no forestry sector)	5.0.200
		m^3/ha				
	Use/demand	million m^3				
		m^3/ha				
Regulating and maintenance						
Carbon sequestration	Use (net flow)	million tonne	2000-2006-2012	NUTS0	EU-28	5.0.300
	Demand	ppm CO_2	2000-2006-2012	Global		
Crop pollination	Potential	dimensionless [0-1]	2000-2006-2012	1 km x 1 km	EU-28	5.0.400
	Demand [b]	thousand km^2	2004-2008	1 km x 1 km	EU-25 (excluding Cyprus, Malta and Croatia)	
	Use	thousand km^2	2000-2006-2012	1 km x 1 km		
	Unmet demand	thousand km^2	2000-2006-2012	1 km x 1 km		
Flood control	Potential	dimensionless [0-100]	2006-2012	100 m x 100 m	EU-26 (excluding Cyprus and Malta, and some regions in Croatia, Bulgaria and Finland)	5.0.500
	Demand	thousand km^2				
	Use	thousand km^2				
	Unmet demand	thousand km^2				
Cultural						
Nature-based recreation	Potential	dimensionless [0-1]	2000-2006-2012	1 km x 1 km	EU-28, but analysis of changes are based on EU-15 (Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden, United Kingdom)	5.0.600
	Demand	million inhabitants	2000-2015	1 km x 1 km		
	Use	million visits	2000-2012	Municipality		
	Unmet demand	million inhabitants	2000-2012	Municipality		

5.3 Main results of the ecosystem services assessment

Table 5.3 and 5.4 present the summary results for the ecosystem service assessment. Each ecosystem service is described in more detail in the following sub-sections. Table 5.3 presents ecosystem services indicators at the EU level reporting the estimated values for the reference year of the EU-wide ecosystem assessment (year 2010)[102] and the changes per decade (expressed in %) based on the longest time period available. Table 5.4 summarizes the trend of ecosystem service indicators in absolute terms allowing a better comparison between the changes in the ecosystem service potential, demand, use and unmet demand.

At a first glance, Table 5.3 and 5.4 show that:

- **Ecosystem service potential** shows a downward trend for crop pollination and flood control, with no significant changes for timber provision and nature-based recreation;
- **Ecosystem service demand** has increased for all ecosystem services assessed, except for timber provision. This shows an increasing reliance of the society on ecosystem services over time;
- **Ecosystem service use** has increased for three ecosystem services (crop provision, crop pollination and nature-based recreation), while timber provision, carbon sequestration and flood control show no significant changes for the period considered. The increase in the use crop pollination and nature-based recreation is due to a higher demand for them (see Table 5.1 for definitions). In the case of crop provision, the increasing crop productivity over time might be a consequence of the economic need to make crop production more profitable (demand), but also of favourable weather conditions or changes in crops types. Interpretation of the changes in ecosystem services based on official statistics, such as crop provision, are more difficult than for services based on spatial models where different indicators cover different perspectives of the ecosystem service;
- **Unmet demand** shows very different patterns for each ecosystem service. There are no significant changes in the unmet demand for crop pollination, while it increases for flood control and decreases for nature-based recreation.

Detailed interpretation of the indicators is provided in the following sub-sections service by service.

[102] Based on interpolated values between 2006 and 2012

Table 5.3. The aggregated values and overall trends of ecosystem service indicators in the EU.

Ecosystem services	Indicators	Units per year	Reference year 2010	Long term trend [a] (% per decade)
PROVISIONING ECOSYSTEM SERVICES				
Crop provision	Use/demand	million tonne	141	7% ↑
		tonne/ha	2	10% ↑
Timber provision	Potential	million m^3	744	1% →
		m^3/ha	5.54	-0.3% ↓
	Use/demand	million m^3	523	4% →
		m^3/ha	4	3% →
REGULATING AND MAINTENANCE ECOSYSTEM SERVICES				
Carbon sequestration	Use (net flow)	million tonne	295	4% →
	Demand	ppm CO_2	389	5% ↑
Crop pollination	Potential	dimensionless indicator [0-1]	0.211	-1% ↓
	Demand [b]	thousand km^2	162	5% ↑
	Use	thousand km^2	79	8% ↑
	Unmet demand	thousand km^2	82.7	2% →
Flood control	Potential	dimensionless indicator [0-100]	62	-0.1% ↓
	Demand	thousand km^2	19	3% ↑
	Use	thousand km^2	5	0.5% →
	Unmet demand	thousand km^2	13	3% ↑
CULTURAL ECOSYSTEM SERVICES				
Nature-based recreation	Potential	dimensionless indicator [0-1]	0.28	3% →
	Demand	million inhabitants	357	4% ↑
	Use	million visits	31	17% ↑
	Unmet demand	million inhabitants	150	-8% ↓

[a] Calculated for the longest period available (2000-2012) except for flood control (2006-2012). Changes larger than ± 5% were considered significant. If smaller, non-parametric Wilcoxon test was used as statistical test of significance (at level of 0.05). Legend for arrows: ↑: Significant increase; →: Stable trend (change not significantly different from 0% per decade); ↓: Significant decrease. Colour scheme for ecosystem service potential: **green - positive impact**; **yellow - neutral or uncertain impact** and **red - negative impact**.

[b] Demand data (pollinator-dependent crops) were only available for 2004 (used for year 2000) and 2008 (used for 2006 and 2012)

Table 5.4. Trends in ecosystem services at the EU level.

Ecosystem services	Changes in ecosystem services per decade (%)			
	Potential	Demand	Use	Unmet demand
PROVISIONING SERVICES				
Crop provision	NA	7 ↑	7 ↑	NA
Timber provision	1 →	4 →	4 →	NA
REGULATING AND MAINTENANCE				
Carbon sequestration	NA	5 ↑	4 →	NA
Crop pollination	-1 ↓	5 ↑	8 ↑	2 →
Flood control	-0.1 ↓	3 ↑	0.5 →	3 ↑
CULTURAL SERVICES				
Nature-based recreation	3 →	4 ↑	17 ↑	-8 ↓
This table reports the changes in ecosystem service indicators for total values of the indicator (absolute terms), not values per unit of area (relative terms). Legend for arrows: ↑: Significant increase; →: Stable trend (change not significantly different from 0% per decade); ↓: Significant decrease. Colour scheme for ecosystem service potential: **green - positive impact**; **yellow - neutral or uncertain impact** and **red - negative impact**.				
Based on the period 2000-2012 (except flood control: 2006-2012)				

5.3.1 Crop provision

5.3.1.1 Definition and methods

Crop provision as an ecosystem service is defined as the ecological contribution to the growth of cultivated crops that can be harvested and used as raw material. This means that the assessment crop provision, understood as ecosystem service, should not be based on total yield production, which is made possible by substantial human inputs invested for crop production (i.e., irrigation, human labour, fertilization). Therefore, for a more robust assessment of crop provision in this assessment, we have considered the use of crop provision as the fraction of the total yield that can be attributable only to the role of the ecosystem and not to human inputs.

With this purpose, an approach based on the '*emergy*' (embedded energy) concept (Pérez-Soba et al., 2019) is applied to separate natural input (such as sun, rain, soil) from human input (including fertilizer, irrigation, machinery). In this we it is possible to disentangle the role of the ecosystem ('ecosystem contribution') from total crop yield production. The ecosystem contribution ($EcoCon$) was calculated as a ratio according to Equation 1.

$$EcoCon = \frac{Natural\ inputs}{(\text{Natural inputs+Human inputs})} \qquad \text{(Equation 1)}$$

where natural and human inputs are measured in common units of energy. $EcoCon$ varies in theory between 0, when yield is entirely derived from human inputs, and 1 when no human input is provided, although in practice both types of inputs are always present. $EcoCon$ was separately calculated for 13 different crop types for which data were available: soft wheat, durum, wheat, barley, oats, maize, other cereals, rape, sunflower, fodder maize, other fodder on arable land, pulses, potatoes and sugar beet. These crop types represent about 82% of the extent of all arable land in the EU. At the EU level, $EcoCon$ shows average values of 0.09 for potatoes and 0.3 for barley and oats. Permanent crops could not be considered in this assessment because of the lack of data to assess $EcoCon$.

The ecosystem contribution was assessed in a spatially explicit way at 1 km x 1 km spatial resolution. The application of this indicator to the official statistics (Eurostat [apro_cpsh1]) to calculate the actual flow was only possible at the spatial resolution at which crop yield statistics were available: country level. $EcoCon$ for each crop type and country were applied to official statistics of crop production to quantify crop provision as ecosystem service based only on the amount of yield that is attributable to the role of the ecosystem (the role of human inputs is excluded). See further technical details in Vallecillo et al. (2019b).

This assessment covers crop provision by EU agro-ecosystems; therefore crop imports are not taken into account in this analysis.

5.3.1.2 Results and discussion

At the EU level, the estimates based on the 'emergy' approach show that on average **21% of the total yield was derived from the ecosystem contribution** (which is considered as the use of crop provision), while the remaining 79% was generated by human inputs (Figure 5.2). The ecosystem contribution ratio shows large spatial variability (Figure 5.3), showing lower values in areas with intensive cereal production like in the Po Plane in Italy and Bayern in Southern Germany. On the contrary, larger values can be found in Eastern Europe where there usually are lower quantities of mineral fertilizers and less machinery. Exploratory analysis showed, as it was expected, that the ecosystem contribution was higher in countries such as Estonia and Hungary with lower rates of irrigation and fertilizers and with more extensive agriculture Vallecillo et al. (2019b).

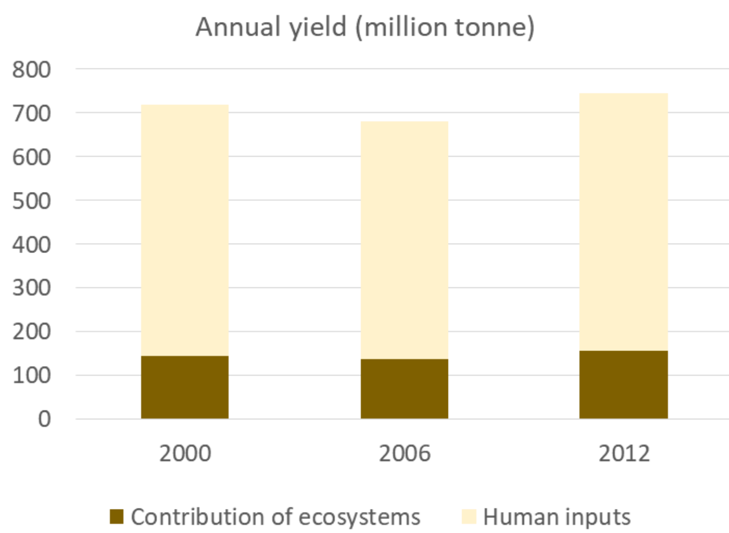

Figure 5.2. Crop yield in the EU derived from the contribution of ecosystems and from human inputs.

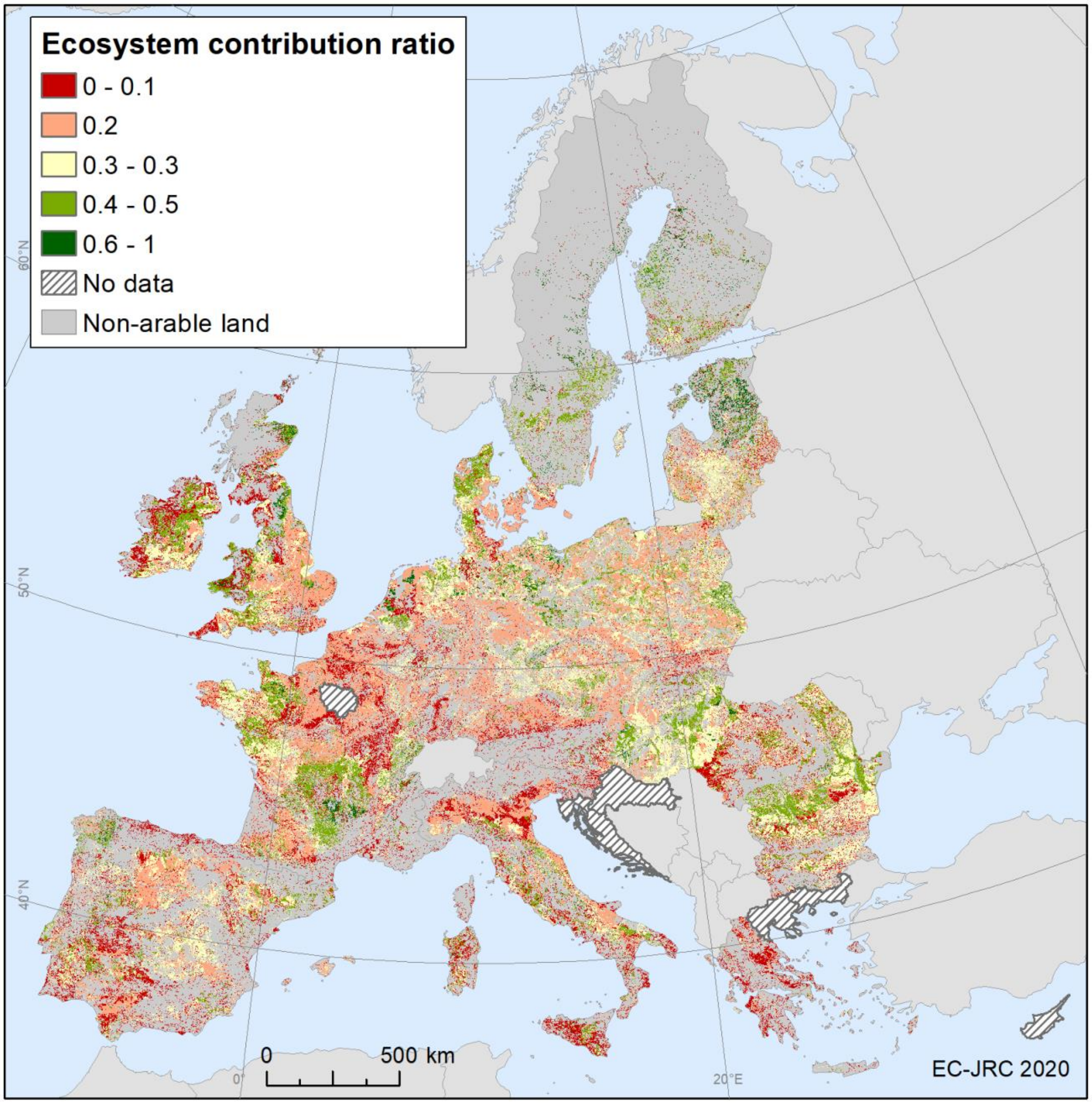

Figure 5.3. Ecosystem contribution ratio for crop production in arable land.

The use of crop provision increased by 7% per decade when looking at total tonnes produced by arable land (Table 5.3 and 5.4, see also maps of changes in Fact sheet 5.0.100). Crop provision in relative terms, as measured by tonnes of yield produced per hectare (crop productivity), shows also an increase per decade of 10% (Table 5.3). The agriculture sector is, in general terms, aiming at maximizing crop productivity to make the economic activity more profitable. Therefore the increasing crop productivity over time (Figure 5.4) might be a consequence of the economic need to make crop production more gainful[103]. Other drivers that might explain the increasing crop productivity are the possible improvement of weather conditions or also changes in crops types.

When looking separately to the different periods covered in the assessment (between 2000 and 2006 and between 2006 and 2012), trends in crop provision were very different. While in the first period, there was a decrease in the yield derived only from the role of ecosystems (with no significant changes in the productivity), between 2006 and 2012 an important increase of the yield took place in absolute and relative terms (Figure 5.4).

[103] Note that the need for profitable production of crop production is not considered in terms of ecosystem service demand.

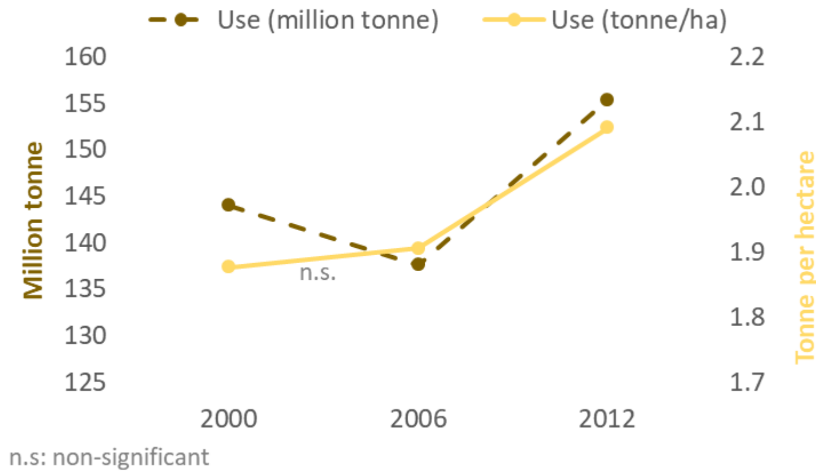

Figure 5.4. Crop provision derived from the ecosystem contribution in the EU over time.

Unfortunately, there were **no data available to assess how ecosystem contribution changes over time**, and the same percentage of ecosystem contribution was applied for the three years assessed. Therefore, the increase of crop provision reported is simply explained by the increase in the total yield production, and not to a more active role of the ecosystem contributing to the yield growth.

The assessment of the ecosystem contribution for crop provision could be a good indicator related to the **Sustainable Development Goal (SDG) 2** and specifically **Target 2.4**: "*by 2030 ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems…*". As described above, lower ecosystem contribution is mainly found in areas with intensive cereal production, while higher scores would likely be found in extensive agricultural land. However, further analyses are actually needed to better assess how ecosystem contribution varies across different management practices in agriculture and also with the different greening measures proposed under the CAP.

Ultimately, an **integrated analysis would be required** to better assess the links between ecosystem contribution to crop provision and the condition of agro-ecosystems, but also the possible synergies and trade-offs with other ecosystem services. For instance, it should be tested whether low rates of ecosystem contribution may compromise the ecosystem potential to provide regulating or cultural ecosystem services. For instance, it could be expected that areas with intensive cereal production, showing low ecosystem contribution, present also low ecosystem service potential for nature-based recreation (less attractive for people) and for flood control (because of the homogeneous non-woody vegetation).

5.3.2 Timber provision

5.3.2.1 Definition and methods

Timber provision as an ecosystem service is defined as the contribution of ecosystems to the growth of wood harvested as raw material for different purposes (i.e. construction, energy).

The potential of forests to produce timber in a sustainable way was estimated as the net annual increments of growing stocks (NAI) based on Eurostat statistics (Annex 1)[104]. NAI are only available for forest available for wood supply (FAWS), therefore, all results refer only to this type of forest. By using NAI as an indicator of timber provision potential, we assumed, based on the Eichhorn's rule (Eichhorn, 1904), that the role of human inputs was negligible in affecting the final amount of woody biomass grown. The assessment of the use of timber provision was based on the amount of fellings, also available in Eurostat statistics (Annex 1). It is important to highlight

[104] Theoretical upper limit to guarantee sustainability for steady-state condition of forest.

that we assessed timber provision by EU forest ecosystems; therefore wood imports are not taken into account in this analysis. The description of timber provision indicators is provided in Table 5.1 and 5.2. Further details are provided in Fact sheet 5.0.200.

5.3.2.2 Results and discussion

The total values of NAI for the EU countries showed statistically non-significant differences between 2000 and 2010[105] (Table 5.3 and 5.4). This stable trend for the longest time period available is due to the opposing trends followed by the NAI for the two periods assessed: between 2000 and 2005 there was a decrease in NAI, that was compensated by the increase taking place between 2005 and 2010 (Figure 5.5). NAI in relation to forest extent showed a slight, although statistically significant, decrease between 2000 and 2010 (Table 5.3), following similar trends as those described for total NAI: a decrease between 2000 and 2005, followed by an increase between 2005 and 2010. Knowing the exact drivers of these changes remains very challenging when making use of official statistics for the assessment of ecosystem services. Assessment of changes in NAI would benefit from complementary modelling exercises.

The use (and demand) of timber provision, as assessed by the annual fellings, showed a statistically non-significant change between 2000 and 2010 (Table 5.3 and 5.4) due to the different trends for the two periods assessed; fellings increased in the first period (2000-2005), while decreased for the second (2005-2010). The decrease in the second period was driven by the economic crisis of 2008, causing a drop in the amount of fellings in 2008 and 2009, gradually recovering in the following years until 2015 (Camia et al., 2018).

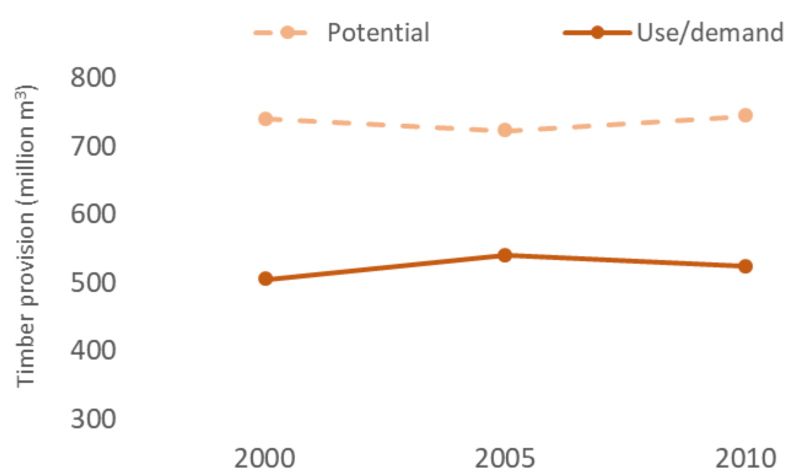

Figure 5.5. Timber provision as ecosystem service in the EU over time.

The amount of fellings reported in the EU was not exceeding the amount of timber that forest can annually offer (NAI), guaranteeing in general terms the sustainable use of EU's forest ecosystems. However, it has been shown that wood fellings are strongly underreported leading therefore to an amount of fellings closer to NAI than the one reported here (Camia et al., 2018). Sweden was the only country where fellings reported exceeded NAI in 2005 and 2010, leading to a reduction of the timber stocks in forest, which, in general terms and at the country level scale of this assessment, might have negative consequences on the ecosystem in the long term. For a robust assessment of the sustainability of timber provision, the species composition and the age class volume should also be considered. Unfortunately, these data were not available at EU level.

The comparison of the maps of changes in the potential and use of timber provision shows some relevant results (Figure 5.6). In Sweden and Austria in spite of the decrease in the amount of timber that forest can offer (NAI),

[105] Timber provision data are available for 2000, 2005 and 2010; which we made matching with CLC reference years (2000, 2006, 2012 respectively) for integration with other ecosystem services.

there was an increase in the use of timber provision. Although fellings in these countries are also due to storm events and sanitary harvesting to limit the propagation of parasites, this situation maintained over time may lead to a reduction of timber stocks in the forest, affecting the ecosystem condition. Therefore, differences in the trends between NAI and fellings could be used as early warning of possible overuse of timber provision in the future. This type of information could be used in support to the monitoring of the **SDG 15** and specifically **Target 15.2**: "*by 2020, promote the implementation of sustainable management of all types of forests, …*". It is also very relevant for several EU policies such as the EU Timber Regulation, the Bioeconomy Strategy and Renewable Energy policies.

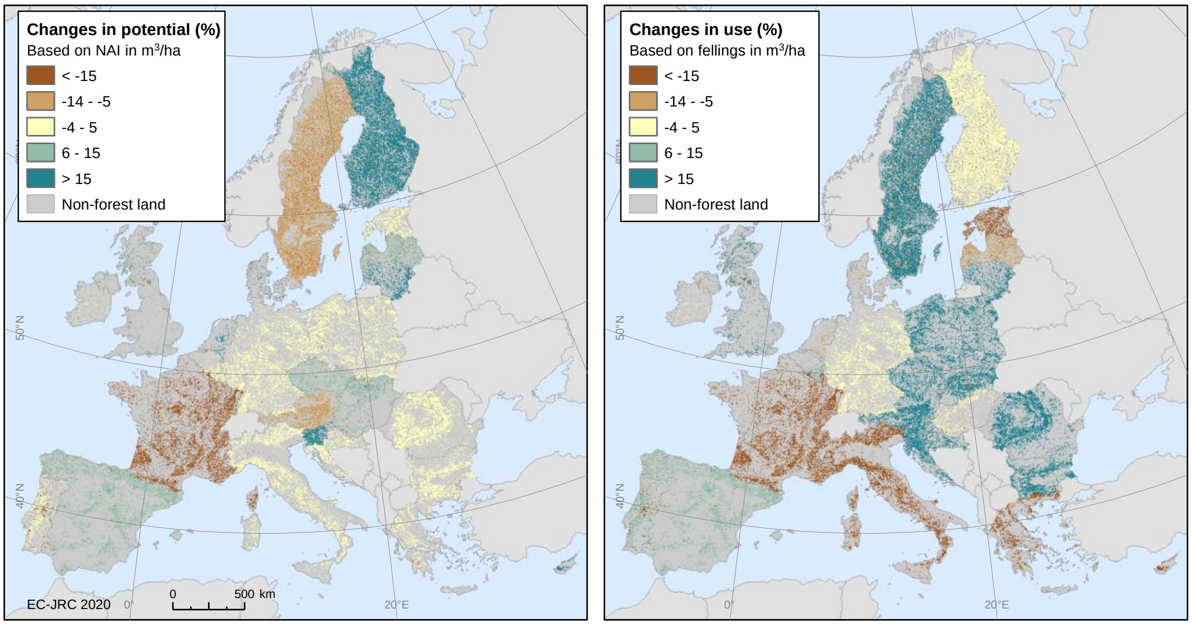

Figure 5.6. Maps of changes in the potential and use of timber provision between 2000 and 2010.

Conclusions of this timber provision assessment are derived from the interpretation of official statistics and the statistical tests applied to infer about the significance of the changes (see Chapter 2). Therefore, results slightly differ from the study of Camia et al. (2018) on trends described for the total biomass (not only timber from stemwood as done here) where statistical significance of the changes is not tested and changes are analysed until 2015.

Official statistics present relatively high uncertainty. As mentioned before, the amount of fellings in general terms is underreported (Camia et al., 2018) and quality of the data for year 2000 is not fully consistent (Tomppo et al., 2010). Therefore, results should be interpreted with caution, especially for the trend reported for the first period (between 2000 and 2005). Moreover, we did not take into account fellings derived from illegal logging. Estimates of illegal logging at the EU level, and especially a more accurate assessment of NAI and fellings, would contribute to provide a more robust conclusion for timber provision as ecosystem service in the EU.

5.3.3 Carbon sequestration

5.3.3.1 Definition and methods

Carbon sequestration as ecosystem service is considered as the net removal by ecosystems of carbon dioxide (CO_2) from the atmosphere, contributing therefore to mitigate climate change.

In the literature 'carbon storage' is sometimes also considered together with the carbon sequestration (Burkhard et al. (2017); however, in this assessment we focused only on net CO_2 sequestration for three different reasons:

1) Conceptually, ecosystem services are considered flows between ecosystems and socio-economic systems (Burkhard et al., 2017; Maes et al., 2013). This flow cannot be quantified for carbon storage. Actually, under the ecosystem accounting standard of United Nations , quantification of carbon stocks, are considered within the thematic accounts, separately from ecosystem services accounts;
2) Carbon storage and their changes over time are ultimately the consequence of CO_2 flows (removals or emissions) between ecosystems and the atmosphere as reported in this assessment;
3) Carbon storage, as measured by above- and belowground carbon stocks, is to some extent considered as an ecosystem condition indicator. Carbon stocks are also reported in the chapters on Agro-ecosystems and soil condition;

The concentration of CO_2 in the atmosphere was considered in terms of the demand for this ecosystem service: in the absence of increasing CO_2 in the atmosphere, and its direct consequences on climate change, this ecological function would not be considered as an ecosystem service. The demand for this ecosystem service takes place at global level, since it is the whole globe in the need to reduce CO_2 concentration in atmosphere. In this sense, ecosystems may play an active role as service providers when there is a net flow of CO_2 sequestered from the atmosphere, which is considered in terms of services use (see also Table 5.1 and 5.2).

We used the best available dataset reporting flows of CO_2 by EU ecosystems over time: the greenhouse gases (GHG) inventory for the Land Use, Land Use Change and Forestry (LULUCF) sector (European Environment Agency, 2018). GHG inventories are reported annually by countries as prescribed by Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC). LULUCF data provide net emissions and removals of CO_2 per different land use categories (forest land, cropland, grassland, wetlands, settlements and other land)[106], which correspond to different MAES ecosystem types (see Fact sheet 5.0.300). Carbon fluxes reported under 'harvested wood products' in LULUCF are not accounted for in this assessment to better capture the ecosystem functioning determined by the land use and land use changes. It is important to highlight that the main goal of this section is to make use of LULUCF data to assess the role of ecosystems sequestering CO_2 for a later integration with other ecosystem services data of the EU-wide ecosystem assessment. Therefore, we only included in this analysis the years for which data for other ecosystem services were available in this study (years 2000, 2006 and 2012). Detailed analysis of LULUCF inventories, considering the entire time series reported since 1990, including as well other GHG such as methane and nitrous dioxide, and more detailed information on the drivers of changes is provided in dedicated reports (i.e. National Inventory Reports; NIR[107]).

Ecosystems play a crucial role in the sequestration of CO_2. On the one hand, ecosystems act as sinks of CO_2, which is considered as **ecosystem removals** based on reported LULUCF data[108] (Figure 5.7). On the other hand, ecosystems may also act as sources, when emissions of CO_2 from ecosystems are released to the atmosphere (**ecosystem emissions**, Figure 5.7). Accounting for emissions derived from ecosystems is relevant to calculate the net flow of CO_2 sequestered from the atmosphere. The difference between ecosystem removals and emissions, as reported in LULUCF data, is considered as the **net CO_2 flow of the ecosystem**, resulting from land use (management) and land use changes. A positive sign of the net CO_2 flow represents a **net CO_2 sequestration** by ecosystems and it is considered as the ecosystem service use. On the contrary, a negative sign of the net CO_2 flow implies that ecosystems are net sources of CO_2 since ecosystem emissions are larger than the removals. In this last case, the ecosystem would not be considered as service provider, since it does not longer contribute to reduce the atmospheric concentration of CO_2.

[106] Net emissions and removals refer to carbon pools of living biomass, death organic matter and soil.
[107] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2020
[108] Ecosystem removals correspond to the negative values reported in LULUCF data, while ecosystem emissions are the positive values of the emissions inventory. Note that signs used in this assessment and LULUCF data are the opposite, because the focus here is on the role of the ecosystem and not on emissions inventory.

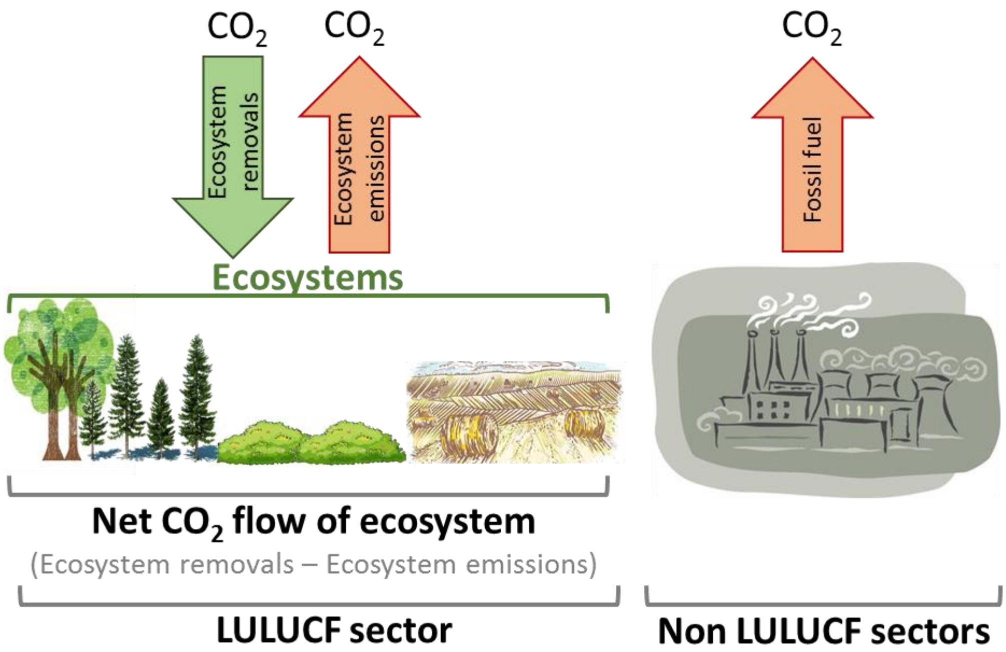

Figure 5.7. Scheme of the main CO_2 flows assessed.

5.3.3.2 Results and discussion

The increasing concentration of CO_2 in the atmosphere taking place at global level shows a growing need for carbon sequestration by ecosystems (Table 5.3 and 5.4). This increasing demand is the same independently on the location.

At the EU level, for the reference year of the EU-wide assessment (2010), there was a **net CO_2 sequestration** of 295 million tonnes of CO_2[109] (Table 5.3) and statistical analysis of EU data at country level shows **no significant changes between 2000 and 2012** (Table 5.3 and 5.4). It should be considered that the high inter-annual variation in the net CO_2 flows, mainly due to the CO_2 emissions derived from natural disturbances (fires, wind throws, etc.), is not fully displayed in this assessment.

When looking separately to the different periods covered in the assessment (between 2000 and 2006 and between 2006 and 2012); we found different patterns of changes in net CO_2 sequestration. Although within the overall period assessed there were no significant changes, during the second period (between 2006 and 2012) there was an increase of the net CO_2 sequestration (Figure 5.8). Since net CO_2 sequestration is calculated as the difference between ecosystem removals and emissions, its increase can only be explained by the **reduction of ecosystem emissions** for the same period, given that CO_2 removals, mainly by forest, showed no significant changes (Figure 5.8).

Analysis of the ecosystem service 'carbon sequestration' shows important differences among reported ecosystem types. **Forest is the only ecosystem type consistently reported as a net sink of CO_2 at the EU level**, showing non-significant differences between 2000 and 2012 (Table 5.3 and 5.4). The other ecosystem types (urban[110], cropland, grassland and wetlands) were reported at the EU level as net sources of CO_2 over time

[109] Based on the interpolation between the values of 2006 and 2012 for consistency with other ecosystem services.
[110] Corresponding to settlements in LULUCF data

(Figure 5.9[111]). However, LULUCF data showed high variability across countries (see Fact sheet 5.0.300 for further details). Cropland and urban ecosystems were the most important sources of CO_2 at the EU level. Emissions from croplands were decreasing because of cropland abandonment and changes in management practices: increase of woody crops and the advancement of less intensive soil management practices (European Environment Agency, 2018). For urban ecosystems there was an upward trend of CO_2 emissions driven by the carbon stock losses resulting from the conversion of other land cover types into artificial use (land take).

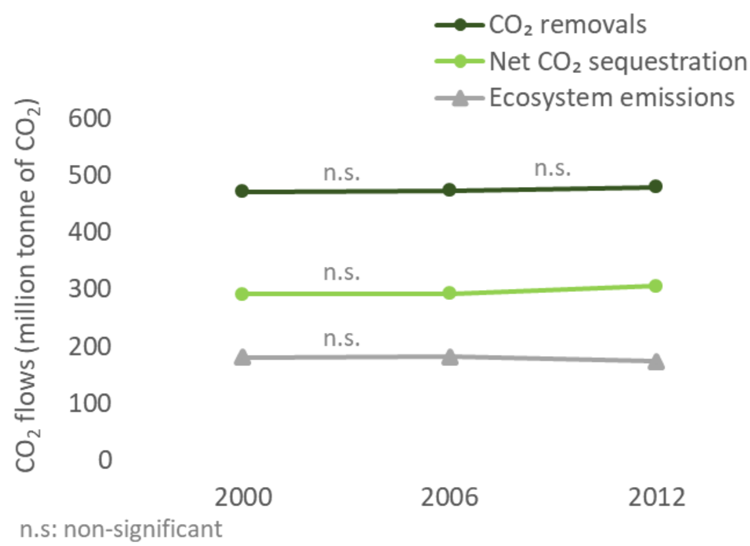

Figure 5.8. CO_2 ecosystem flows in the EU over time.

Emissions released from wetlands and grasslands call special attention, since these ecosystem types could potentially act as important net sinks of CO2 when adequate management practices are applied (Nahlik et al., 2016). At the EU level, net emissions from grasslands, mainly driven by the management of organic soils (European Environment Agency, 2018), were decreasing over time (Figure 5.9). In the case of wetlands, as reported under the LULUCF data, net emissions were mainly associated with the management of peatland areas. Peat extraction, although affecting small areas, has a big impact on the balance of CO2 fluxes, leading to considerable net emissions (European Environment Agency, 2018). The reporting of wetlands does not cover only peatlands, but also flooded lands and other types of wetlands such as artificial water bodies, which could potentially act as net carbon sinks. However, the lack of IPCC[112] methods for reporting carbon stock changes in flooded land and other wetlands blurred the overall picture of CO_2 flows in these land uses, hindering the clarity of whether wetlands were net sources or sinks of CO_2 at EU level. Moreover, emissions and removals from the LULUCF sector refer only to managed land[113] (considered here as proxy for ecosystem types). Managed land in the case of wetlands represented only about 30% of the total wetland extent reported in the EU. This implies that **CO_2 emissions and removals derived from the remaining 70% of the wetland extent, considered unmanaged, are unknown.** This analysis raises awareness on the knowledge gap for most unmanaged wetlands in the EU (mainly flooded areas and other wetlands), for which the vast majority of countries, although

[111] 'Other land', corresponding to sparsely vegetated land, was only reported as net source of CO_2 for 2012. For this year, CO_2 emissions of this ecosystem type were only 0.3% of the total ecosystem emissions. For these reasons, 'other land' was not included in Figure 5.9.

[112] The IPCC 2006, used as guidance for LULUCF inventories, does not include methods for estimating carbon stock changes in Flooded areas and Other wetland, except peat extraction areas, therefore the reporting of emissions and removals in these areas is not considered mandatory

[113] Used as a proxy to assess anthropogenic emissions targeted in the GHG inventories. However, definitions of managed and unmanaged is highly variable across countries

providing information on their areas did not report the associated CO_2 flows. Importantly, the wetland category in LULUCF includes only those wetlands that are not already classified as forest, cropland or grassland. This may show an underestimation in the extent of this ecosystem type, and their associated removals and emissions of CO_2, especially if we consider the broad definition that wetlands may have (see Chapter 3.4).

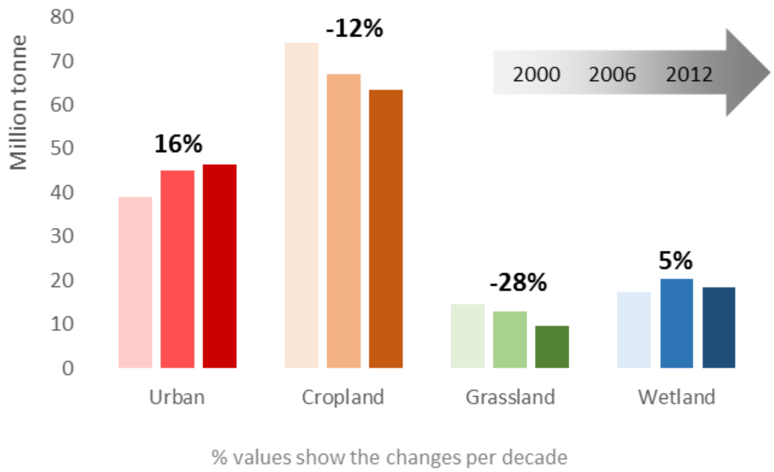

Figure 5.9. MAES ecosystem types reported by LULUCF data as net sources of CO_2 over time.

In this assessment, we focused only on CO_2 and not on other greenhouse gases (GHG) such as methane and nitrous dioxide, because they are mainly reported in LULUCF data as emissions to the atmosphere. Although emissions of other GHG are very important for global climate regulation in the broad sense, they are not considered as an ecosystem service flow, because ecosystems do not contribute to generate benefit to the society when there is no net sequestration.

5.3.3.3 Mitigation of anthropogenic emissions by ecosystems

As mentioned before, there is an increasing global demand for sequestration of CO_2 by ecosystems, since concentration of CO_2 in the atmosphere shows an upward trend. Evidently, the EU alone cannot fulfil the increasing global demand for this ecosystem service, which takes place at global level, no matter where emissions come from. Therefore, the assessment of the sequestration of CO_2 at the EU scale should also be framed from the perspective of policy targets and assess how ecosystems (and their management) contribute to the achievement of the overall goal of net emission reduction by the middle of the century[114] (IPCC, 2019). This aspect is also stressed by the LULUCF regulation of the EU[115], which sets the basis for a consistent accounting of GHG emissions and removals in the LULUCF sector, in the frame of the emission reduction target through mitigation.

In this assessment, the role of ecosystems in mitigating CO_2 emissions derived from the combustion of fossil fuel (Figure 5.7) was quantified using the following equation:

$$Mitigation\ by\ ecosystems = \frac{\text{Net CO}_2\text{ flow of ecosystem}}{\text{CO}_2\text{emissions from fossil fuel}}$$

For the reference year 2010, **ecosystems of the EU mitigated about 6.5% of the total EU CO_2 emissions from fossil fuels**, increasing up to 6.9% in 2012, which corresponds to an improvement in the mitigation by about 13% per decade (see also Fact sheet 5.0.300). This increase was mainly due to the reduction of CO_2 emissions from burning fossil fuel, since the role of ecosystems sequestering CO_2 did not change between 2000

[114] COM (2018) 773, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773
[115] Regulation (EU) 2018/841, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018R0841

and 2012 (Table 5.3)[116]. In this sense, more effort could be dedicated to enhance the role of ecosystems in mitigating CO_2 emission. In addition to enhancing net CO_2 removals by forests, the reduction of net CO_2 emission by other ecosystem types should also be considered as a priority. Reduction of emissions or enhancement of removals by ecosystems can be targeted by adequate management practices (land use) or regulation of land cover changes. For instance, emissions from urban ecosystems (settlements in LULUCF data) are mainly driven by the land take (European Environment Agency, 2018). Therefore, measures preventing land take may contribute to reverse the current upward trend of CO2 emissions released from urban ecosystems (Figure 5.9). These measures would also contribute to the SDG 13 and specifically Target 13.2: "integrate climate change measures into national policies, strategies, and planning", as well as to EU´s climate policies.

It is also highly important to improve the reporting quality of emissions and removals of CO2 for grasslands and especially for wetlands, to know with higher confidence if these ecosystems act as net sources or sinks of CO2. As mentioned before, the use of LULUCF data for the assessment of CO2 sequestration includes important limitations, especially for wetlands. Although there have been some attempts to improve the reporting of emissions for wetlands (IPCC, 2014), implementation of the new guidelines is not yet mandatory and therefore, they are not systematically applied by all countries. In this sense, the application of the refined methods for wetlands is also encouraged by the LULUCF regulation to better assess the contribution of this ecosystem to the sequestration of CO2.

Despite the limitations of the GHG inventories, they constitute the most detailed, and frequently updated, source of information about CO2 flows by ecosystem type at EU level. Among the main limitations, it is important to mention that estimates of GHG emissions and removals present high uncertainty. LULUCF uncertainty was estimated in 32.36% (European Environment Agency, 2018). To reduce this uncertainty, Member States (MS) continuously implement improvements that are then translated in the recalculations of whole time-series. It should also be noted that GHG inventories submitted by MS undergo every year an expert review, carried out by the UNFCCC experts, which provide recommendations to increase the so called reporting principles of transparency, accuracy, consistency, comparability and completeness.

Moreover, GHG inventories currently present differences on the completeness reporting among countries. Research efforts should provide complementary methods to better assess carbon sequestration by ecosystems (especially by wetlands) in support to the objectives of the LULUCF regulation. For instance, Grassi et al. (2018) provide an excellent example of a modelling exercise to improve inventories of emissions and removals in forests based on the management practices.

Complementary approaches could be further developed in the future by modelling separately the potential and the actual flows of CO2 sequestration. This would shed light on how much the role of ecosystems may be enhanced through restoration to maximise CO2 sequestration. There have been some attempts to estimate of the potential CO2 sequestration by ecosystem (Griscom et al., 2017); however, these values are context-dependent (e.g. soil type, climate). To the best of our knowledge, there are not still spatial modelling approaches capturing the complexity of both processes: the potential flow of CO2 and the actual one. Most attempts to assess CO2 sequestration potential refer to carbon storage in the soil, as for instance Chen et al. (2018). However, as mentioned in the beginning of this section, storage was not considered as an ecosystem service in this assessment.

5.3.4 Crop pollination

5.3.4.1 Definition and methods

Crop pollination as ecosystem service is defined in this assessment as the transfer of crop pollen by wild bees[117] resulting in the fertilization of crops, maintaining and/or increasing the crop production. The development of spatial models provides useful information on different indicators of crop pollination: potential, demand, use, and unmet demand (Table 5.1 and 5.2). Crop pollination potential has been quantified as environmental suitability to

[116] Long-term changes are described in EEA (2018) [page 673], shows a slight increase of the LULUCF sector sequestering CO_2 since 1990, but a slight decrease since 2010; however, statistical significance of this trend is not provided

[117] Other insect pollinators such as butterflies or hoverflies have not been considered in this assessment.

support the occurrence of wild bees (dimensionless indicator ranging between 0 and 1, with 1 being the highest suitability). The demand is represented by the distribution of pollinator-dependent crops. The spatial overlap between areas with high environmental suitability (> 0.2) and pollinator-dependent crops has been reported as the use of this service. We assumed that in the overlapping areas, pollinators effectively contribute to increase crop production. Complementarily, areas that need pollination not overlapping with suitable areas for pollinators have been considered as the unmet demand. See further details in Vallecillo et al. (2018). It is important to note that this chapter covers the assessment of pollination for crop production. Future assessment should also include the contribution of pollinators to the maintenance of biodiversity and also include other pollinators besides wild bees.

5.3.4.2 Results and discussion

Ecosystem potential to support pollinators shows higher values in Central-Eastern Europe (Figure 10). This pattern is driven especially by the suitability of these areas for bumblebees. At the EU level, **crop pollination potential decreased by 1% per decade** (Table 5.3 and 5.4), showing high variability across the EU territory (Figure 5.10). While areas with increases of pollination potential were mainly found in Southern Europe, there appeared to be a general **decrease in North-West Europe**. This decrease of pollination potential is in line with the results of the assessment made by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2016). Identifying the exact drivers of these changes is difficult given that the pollination potential indicator integrates the modelling of different species, for which responses to environmental factors vary largely. Specific analyses would be needed to disclose the role of the different environmental drivers behind the changes found.

An analysis of changes in the pollination potential restricted to Natura 2000 sites also showed a significant decrease by 1% per decade (see Fact sheet 5.0.400). Although in protected areas, land cover changes are usually less pronounced than outside those, changes in the landscape surrounding a given site are also very relevant for the pollination potential we modelled. For instance, a decrease of semi-natural vegetation outside a Natura 2000 site may have also a negative impact on the suitability for pollinators within this site.

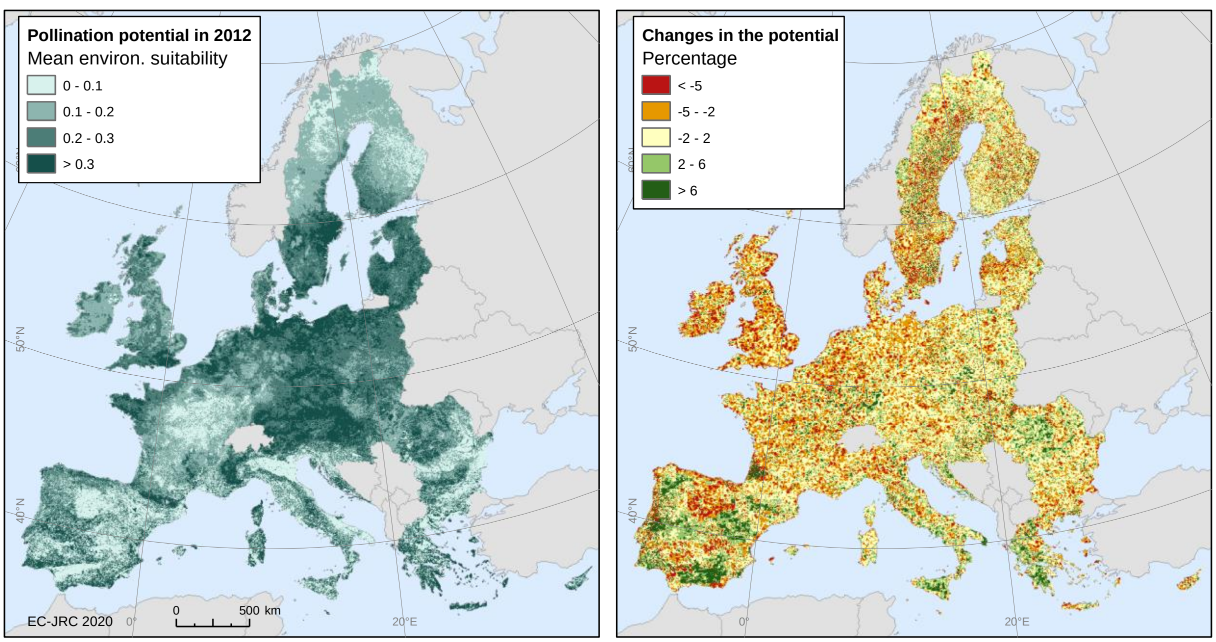

Figure 5.10. Crop pollination potential in the EU and changes between 2000 and 2012.

While pollination potential declined, the **demand for crop pollination increased by 5%** per decade due to the expansion of pollinator-dependent crops (Table 5.3 and 5.4). The overlap between pollinator-dependent crops and suitable areas for pollinators, considered in term of **service use, increased by 8% per decade** mainly led by the expansion of pollinator-dependent crops (Table 5.3 and 5.4). Overlapping areas increased at a higher rate than pollinator-dependent crops. This suggests that the decrease of suitable areas for pollinators did not take place in crop areas or even that in some locations with pollinator-dependent crops the suitability for pollinators increased.

The total extent of pollinator-dependent crops in areas with low suitability for pollinators (unmet demand) shows a stable trend at EU level between 2000 and 2012 (Table 5.3 and 5.4). When looking at the share of the demand considered as unmet demand (relative terms), we even found a decrease by 5% per decade (Fact sheet 5.0.400). This confirms the limited impact of the decrease in the pollination potential on pollinator-dependent crops. Although changes in the unmet demand between 2000 and 2012 could be considered to be positive, there is still about 51% of the crop extent in the EU grown in areas with low environmental suitability to support pollinators. This shows that there is still a lot of room for the enhancement of ecosystems to contribute to crop production. Areas of unmet demand are mainly found in South Europe (Figure 5.11), as a consequence of having lower pollination potential in these regions together with high demand. Maps of all indicators and their changes are provided in Fact sheet 5.0.400.

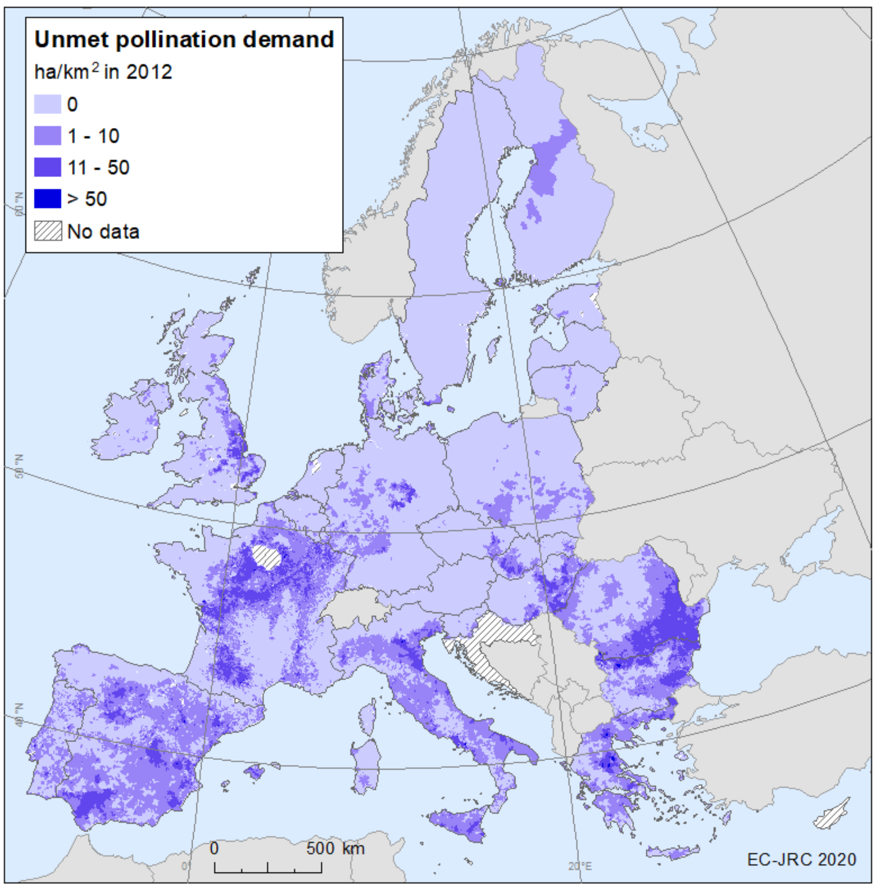

Figure 5.11. Maps of unmet demand for crop pollination and changes between 2000 and 2012.

The comparison of the different periods assessed (2000-2006 and 2006-2012) shows a different performance of crop pollination (Figure 5.12). While pollination potential, demand and use by crops were increasing in the first period, in the second one (between 2006 and 2012) there was a decrease in the pollination potential (-1.4%) and the use area (-3%) due to the shrinkage of pollination potential where pollinators are needed[118]. Importantly, the extent of pollinator-dependent crops lacking suitable areas for pollinators (unmet demand) increased in the second period (2.8%), which may be seen as a warning that the lack of suitable areas for pollinators could cause a real bottleneck for crop production. This could be prevented, for instance, by **restoring pollinator-friendly habitats** in areas where there is unmet demand (Figure 5.11). Similarly to crop provision, the assessment of crop pollination could be linked to the **SDG 2, Target 2.4**: "*by 2030 ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems…*". This is also particularly relevant for EU policies like CAP and the From Farm to Fork initiative, apart from its relevance to the implementation and monitoring of the future Biodiversity Strategy.

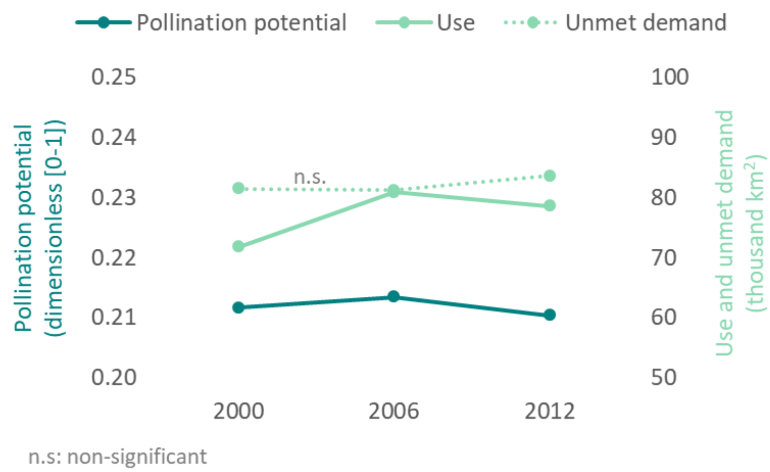

Figure 5.12. Indicators of crop pollination in the EU over time.

Changes in the demand, use and unmet demand for crop pollination should be interpreted with caution since, due to lack of data, we assumed to have the same extent of pollinator-dependent crops between 2006 and 2012.

The assessment of crop pollination was based on spatial models developed only for two groups of pollinator species (bumblebees and solitary bees). Only the model of bumblebees made use of observed data, while the other was an expert-based model. Occurrence data for bumblebees were available at a rather coarse spatial resolution (10 km x 10 km), which limits the accuracy of the model beyond this scale. This issue clearly points out that further knowledge on the abundance and quality of different pollinators is needed. Data at the EU level on different species of pollinators is scarce. It is important, therefore, that significant investment is made to support comprehensive and regular monitoring of pollinators and their habitats. In this sense, the **EU Pollinators Initiative**[119] will contribute to address part of this knowledge gap.

5.3.5 Flood control

5.3.5.1 Definition and methods

Flood control as an ecosystem service is defined as the reduction of runoff by ecosystems that mitigates or prevents potential damage to land assets (i.e. infrastructure, agriculture) and human lives. This assessment covers only riverine floods and it is focused on the protection of artificial areas[120] by ecosystems against floods.

The development of spatial models allows the assessment of different indicators of flood control by ecosystems: potential, demand, use, and unmet demand (Table 5.1 and 5.2). Flood control potential has been quantified by using as proxy the potential runoff retention by ecosystems (dimensionless indicator ranging between 0 and 100,

[118] We had to assume no changes in the demand because of lack of data.
[119] https://ec.europa.eu/environment/nature/conservation/species/pollinators/index_en.htm
[120] As defined by CORINE Land Cover

with 100 being the highest runoff retention). Artificial surfaces located in floodplains with a return period of 500 years are in need to be protected from floods and their extent (in km^2) was considered in terms of demand for flood control. Flood control by ecosystems is considered to be used only when areas of high runoff retention[121] are located upstream to demand areas, and contributing therefore to reduce downstream runoff. In this way, the use of flood control by ecosystems is quantified as the extent of artificial areas in floodplains protected by upstream ecosystems (in km^2). Complementarily, areas of demand that are not protected by upstream ecosystems have been considered as unmet demand.

Description of flood control indicators is provided in Table 5.1 and 5.2. Fact sheet 5.0.500 also shows maps of all flood control indicators and their changes over time. Further details on the methods to assess flood control by ecosystems can be found in Vallecillo et al. (2019b) and Vallecillo et al. (2020).

5.3.5.2 Results and discussion

Ecosystems with the highest potential to reduce runoff are wetlands, followed by woodland and forest, while urban ecosystems and sparsely vegetated land show the lowest flood control potential (Figure 5.13).

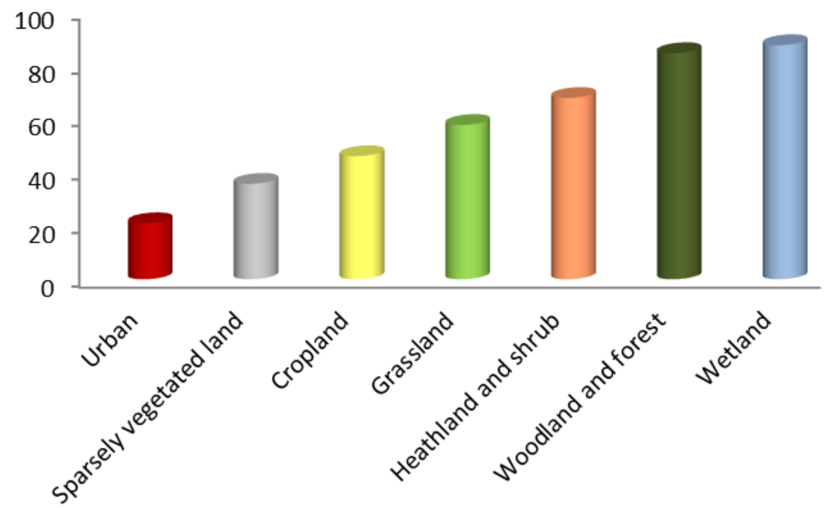

Figure 5.13. Average flood control potential in 2012 at EU level.

The trend analysis between 2006 and 2012 raises awareness of the important role of flood control by ecosystems. On average at EU level, there was a **very slight decrease by 0.1% per decade in the potential runoff retention by ecosystems** (Table 5.3 and 5.4). This overall decrease showed a lot of spatial variability across the EU territory. By looking only at areas with changes larger than ±5% (considered as significant), we found that 43 thousand km^2 of land showed an increase in the potential runoff retention, which were overtaken by about 55 thousand km^2 of land experimenting a decrease (Figure 5.14). See also mapping in Fact sheet 5.0.500. Increases in imperviousness and land cover changes such as the conversion of pastures to arable land and deforestation are identified as the main drivers of this decrease.

[121] Thresholds vary by ecosystem type: 61 for natural and semi-natural ecosystems, 52 for agriculture areas, 27 for artificial areas. For further details see Vallecillo et al. 2020.

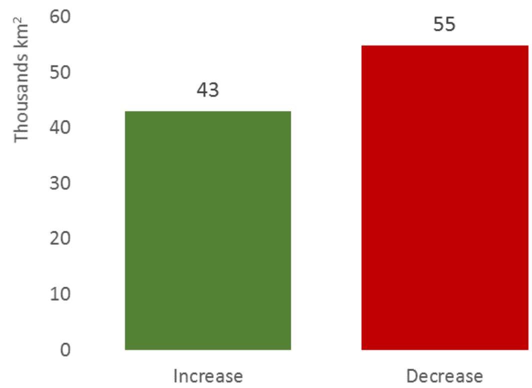

Figure 5.14. Extent of flood control potential changes in the EU between 2006 and 2012.

The demand for flood control has increased by 3% per decade (Table 5.4) confirming that floodplains are increasingly built up. Usually, an increase in the demand is aligned with an increase in the use of the ecosystem service because there are more areas benefiting from the protective role of ecosystems. In this case, **the use of flood control by ecosystems showed a stable trend** in spite of the increase of the demand, which shows a worsening protective role of ecosystems. Although the decrease of flood control potential is not very large at EU level, it is taking place in areas where there is a high need for ecosystems controlling floods.

Complementarily, the unmet demand shows a lack of flood control by ecosystems: **7% of the artificial areas in the EU were not protected by upstream ecosystems**, which represent 68% of artificial areas in floodplains (the share of demand considered unmet is provided in Fact sheet 5.0.500) (Figure 5.15). Although in many cases, flood control by ecosystems is complemented with man-made infrastructure for flood protection, the role of ecosystems is still very relevant. In fact, ecosystems act in synergy with man-made infrastructure reducing flood peaks and keeping it within safe operational limits. If the ecosystem potential to reduce water runoff decreases, man-made infrastructure will have to withstand higher amounts of runoff for which they were initially not designed. Importantly, we found that **the unmet demand increased by 3% per decade**, at the same rate as the demand, confirming the worsening protective role of ecosystems.

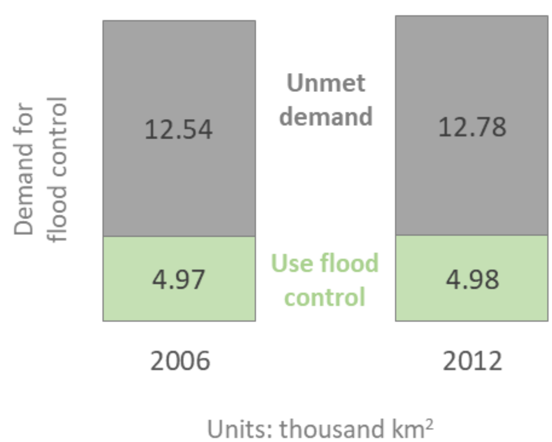

Figure 5.15. Demand, use and unmet demand for flood control in the EU.

The outcome of this assessment highlights the need of integrating the role of ecosystems providing flood protection in the flood risk management and restoration plans. Moreover, these results can provide policy support in relation to the mitigation of flood effects through sustainable ecosystem management. In this sense,

ecosystem management measures and nature-based solutions to enhance flood control should be prioritized in areas of unmet demand (Figure 5.16). Flood damage mitigation through nature-based solutions and ecosystem restoration are especially important under the expected increase of damages caused by river floods in the EU due to climate changes (Alfieri et al., 2018).

The indicator of unmet demand for flood control may also be useful to monitor the **SDG 1** and specifically **Target 1.5**: "... *reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters*". Although Target 1.5 refers primarily to 'poor' people, when it comes to vulnerable situations, also industrialized countries get exposed to risks of disasters, of course, with a different degree of implications. Flood control indicators are also relevant for EU policies like Climate Adaptation and the Floods Directive in order to better integrate the role of ecosystems providing flood protection.

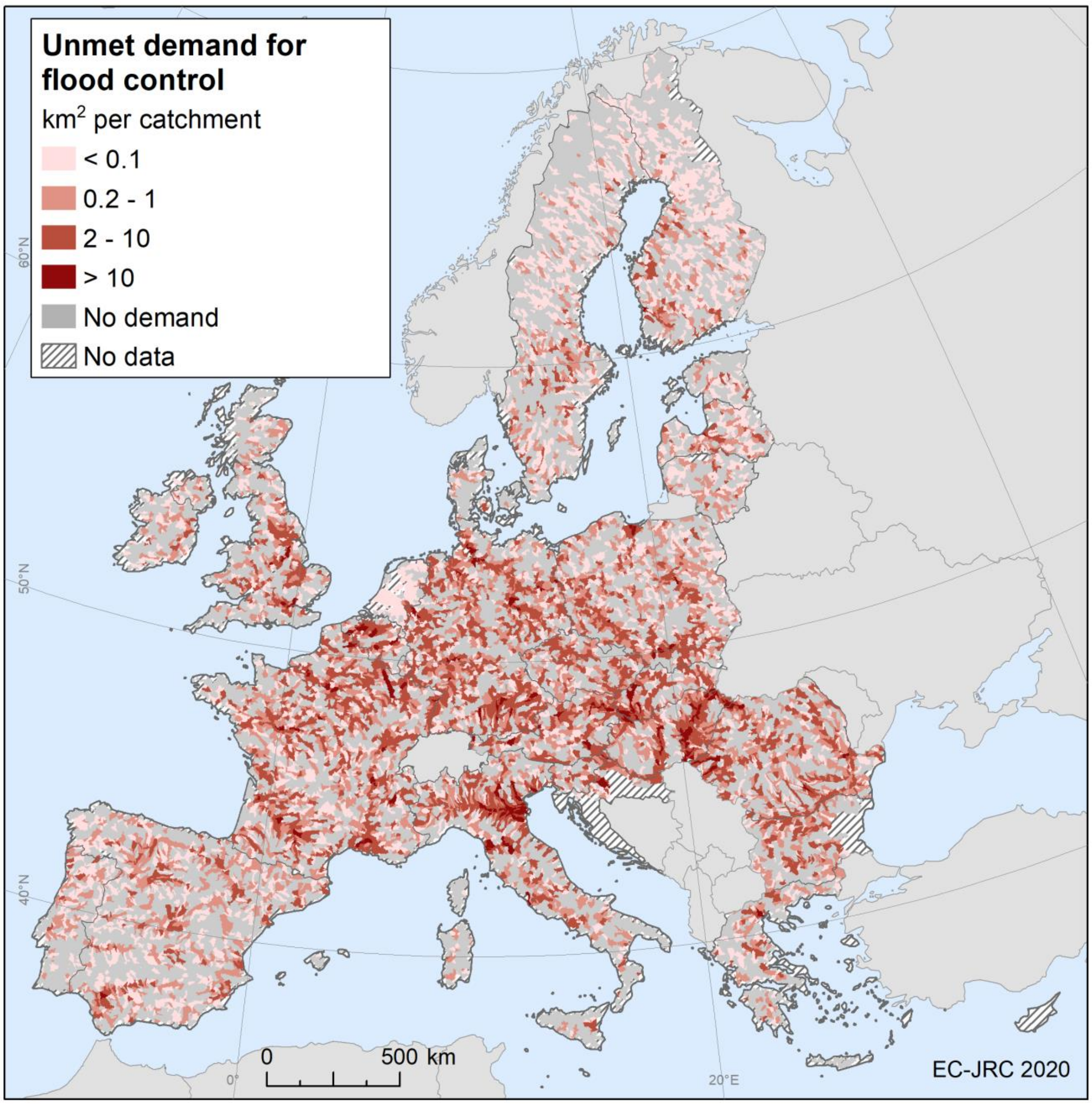

Figure 5.16. Unmet demand for flood control in 2012.

5.3.6 Nature-based recreation

5.3.6.1 Definition and methods

Nature-based recreation is a cultural ecosystem service defined as the biophysical characteristics or qualities of ecosystems that are viewed, observed, experienced or enjoyed in a passive, or active, way by people. This assessment covers daily-based recreation. Longer trips for enjoying nature were not considered yet.

Similarly to other ecosystem services, spatial models allow assessing different indicators of nature-based recreation: potential, demand, use, and unmet demand (Table 5.1 and 5.2). Nature-based recreation potential is considered as a dimensionless indicator of the availability of opportunities provided by nature (ranging between 0 and 1, with 1 representing the highest nature-based recreation opportunities). This dimensionless indicator was then used to define service providing areas (SPAs) based on both, the recreation potential and proximity to users, since we are focused in the assessment of recreation for a daily use. We termed these SPAs 'suitable areas for daily recreation', and this was an intermediate step required to quantify the use of nature-based recreation on a daily basis. Further details can be found in Vallecillo et al. (2019c). The demand for nature-based recreation was assessed as the number of inhabitants, since population need natural sites for recreation purposes. Then, the use of nature-based recreation was estimated as the number of potential visits that inhabitants will do to the 'suitable areas for daily recreation'. Visits were calculated using a mobility function only for the inhabitants that live closer than 4 km from suitable areas for daily recreation. Complementarily, inhabitants living beyond 4 km from suitable areas for daily recreation have been considered as unmet demand. Beyond this distance, citizens may need to take a car to reach 'suitable areas for daily recreation' or might use recreational areas with lower opportunities for, or lower quality of, nature-based recreation, therefore generating fewer benefits from nature.

A description of indicators of nature-based recreation is also provided in Table 5.1 and 5.2. More detailed definitions and maps of the indicators are shown in the fact sheet of nature-based recreation (Fact sheet 5.0.600). Analysis of changes over time is based on the 15 countries that were Member States by 2000[122] (EU-15 from here onwards). For the other countries, the lack of data does not allow to make sound comparisons.

5.3.6.2 Results and discussion

The **nature-based recreation potential showed a stable trend** between 2000 and 2012. The lack of changes for this period can be explained by the importance of two offsetting drivers: while designation of Natura 2000 sites was enhancing the ecosystem-based potential, sprawl of artificial land decreased it. Only for the first period analysed (between 2000 and 2006) there was an upward trend in the recreation opportunities offered by ecosystems (Figure 5.17).

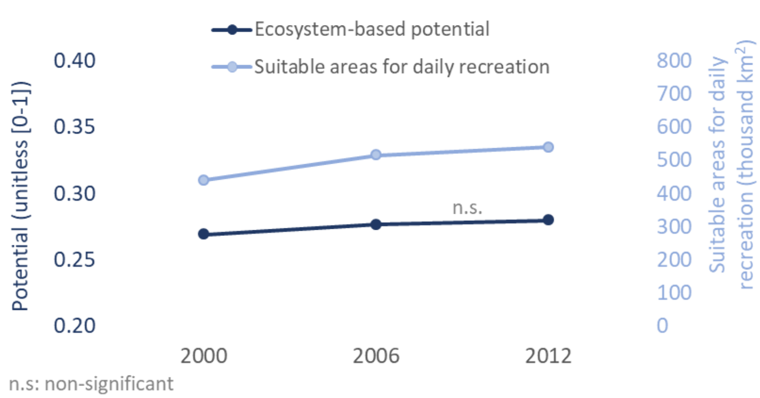

Figure 5.17. Indicators of nature-based recreation in the EU-15.

[122] Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden and United Kingdom

Urban sprawl also increased the proximity of citizens to natural sites making these areas more suitable for daily activities, for which short distances between people and natural areas are required. **Although 'suitable areas for daily recreation' increased by 19%, the quality of these areas[123] remains stable** at the EU-15 (Figure 5.17).

The increase of 'suitable areas for daily recreation', together with an increase of the population in the need of recreation in nature led to a **notable upward trend in the use of nature-based recreation**, increasing by 17% per decade (Table 5.3 and 5.4). In this sense, nature-based recreation provides an example, in which **human factors (not natural capital) enhanced the use of the service**: by the increase of the population and their proximity to natural sites. This may lead to the congestion of natural sites in the medium-long term with a negative impact on ecosystem condition, but also on the contribution of ecosystems to human well-being (not so pleasant recreate in congested areas). In this sense, an enhancement of the nature-based recreation potential would contribute to satisfying the increasing needs for recreation without compromising the quality of ecosystems or of the experiences/feelings of visitors. Enhancement of ecosystem-based potential, by creating for instance new natural areas within the close proximity of cities, is especially required in regions with high unmet demand (i.e. people living beyond 4 km from suitable areas for daily recreation). This outcome may support the planning and deployment of Green Infrastructure[124]. Although the unmet demand decreased by 8% per decade (Table 5.3 and 5.4), by 2010 there was still about 42% of the EU population with difficulties to reach areas providing high-quality opportunities for nature-based recreation (the share of demand considered unmet is provided in Fact sheet 5.0.600). This share of the population might need to take the car or public transport to walk, observe flora and fauna or practice jogging in nearby natural sites after work. The assessment of the **unmet demand for nature-based recreation** presents a good basis for the planning of measures related to the **SDG 11** for the provision of access to safe and inclusive green and public spaces. The linkage to this SDG is possible because our assessment is focused only on daily recreation.

5.4 Convergence of evidence for ecosystem services

An overall summary of ecosystem services indicators is already presented in Table 5.3 and 5.4. Figure 5.18 provides a synthesis of the trends. This synthesis shows opposing trends between the ecosystem service potential and demand[125]. While the potential was decreasing or stable, the demand was increasing for most ecosystem services, except for timber provision, which showed no changes. According to the current assessment, the increase in ecosystem services demand is mainly due to an expansion of pollinator-dependent crops, the expansion of built up areas in floodplains and population increase. This demonstrates that there was an **increase in the reliance of the EU society on ecosystems between 2000 and 2012, whereas ecosystems at the EU level were not enhanced to provide a higher quantity of the services assessed**: timber provision, pollination, flood control and nature-based recreation.

[123] As measured by the nature-based recreation potential

[124] COM/2013/0249 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249)

[125] Convergence of evidence for spatial data was not feasible since the limited number of ecosystem services with spatial grid data associated.

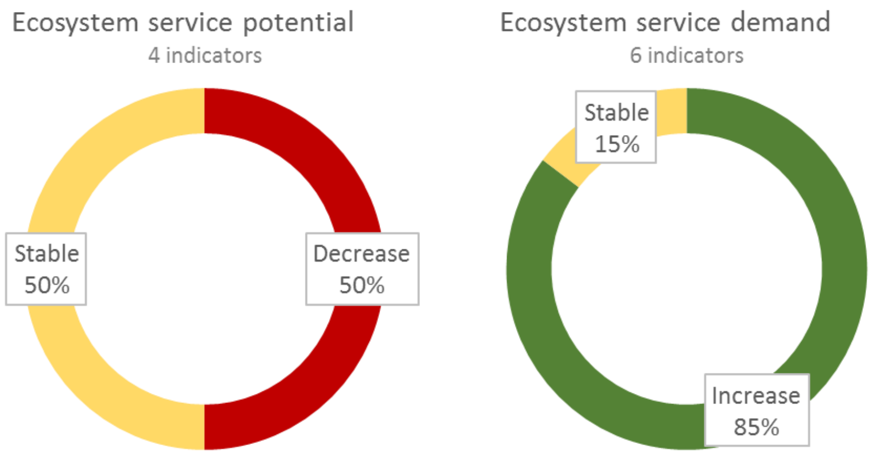

Figure 5.18. Convergence of evidence for changes in ecosystem service potential and demand.

Although the unmet demand could be only quantified for three ecosystem services, we found that on average there was **about 54% of the demand for ecosystem services not sufficiently covered by ecosystems** (Figure 5.19). The average decrease in the unmet demand over time denotes that an increasing percentage of the demand is benefiting from the services provided by ecosystems, contributing more significantly to human well-being (Figure 5.19). This reduction in unmet demand is mainly steered by nature-based recreation, which showed a decrease in unmet demand by 8% per decade (Table 5.4). This means that an increasing number of people was benefiting from nature-based recreation. However, as mentioned before, this decrease of the unmet demand was mainly explained by urban sprawl bringing closer people to natural sites (Figure 5.17).

Analysis of the differences between the two periods assessed (2000-2006 and 2006-2012) shows that there **appears to be a deterioration of ecosystem services towards the last period assessed**. Between 2000 and 2006, the enhancement of the ecosystem potential for pollination and recreation (Figures 12 and 17) contributed to the overall reduction of the unmet demand (Figure 5.19). This reduction has then slowed down in the second period (Figure 5.19), since the decrease in pollination and flood control potential between 2006 and 2012 has led to a rise in the unmet demand for these ecosystem services (Figures 12 and 15).

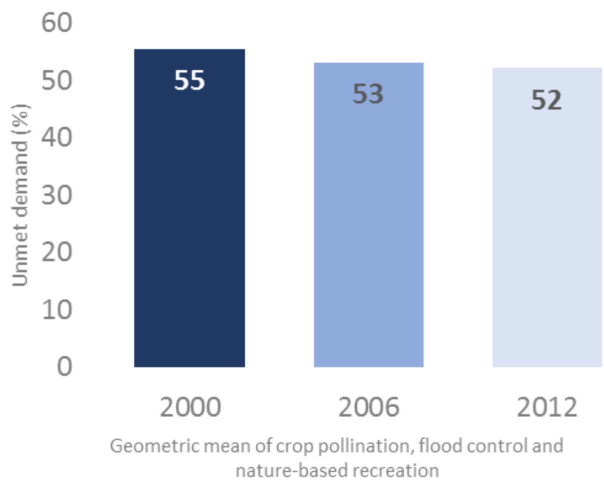

Figure 5.19. Percentage of demand not sufficiently covered by ecosystems (unmet demand).

Despite an overall decrease in the unmet demand, this assessment shows **a large gap between societal needs for regulating and cultural ecosystem services and the amount of services effectively delivered by ecosystems**. To narrow this gap, restoration actions and nature-based solutions should be prioritized in areas where the need for regulating and cultural services is not currently covered by ecosystems.

5.5 Conclusion and future research challenges

This section summarises the main outcomes derived from the assessment of six ecosystem services, making use of the best available data at EU level. The key message derived from this assessment is the **need to enhance the role of ecosystems in delivering services to cope with the increasing societal needs**. Actually, the assessment of the unmet demand has shown that there is a large gap between the societal needs for ecosystem services and the amount of services effectively delivered by ecosystems. In this context, the unmet demand for ecosystem services proves as a useful concept for the planning of restoration measures targeting the enhancement of ecosystem services by narrowing the gaps between the needs for ecosystem services and what ecosystem are effectively offering (Box 5.1).

Given the complexity of the modelling involved in the assessment of ecosystem services, the outcome is derived from a relatively limited number of years (2000, 2006 and 2012) and of ecosystem services (six). Moreover, model outputs were only available until 2012. In this sense, development of tools in Geographic Information Systems to model ecosystem services indicators (potential, demand, use and unmet demand) would contribute to a more regular update and systematic modelling of ecosystem services.

This assessment has also been useful to identify key data gaps for the ecosystem services. The understanding of data gaps can help target future research and monitoring priorities to improve knowledge on ecosystem services. In general terms, this assessment has shown that more representative time series of environmental data are needed to better assess changes over time. However, it is also important that time series available can ensure data consistency to make robust comparisons over time, which it is sometimes not so straightforward. Ecosystem services assessment would also benefit from statistical data at a more detailed spatial resolution, ideally at 1 x 1 km.

BOX 5.1. Restoration actions for enhancing regulating and cultural ecosystem services

Restoring ecosystems using nature-based solutions can improve the resilience of ecosystems, enabling them to deliver vital ecosystem services. This assessment has been useful to identify five main restoration actions to be potentially implemented, preferably in areas of unmet demand when available:

1. Restoration hedgerows in agricultural areas to create pollinator-friendly habitats and also contribute to enhance flood control by ecosystems (co-benefit),

2. Planning of green peri-urban areas to enhance the use of flood control and nature-based recreation where is more needed (co-benefit),

3. Prevention of land take, especially in floodplains, to reduce emissions of CO2 by urban ecosystems and, at the same time, reduce the need to control floods by ecosystems.

4. Wetlands restoration (mainly peatbogs) to enhance their potential role as sinks of CO2,

5. Grassland and cropland management (e.g. sustainable grazing, application of less intensive soil management practices) to reduce emissions from these ecosystem types,

These measures would be translated in an enhancement of the ecosystem's contribution to human well-being, especially when considering the multiple co-benefits they may generate. Some co-benefits are described here, but there are many other co-benefits for other ecosystem services not included in this assessment.

This information could be used to give support to the restoration targets of the forthcoming Biodiversity Strategy.

Data and methodological gaps depend on the type of ecosystem service assessed. For instance, for crop provision, further research to develop new methods to quantify the ecosystem contributions over time is needed. In this report, we refer to Vallecillo et al., (2019b) that make use of a scientifically sound method, but further efforts should be dedicated to better understand how the ecosystem contribution changes over time in relation to the measures proposed under the Common Agriculture Policy (CAP) and agri-environmental measures. Moreover, detailed spatio-temporal data is required to better analyse synergies and trade-offs of the ecosystem contribution with other ecosystem services. Spatial information on the distribution of different crop types would be also useful to cover the current data gap for mapping the demand for crop pollination. In the current assessment, we used modelled data (Britz et al., 2014), that were only available for 2004 and 2008. Improvement of this knowledge would contribute to better support decision making in relation to the planning of restoration of pollinator-friendly habitats in areas where there is higher need.

The assessment of crop pollination clearly points out that further knowledge is needed in relation to the abundance and quality of different pollinators. Data at the EU level on different species of pollinators is scarce. In this sense, the Pollinators Initiative of the EU[126] will contribute to reduce this knowledge gap. In addition, the assessment of crop pollination at the EU level does not include key pressures on pollinators such as pesticides or invasive species. Further research and data would be needed to integrate the impact of these drivers on pollinators at the EU level.

There is also a need to improve the knowledge of the role of ecosystems sequestering CO_2, including also unmanaged ecosystems. Data available at EU level by ecosystem type (LULUCF data) provide emissions and removals from managed ecosystems, which in the case of wetlands, represents a key knowledge gap leading to an underestimation of their role in sequestering CO_2. Actually, wetlands are reported as sources of CO_2 because of the emissions derived from peatlands, without consistently assessing flooded areas and other types of wetlands.

More representative time series of ecosystem condition indicators such as High Nature Value farmland and bathing water quality would be useful to better model the potential for nature-based recreation, as an example. In general, further research and spatial EU data are needed to better quantify ecosystem condition indicators over time, which ultimately are, together with the ecosystem type and extent, the key drivers of ecosystem services.

In practice, the analytical linkage between ecosystem condition and ecosystem services is still weak. Most ecosystem service models are mainly based on land cover data, with only a limited number of ecosystem condition indicators integrated. In this sense, the progress made in other chapters of this report assessing ecosystem condition sets an important basis for a future improvement in the assessment of ecosystem services and better understand how ecosystem condition drives the capacity to provide different ecosystem services.

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[126] https://ec.europa.eu/environment/nature/conservation/species/pollinators/index_en.htm

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Annex 1. Input data for ecosystem service indicators

	Data	Links / References
PROVISIONING		
Crop provision		Source: Vallecillo et al. 2019, page 13
USE	Ecosystem contribution ratio	Data derived from RC Report (https://ec.europa.eu/jrc/en/publication/emergy-perspective-natural-and-anthropic-energy-flows-agricultural-biomass-production)
	Spatial distribution crop yield 2008	Common Agricultural Policy Regionalised Impact (CAPRI) data (https://www.capri-model.org/dokuwiki/doku.php)
	Yield data country level	Eurostat dataset [apro_cpsh1] (https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpsh1&lang=en)
Timber provision		Original from the EU-wide ecosystem assessment
TIMBER PROVISION POTENTIAL	Net annual increments at country level	Eurostat datasets [for_vol] (https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do)
	Land-use land cover data	CORINE Accounting Layers V18.5 (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data)
USE	Felling at country level	Eurostat datasets [for_vol] (https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do)
	Land-use land cover data	CORINE Accounting Layers V18.5 (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data)
REGULATING AND MAINTENANCE		
Carbon sequestration		Source: Vallecillo et al. 2019, page 42
DEMAND	Atmospheric concentration of CO_2	https://www.eea.europa.eu/data-and-maps/daviz/atmospheric-concentration-of-carbon-dioxide-4#tab-chart_5_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_polutant%22%3A%5B%22CH4%20(ppb)%22%5D%7D%7D
USE	EUROSTAT [env_air_gge] (EEA, 2018)	Eurostat dataset (https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_air_gge&lang=en)
Flood control	Source: Vallecillo et al. 2019, page 67 and Vallecillo et al. 2020	
FLOOD CONTROL POTENTIAL	Land-use land cover data	CORINE Accounting Layers V18.5 (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data)
	Slope	EU Dem 100 m: https://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1-0-and-derived-products/eu-dem-v1.0?tab=download
	Hydraulic properties	USDA soil textural classes (https://esdac.jrc.ec.europa.eu/resource-type/datasets)
	Imperviousness	https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/view
	Riparian zones	https://land.copernicus.eu/local/riparian-zones
DEMAND	Agriculture and artificial land covers	CORINE Accounting Layers V18.5 (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data)
	Flood hazard map (return period 500 years)	https://data.jrc.ec.europa.eu/collection/id-0054
	Road network	Road network from TeleAtlas 2006 version
USE	Flow direction and flow accumulation	Derived from the EU Dem 100 m: https://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1-0-and-derived-products/eu-dem-v1.0?tab=download
UNMET DEMAND	Demand for flood control minus use	INCA output data
Crop pollination		Source: Vallecillo et al. 2018, page 33
POLLINATION POTENTIAL	Land-use land cover data	CORINE Accounting Layers V18.5 (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-

	Data	Links / References
		data)
	Roads	Road network from TeleAtlas 2006 version
	Climate data	Gridded Meteorological data from Agri4Cast (http://agri4cast.jrc.ec.europa.eu/DataPortal/SignIn.aspx?idResource=7&o=d) and E-OBS (http://www.ecad.eu/download/ensembles/download.php)
	Bumblebee records	Atlas Hymenoptera (http://www.atlashymenoptera.net/)
POLLINATION DEMAND	Pollination dependent crops	CAPRI data (https://www.capri-model.org/dokuwiki/doku.php)
USE	Pollination dependent crops	CAPRI data (https://www.capri-model.org/dokuwiki/doku.php)
	Areas with high pollination potential (>0.2)	INCA output data
UNMET DEMAND	Pollination dependent crops	CAPRI data (https://www.capri-model.org/dokuwiki/doku.php)
	Areas with high pollination potential (<0.2)	INCA output data
CULTURAL		
Nature-based recreation		Source: Vallecillo et al. 2018, page 11
NATURE-BASED RECREATION POTENTIAL	Land-use land cover data	CORINE Accounting Layers V18.5 (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data)
	Protected areas	World database of Protected areas (https://www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas)
	Bathing Water Quality	State of Bathing water (https://www.eea.europa.eu/themes/water/status-and-monitoring/state-of-bathing-water/state/state-of-bathing-water-3)
	Distance to Coast (sea and inland water bodies)	CORINE Accounting Layers V18.5 (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data)
	Coastal geomorphology	EUROSION Coastal Erosion Layer (Eurosion 2005)
SUITABLE AREAS FOR DAILY RECREATION	Nature-based recreation potential	INCA output data
	Tele atlas	Road network from TeleAtlas 2006 version
	Residential areas	CORINE Accounting Layers (https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data)
DEMAND	Population	Global Human Settlement Layer (http://ghsl.jrc.ec.europa.eu/ghs_pop.php)
USE	Local administrative units	http://ec.europa.eu/eurostat/web/nuts/local-administrative-units
	Mobility function	UK-Monitor of Engagement with the Natural Environment (https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results)
UNMET DEMAND	Population	Global Human Settlement Layer (http://ghsl.jrc.ec.europa.eu/ghs_pop.php)
	Suitable areas for daily recreation	INCA output data

EEA (2018) National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism. Published by Eurostat (update 05/06/2018). Downloaded on the 06/06/2018. Retrieved from http://appsso.eurostat.ec.europa.eu/nui/show.do?lang=en&dataset=env_air_gge

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Vallecillo, et al (2020) Accounting for changes in flood control delivered by ecosystems at the EU level. Ecosystem Services 44 p. 101142. http://dx.doi.org/10.1016/j.ecoser.2020.101142 .

6 Integrated assessment

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Summary: This chapter presents an integrated summary on the assessments of ecosystem extent, pressures, ecosystem condition and ecosystem services.

Marine ecosystems are the most extended ecosystems in the EU covering 5.8 million km^2. On land, forests and cropland are the dominant ecosystem types in the EU, followed by grasslands, urban areas, heathlands and shrub, rivers and lakes, inland wetlands and sparsely vegetated land. The extent of different ecosystem types is rather stable over time. Urban areas increased in size. Agroecosystems, wetlands and heathlands and shrub slightly decreased since 2010.

Despite the wide coverage of environmental legislation in the EU, there are still large gaps in the legal protection of ecosystems. On land, 76% of the area of terrestrial ecosystems, mainly forests, agroecosystems and urban ecosystems, is excluded from a legal designation under the EU's nature directives. Freshwater and marine ecosystems are subject to specific protection measures under the Water Framework and Marine Strategy Framework Directives.

Overall, the condition of most ecosystems in the EU is unfavourable. This conclusion is based on the official data from recent reporting from Member States on the conservation status of habitats, and the chemical and ecological status of water bodies.

The analysis of trends in pressures on ecosystems shows a mixed picture. Based on the available data, it is concluded that land take and pollution (but in particular nutrient enrichment) are declining. The most recent values for indicators that approximate these pressures are below the baseline value for 2010. However, the absolute values of these pressures remain high and further reductions are needed. Impacts from climate change on ecosystems are increasing. Of specific concern are rising land and sea surface temperatures, decreased effective rainfall, a higher incidence of extreme drought events and ocean acidification which are significantly different from the baseline values. Pressure by invasive alien species (IAS) of union concern is acting on all ecosystems. In particular urban ecosystems and grasslands are highly penetrated with these harmful species. Despite downward trends of emissions of nitrogen and phosphorus to the environment, the combination of these pressures and their possible interactions with climate change and the seemingly unstoppable spread of invasive alien species represent a serious threat for the EU's biodiversity and ecosystems. Pressures from overfishing activities and marine pollution are still high, leading degradation and loss of marine biodiversity and habitats. Erosion by water has decreased in the long-term but the trend stabilised on the short-term (since 2010) with rates that exceed soil formation.

The analysis of trends in ecosystem condition delivers also a mixed outcome. On the long term, air and freshwater quality is improving. In forests and agroecosystems, which represent over 80% of the EU territory, there are improvements in structural condition (biomass, deadwood, area under organic farming) relative to the baseline year 2010 but some key bio-indicators such as tree-crown defoliation continue to increase and are signs that ecosystem condition is not improving. Species-related indicators show no progress or further declines, in particular in agroecosystems. For the 81% of habitat assessments in poor or bad status, only 9% show improving trends, while 36% show continuing deterioration at the EU level. Soil organic carbon remains stable over time between 2009 and 2015.

The analysis of trends in ecosystem services concluded that the current potential of ecosystems to deliver timber, protection against floods, crop pollination, and nature based recreation is equal to or lower than the baseline value for 2010. At the same time, the demand for these services has significantly increased. This risks to further erode the condition of ecosystems and their contribution to human well-being.

Increasing impacts of climate and IAS and the downward trends of specific condition indicators are not simply cancelled out by positive trends of the abiotic quality and structural condition of ecosystems. Significant progress towards healthier ecosystems means that most of these indicators show clear and consistent upward trends. This is not the case yet and more efforts are needed to bend the curve and put ecosystems on a recovery path.

6.1 State and trends in ecosystem extent and area covered under different legal designation

This ecosystem assessment has used the MAES ecosystem typology to organize the work and to report on the condition of various ecosystems in line with the definitions provided by environmental legislation. This typology is also conditioned by accounting rules to avoid double counting in the quantified assessment of ecosystem extent and ecosystem services, which is a key condition to allow for using this information in natural capital accounting reporting (e.g. LULUCF). The ecosystem typology was developed in 2013 and is presented in the first MAES report. This section reports the trends of ecosystem extent in the EU-28 and the EU marine regions. It also outlines how different ecosystem types are legally protected and what are the next steps to move from a land account to an ecosystem account that allows the monitoring of gains and losses of ecosystems in the EU.

6.1.1 Extent of ecosystems in the EU-28.

The MAES ecosystem typology consists of seven terrestrial ecosystem types, one freshwater ecosystem type and four marine ecosystem types. The seven terrestrial ecosystems are urban ecosystems, cropland and grassland which have been aggregated into agroecosystems, forests, inland wetlands, heathlands and shrub, and sparsely vegetated land. The freshwater ecosystem type is rivers and lakes. The four marine ecosystems are marine inlets and transitional waters, coastal ecosystems, shelf and open ocean. In this study, assessments for these ecosystem types have been combined but reported for the EU's four marine regions: the Baltic Sea, the Black Sea, the Mediterranean Sea and the North-east Atlantic Ocean.

The first MAES report (2013) propose definitions of each ecosystem type and provide a crosswalk between the Corine Land Cover classification and the MAES ecosystem typology. This crosswalk, which is a tier-1 approach for mapping ecosystems, is the basis for the thematic and cross-cutting assessments that are presented in this report. The choice for using only land cover data to delineate ecosystem types has been made on the basis of data availability for trend analysis. Corine Land Cover data come with a time series that has updates for 2000, 2006, 2012 and 2018. The availability of these data allowed to assess trends in ecosystem extent but also to calculate the value of indicators that are dependent on land cover statistics, such as fragmentation or landscape heterogeneity. In addition, the assessment of trends in ecosystem services strongly relied on the use of the Corine Land Cover change layers, which are used in ecosystem extent accounts (see Chapter 2 section 7). Figure 6.1 maps the different ecosystem types using the tier-1 approach. This map acted as a reference for delineating the terrestrial and freshwater ecosystem types throughout this study.

However, ecosystems are more than simply land cover. An ecosystem is a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (definition from the Convention on Biological Diversity). It follows that in addition to land cover, other characteristics should be used to delineate ecosystem types. These include soil properties, information about the occurrence of habitats or species that structure the ecosystem, or functional characteristics related to vegetation or biomass such as productivity. The European Environment Agency has made available an updated map of ecosystems, based on a better biological characterization of terrestrial and marine ecosystems across Europe and taking into account EUNIS (European Nature Information System) habitat presence in terrestrial, freshwater and marine ecosystems (Weiss and Banko, 2018).

As already stipulated, this assessment used a tier-1 approach to defining the extent of ecosystems based on Corine Land Cover. The extent of ecosystems in the EU-28 for 2018 is presented in Table 6.2, whereas the relative shares per ecosystem type are shown in Figure 6.2. Forests and cropland cover together 72% of the EU-28. They each account for a total area of nearly 1.6 million km^2. Grasslands including pasture covers 11% of the territory. Urban ecosystems represent 5%. The other ecosystem types each cover less than 5%.

The extent of marine ecosystems is reported in Table 6.2. The total marine area within the EU marine regions amounts to almost 5.8 million km^2.

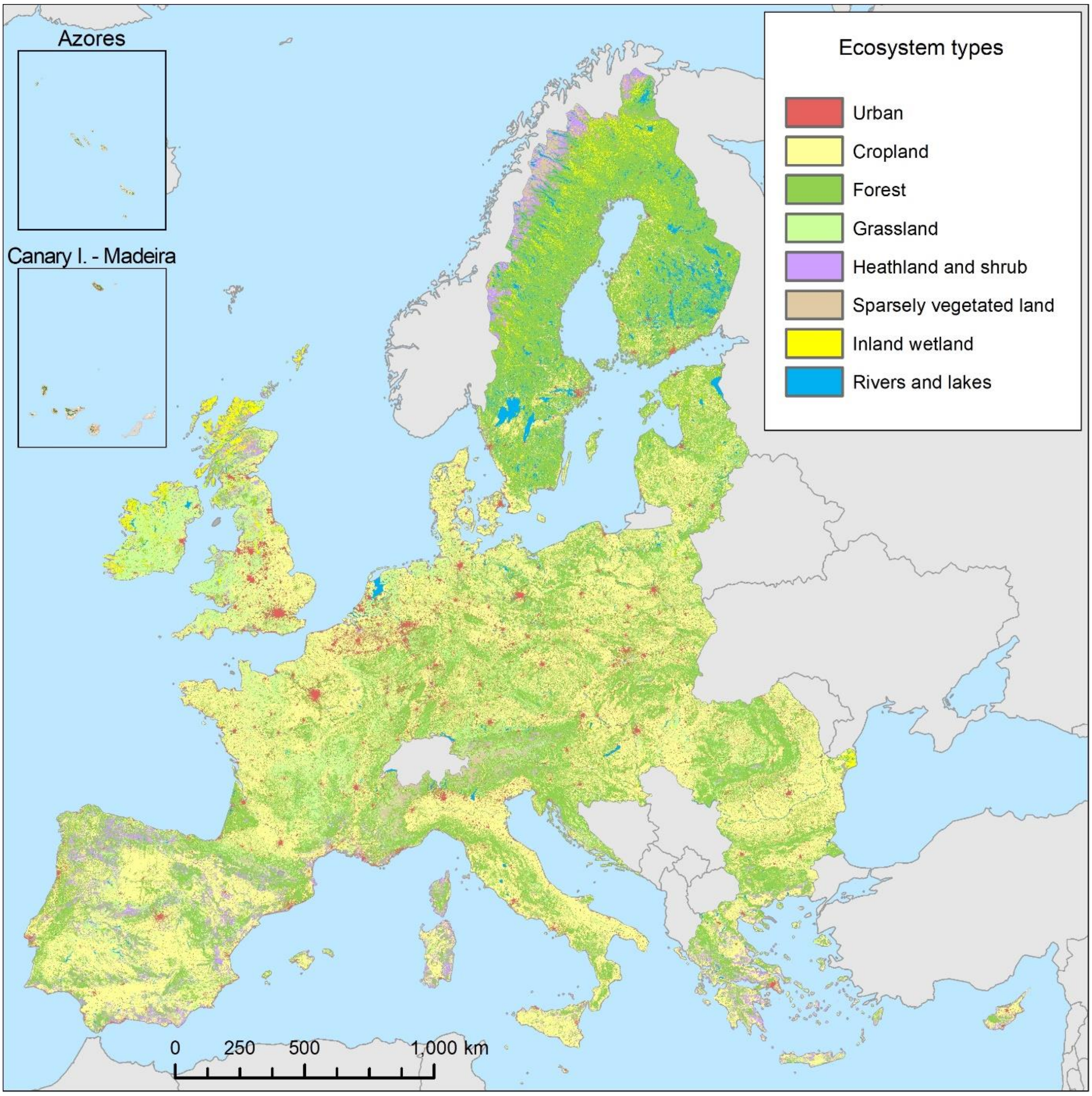

Figure 6.1. Terrestrial and freshwater ecosystem types 2018 (MAES typology – tier 1 based on crosswalk between MAES ecosystem types and the CLC land cover map, Annex 2 of the first MAES report).

Table 6.1 Total extent of MAES ecosystem types within the EU-28 and the proportion of Annex 1 habitat (habitats listed in Annex 1 of the Habitats Directive) and Natura 2000 area.

Ecosystem type		**Area (km^2)**	**Proportion of Annex 1 habitat (%)**[1]	**Proportion of Natura 2000 area (%)**	**Proportion of Annex 1 habitat* within Natura 2000 (%)**
Urban ecosystems		222,189	0%	3.05%	0%
Agroecosystems	Cropland	1,596,051	0%	8.47%	0%
	Grassland	500,566	46.50%	18.79%	14.63%
Forest		1,597,533	28.25%	22.63%	9.68%
Inland wetlands[2]		98,003	115.19%	37.37%	29.97%
Heathland and shrub		181,814	69.36%	40.66%	33.90%
Sparsely vegetated land		67,986	53.54%	52.61%	27.26%
Rivers and lakes[3]		109,261	64.25% (21.98%)	37.37%	25.41%
Marine inlets and transitional waters (coastal wetlands)[4]		24,776	-	86.59%	-
Total		**4,398,178**	**24%**	**18%**	**8%**

Data sources: Area of MAES ecosystem types based on ecosystem extent accounts provided by EEA; area of Annex 1 habitats based on data from the Art.17 conservation status assessment reports; area of Natura 2000 provided by EEA. All area data in Fact sheet 3.0.100.

[1]The share of Annex 1 habitat excludes Romania (the area of rivers and lakes and sparsely vegetated land is overestimated in the report)

[2]The total area of wetland habitats under Annex 1 is reported higher than the total area of inland wetlands. This is in part due to a different classification of wetlands and partly due to a double counting of habitats. See also chapter 3.4 for an extended wetlands definition.

[3]The relative area of Annex 1 habitat (64.25%) for rivers and lakes is probably an overestimation as it is difficult to assess how much of the river network (km) is covered by Annex 1 habitats. Therefore also a lower estimate is provided (21.98%) which it the relative area of Annex 1 freshwater habitats of the area of rivers, lakes and riparian areas (excluding Romania, see Indicator fact sheet 3.6.001)

[4]The total area of coastal wetland habitats under Annex 1 which are listed in Table 3.4.14 equals 84,487 km^2 which exceeds the value reported in the table.

Table 6.2. Total extent of EU marine regions (*sensu* the Marine Strategy Framework Directive) and proportion of Annex 1 habitat (habitats protected under the Habitats Directive) and marine protected area.

Regional sea basin	**Area (km^2)**	**Proportion of Annex 1 habitat (%)***	**Proportion of marine protected area (%)**
Baltic Sea	368,720	11.43%	16.50%
Black Sea	64,384	0.19%	14.20%
Mediterranean Sea	1,274,892	2.73%	11.70%
North-East Atlantic Ocean	4,082,719	10.61%	9.90%
Total	**5,790,715**	**9%**	**11%**

Data sources: EEA (Art. 17 data on the area of Annex 1 habitats and Marine Protected Areas) All area data in Fact sheet 3.0.100.

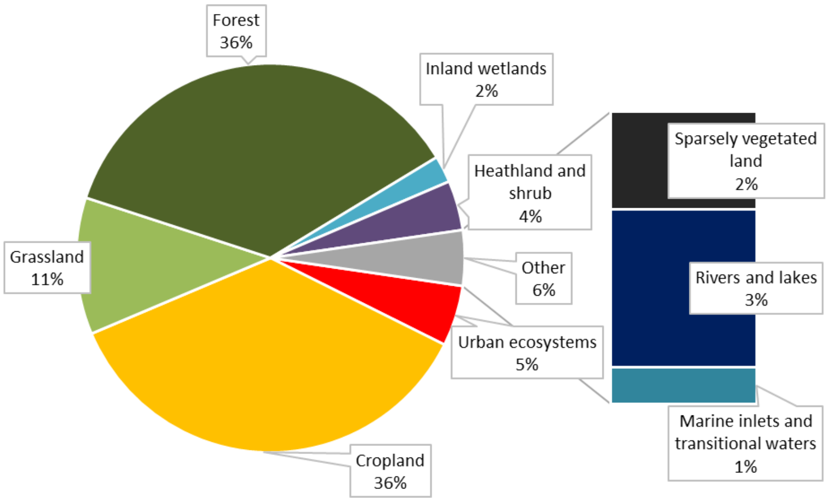

Figure 6.2. The proportion of MAES ecosystem types in the EU-28: seven terrestrial ecosystem types, one freshwater type and one marine ecosystem type. Class 'other' is further subdivided in rectangles in the right panel. Data source: EEA, ecosystem extent accounting layer for 2018. https://www.eea.europa.eu/data-and-maps/data/ecosystem-types-of-europe-1

6.1.2 Overlaps between ecosystem types, land cover data and extended ecosystem layers

The ecosystem types of the MAES classification have been identified because of their distinct natural properties which are reflected by their abiotic characteristics, biodiversity, vegetation structure, and their ecosystem functions. But the different ecosystems also are subject to different policies and management forms, each with their specific objectives, targets, governance, or level of competence, which makes it useful to assess them separately and formulate bespoke policy and management options.

Just as policies also natural ecosystems are difficult to classify into a unique category and overlaps occur frequently. Technically, overlaps may lead to double counting of ecosystem processes, condition indicators, or ecosystem services. In practice these overlaps are sometimes unavoidable and also in this assessment, we have been confronted with the difficulties that emerge when trying to categorise and delineate ecosystem types.

In general, forests as well as heathlands and shrubs have been fairly well represented by land cover data (i.e., there is a straightforward link between the Corine Land Cover classes and the ecosystem type). As such, they form relatively homogenous reporting units for collecting data and indicators and for the assessment of pressures, condition and ecosystem services, even if different definitions exist and are used to delineate forests or heathlands and shrubs.

The delineation of ecosystem types other than forests and heathlands and shrub has been less evident and it is interesting to pinpoint some problems that emerged during this ecosystem assessment.

Agroecosystems combine grassland and croplands. Both ecosystem types occur on a gradient from intensive to extensive use. Natural grasslands still exist in the EU although they are rare. Whereas land cover data can be used to separate croplands and grasslands, it turns out that data collections including information about their pressures and condition are often reported together under agricultural statistics and that simple separation of such statistics into a number for cropland and a number for grassland is not evident. This is also the reason why in this assessment they have been reported together.

The assessment of urban ecosystems included data and indicators that cover an area that is wider than the area delineated on Figure 6.1. Urban ecosystems are in Chapter 3.1 defined as a complex, integrated set of ecosystems characterised by high heterogeneity and by the intrinsic presence of humans. Also here, spatial units for reporting statistical information of urban areas often do not match with the ecosystem typology. The EU developed the geographical system of functional urban areas which go beyond artificial land cover. Functional urban areas consist of core cities and the commuting zone around them. In terms of vegetation, core cities typically contain urban green spaces, parks, or trees whereas the commuting zone also contains forests, agricultural land, grasslands and natural areas. Natura 2000 sites exist both in core cities (albeit limited) and in the peri-urban commuting zone. It follows that there is overlap between ecosystem types, in particular in peri-urban areas. Some ecosystem types close to cities have thus been assessed more than once in this report. Figure 6.3 presents the relative shares of the different MAES ecosystem types for functional urban areas. The figure is based on intersecting functional urban areas with the tier 1 ecosystem map presented in Figure 6.1. It shows that functional urban areas (both core cities as well as the more extended core cities and the surrounding commuting zone) in the EU-28 are actually composed of a mix of different ecosystem types. This is not surprising since the full extent of functional urban areas comprises 22% of the EU territory.

Particularly for wetlands, it has been evident that a simple delineation based on Corine Land Cover is insufficient to take into account the full breath of different habitats and ecosystems that exist on the boundary between the terrestrial, inland water, and coastal realms. During the development phase of this European wide assessment, it soon became clear that current delineation (Figure 6.1 and Table 6.1) is too narrow and special efforts have been made to expand the definition of wetlands and to quantify the total area of wetlands following this broader, ecosystem-based definition. Chapter 3.4 includes a detailed delineation of the extended wetland ecosystem layer and the analysis. Results of the 2012 extended wetland ecosystem layer developed show a wetland coverage of about 370,000 km^2 at EU-28 level which is four times the total area covered by inland wetlands alone (including only inland marshes and peat bogs, Table 6.1). Newly added classes to the extended wetlands habitats include valuable wet grasslands and heathlands as well as riparian, fluvial and swamp forests, in addition to marine waters less than six meters deep at low tide (Ramsar definition). These natural habitats have been considered under other ecosystem types (grasslands, heathland and shrub, forest and marine inlets and transitional waters). Figure 6.3 also presents the relative share of MAES ecosystem types that can be found within the extended wetlands layer. Whereas just over 76% of the extended wetlands layer is composed of the ecosystem types inland wetlands, rivers and lakes, and marine inlets and transitional waters, the remaining fraction is mainly covered by forest (13%).

Just as wetlands, riparian areas and floodplains are situated on the interface between water and land. In these ecosystems dry periods alternate with wet periods. This alteration makes it indeed difficult to simply assign riparian areas and floodplains to a single ecosystem type. Both ecosystems are crucially important to protect people and infrastructure from flooding, they host very specific biodiversity, and if flooded, they provide critical functions in terms of water storage, fish production, nutrient trapping, or bird habitats, which justify bespoke assessments that crosscut through the different MAES ecosystem types that are used in this EU ecosystem assessment. Chapter 3.6 provides estimates for the extent of riparian areas and floodplains (297,000 km^2 of riparian land, and 367,000 km^2 of potentially flooded areas). Figure 6.3 shows that riparian areas are mainly constituted of a mix of freshwater ecosystems, cropland and forest. Notably, 7% of riparian areas overlaps with urban ecosystems. Also potential floodplains are largely situated in cropland, forests and grasslands (Figure 6.3).

Sparsely vegetated land comprises very different sub types: beaches and dunes but also rocky habitats above the tree line in mountains. Given the major differences in the ecology between these sub-types, their aggregation into a single ecosystem type may possibly result in confusion when it comes to the interpretation of certain indicators. Both ecosystems share their key importance for recreation and tourism but they require different policy and management. These factors may be considered in a revised ecosystem typology.

Coastal zones are the interface between land and sea. They are also frequently debated ecosystems when it comes to their delineation. The MAES typology puts them under marine ecosystems and recognises two sub classes: marine inlets and transitional waters as well as coastal areas. This study has aggregated all marine ecosystem types (including also shelf and open ocean) into a single group but organised the assessment per marine region (Table 6.2). Also here, data availability, which is often related to the governance and management of the marine environment, have been key factors to decide on the reporting units. There is no single policy on coastal zones but in the EU the competence is divided over several policies which makes their assessment as single reporting unit more complicated.

In summary, two issues emerged during this study: (1) The MAES ecosystem typology challenges the delineation of certain ecosystem types, notably wetlands including riparian areas and floodplains, or of certain biomes or larger geographical entities such as mountains or coastal zones. (2) Sometimes there is data mismatch between ecosystem types on the one hand and reporting units for which data are available and are often based on the particular governance of ecosystems. These two issues can be addressed by a more detailed ecosystem typology but also by the collection of spatially explicit data on pressures and condition.

A more detailed mapping of ecosystem types can solve for instance the problems related to wetlands. A more refined specification and the delineation of ecosystem sub types can be useful to map ecotones or habitats on the boundary between land, fresh water, and sea. Depending on the questions raised, different sub types can be grouped into reporting units without double counting. For instance, an assessment can look at all wet ecosystem types and combine sub classes from forest, grassland and wetland ecosystems to form reporting units that do not necessarily correspond with the higher hierarchy of the ecosystem classification. We already referred to the ongoing work of the European Environment Agency to develop a more detailed ecosystem map for Europe. At global scale, the International Union for the Conservation of Nature has proposed a global, comprehensive ecosystem typology with 25 biomes and 103 ecosystem types (Keith et al., 2020). This typology will possibly be introduced as a global standard for ecosystem accounting promoted by the UN System of Economic-Environmental Accounting (United Nations, 2019).

In addition to a more refined ecosystem typology (including mapped delineations), the promotion and application at wider scale of spatial data is key to ecosystem assessments and accounting. Spatially resolved indicators for pressures and ecosystem condition allow aggregation to various reporting units such as political boundaries, catchments, or geographical regions. This way, ecosystem assessments such as this study are no longer dependent on reporting systems that are defined by specific governance of ecosystem types and for which data are often only available at aggregated reporting level, without the option to disaggregate data or to find the underpinning datasets.

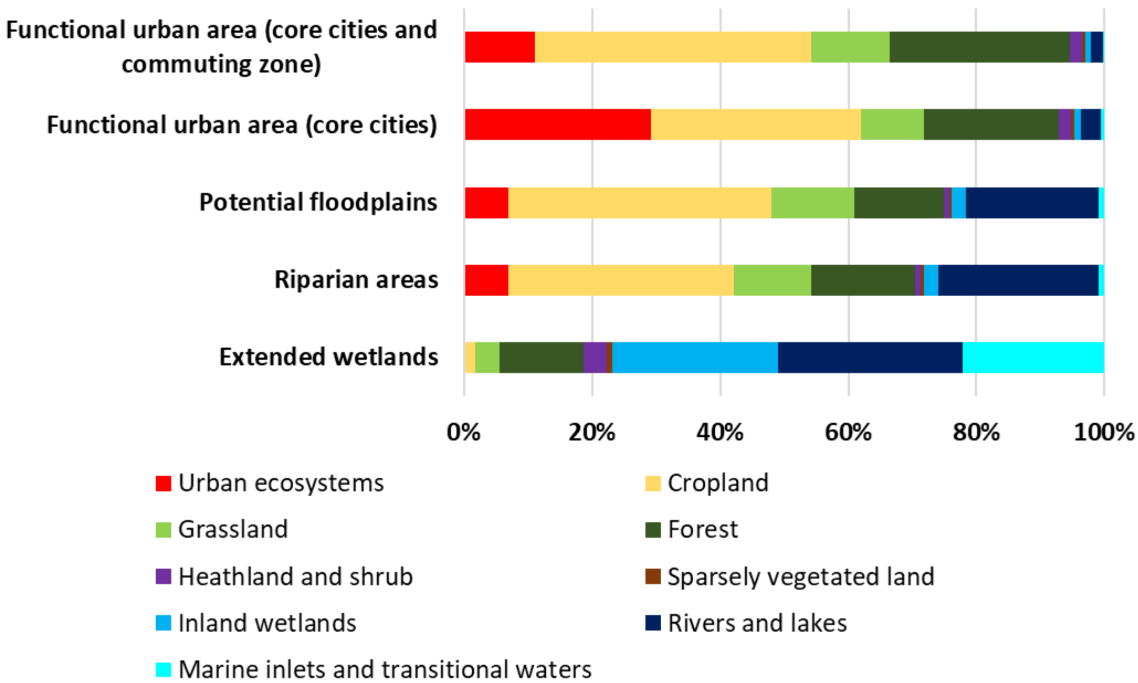

Figure 6.3. The relative composition of different ecosystem types within five extended layers (functional urban areas (core cities only and both core city and commuting zone), potential floodplains, riparian areas and extended wetlands). For each of these extended layers the area of MAES ecosystem type was computed and presented as percentage. Table 6.12 (Annex) contains the data presented in this figure.

6.1.3 Trends in the extent of ecosystems in the EU-28

The total area of each ecosystem type undergoes slow changes (Figure 6.4). The figure shows the rate of change expressed in percent per decade for the terrestrial ecosystem types based on the ecosystem extent accounting layers. These layers are used to quantify land accounts for Europe. The most pronounced change is observed for urban ecosystems due to the expansion of artificial areas, also described as land take. Land take increases at a rate of 3.4% per 10 years. Smaller increases are visible for sparsely vegetated land. Decreases in total area are observed for agroecosystems (cropland and grassland), for heathlands and shrubs and for inland wetlands. Forests, according to the data used, did not undergo significant changes and largely remained the same. Yet, from 1990 to 2015 data from the National Forest Inventories suggest ongoing afforestation with an increase from 1.48 to 1.61 million km^2 (see chapter 3.3). Utilised agricultural areas decreased also more than suggested by the Corine Land Cover statistics (see chapter 3.4). There are differences between reporting systems which can be related to the use of different definitions of the ecosystem type and to different methods to sample land cover and land use. Rivers and lakes and marine ecosystems also undergo changes (according to CLC) but here they are considered as stable in terms of their area.

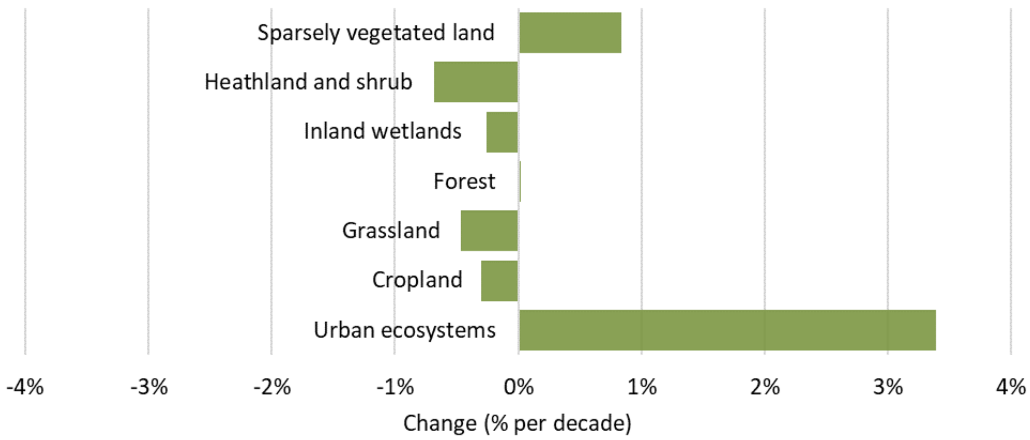

Figure 6.4. Changes in the extent of terrestrial ecosystems in the EU-28 based on the difference between total extent in 2000 and total extent in 2018. Source: EEA Corine Land Cover accounting layers.

6.1.4 How are ecosystems covered by the EU's environmental legislation: policy gaps

Not all ecosystem types are equally covered by environmental legislation. Table 6.3 presents a visual of the designation of ecosystem types under three environmental directives: the Habitats Directive (HD), the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD). The table also includes the share of ecosystems that spatially coincides with the Natura 2000 network, which also contains sites that are designated under the Birds Directive.

The Habitats Directive lists under its Annex 1 the natural habitat types of community interest whose conservation requires the designation of special areas of conservation. Recall that table 6.1 has for each ecosystem type the total extent in the EU-28, the share of this extent under Annex 1 habitat, Natura 2000 and both under Annex 1 and Natura 2000. Almost one quarter (24%) of the land territory of the EU-28 consists of habitats listed under Annex 1. The size of the Natura 2000 network covers 18% of the land mass. Taken together, 8 percent of EU-28 is identified as Annex 1 habitat situated within the Natura 2000 network. For the EU's seas, the statistics are reported in Table 6.2. On a total area of almost 5.9 million km^2 9% is Annex 1 habitat and 11% is designated as marine protected area.

Table 6.3 summarises these statistics in a visual way per ecosystem type. Urban ecosystems and cropland don't have specific habitats that are listed under Annex 1. However, a reasonable share of both ecosystem types falls within the Natura 2000 network. Of the EU's dominant ecosystem type by area, forests, 28% is Annex 1 forests habitat, while 23% of forests are Natura 2000 area. The other ecosystem types benefit from a wider designation. Around 50% of grasslands and sparsely vegetated land are listed as an Annex 1 habitat; for heathlands and shrub, this share is even bigger (69%). Coverage by Natura 2000 varies from 19% to 53% for these ecosystem types.

Freshwater and marine ecosystems including wetlands are not only subject of the nature legislation. As a matter of principle, all surface waters of the EU are covered under the Water Framework Directive (WFD) whereas all marine ecosystems are subject of the Marine Strategy Framework Directive (MSFD). The WFD and the MSFD overlap partially in the coastal waters. Coastal waters are defined in Art. 2 of the WFD as "surface waters on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters". The MSFD applies to all marine waters extending from the baseline to the outmost reach of the area where a Member State has and/or exercises jurisdictional rights. Liquete et al. (2011) estimated that the total area of coastal zone as defined by the WFD equals to 340,524 km^2 (for the 22 EU Member States connected to the sea). This corresponds to 5.9% of the total area of marine ecosystem reported in Table 6.2.

Table 6.3 also reports on the extended wetlands layer. For all wetlands that are included by the extended wetlands definition, reference is made to Table 3.4.16 for a description of the respective coverages under the HD, WFD and MSFD. The spatial analysis of Chapter 3.4 shows also that 41% of the extended wetlands layer is covered by the Natura 2000 network.

In conclusion, freshwater and marine environments as well as wetlands are well covered by these directives and these ecosystems are under multiple designations. For terrestrial ecosystems important gaps in environmental legislation remain. This is particularly evident for the EU's two dominant ecosystem types, forest and cropland which together constitute over three quarter of the EU territory. Enhancing the condition of these ecosystem types can deliver additional gains for biodiversity and ecosystems.

Table 6.3 highlights an important conclusion of this study. Not all ecosystem types are equally protected under EU law (see also Table 6.10 in the Annex with the main legal instruments per ecosystem type). Heathlands and shrub, sparsely vegetated ecosystems close to the sea or up in the mountains, and wetlands are currently profiting from a relatively high protection status. Substantial proportions of these ecosystems are assigned as Annex 1 habitats and covered by the Natura 2000 network. These ecosystems host high levels of biodiversity and their further protection is a key to conservation to habitat and species conservation. Freshwater and marine ecosystems are subject to specific directives that aim to bring these systems in a good condition. Yet, there remain vast areas of the EU territory unprotected and modified: 76% of the EU land territory (as captured by the Corine Land Cover dataset) is not listed under Annex 1 of the Habitats Directive; only 18% is part of the Natura 2000 network. For evident reasons, urban ecosystems, cropland and forests are least protected. These productive ecosystems, sometimes referred to as working landscapes, provide key ecosystem services to humanity (Kremen and Merenlender, 2018). If sustainably managed, these ecosystems can contribute considerably (given their size) to the EU wide conservation of biodiversity and the maintenance of ecosystems and their services (Maes and Jacobs, 2017). This requires specific policies to bring these ecosystems in good condition. A similar principle as the WFD with respect to surface waters or the MSFD with respect to marine waters could apply as both directives aim to bring all freshwater and marine ecosystem in good condition.

6.2 Ecosystem condition in the EU-28 and the EU marine regions

The EU policies make a distinct difference between ecosystem "condition" and "status". Ecosystem condition is the physical, chemical and biological condition or quality of an ecosystem at a particular point in time. Ecosystem status is the ecosystem condition defined among several well-defined categories with **a legal status**. It is usually measured against a pre-defined reference condition and compared to an agreed target documented in the respective EU environmental directives. The Birds Directive (BD), Habitats Directive (HD), Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD) all make use of the term "status" and they have established status levels at which a favourable or good situation is reached. These are respectively, population status of birds (BD) which needs to "secure", the conservation status of habitats and species which needs to be "favourable", the chemical and ecological status of water bodies, which needs to be "good", and the environmental status of marine waters which also needs to be "good".

The directives have set policy targets for a suite of indicators that measure the condition of biota or physical and chemical condition of ecosystems against a certain reference. This allows an evaluation to conclude whether or not the target level has been met. In addition, there is usually an aggregation scheme which outlines how different metrics should be aggregated and interpreted before making a final conclusion about the status of species, habitats or ecosystems.

In contrast, the majority of indicators used in this report to assess trends of pressures and conditions against a baseline year (2010) don't have a legal status. We have not been able to define reference levels for the condition indicators presented in this assessment at which the condition of the ecosystem is assumed to be "good". The Working Group MAES tackling Action 5 of the EU Biodiversity Strategy to 2020 was not mandated to identify such reference layers. Identifying the different indicators levels that separate a favourable from an unfavourable status needs to be part of follow up work (see Next Steps section 7.5). This also means that we cannot make inferences about the actual level of ecosystem condition on a qualitative scale from unfavourable, bad or low to favourable, good or high for instance by using an index. Instead, this assessment measures the changes in time and space of key condition indicators relative to a time-defined baseline. So at this stage, the only source of information on the level of ecosystem condition relative to a reference condition comes from the data collected under the above mentioned directives.

Table 6.3 Percent of the area of ecosystems under different designations.

Ecosystem type	Habitats Directive Annex 1 habitats	Natura 2000 (Marine protected area for marine)	Water Framework Directive	Marine Strategy Framework Directive
Urban ecosystems	0%	3%	Not applicable	Not applicable
Cropland	0%	8%		
Grassland	47%	19%		
Forest	28%	23%		
Heathlands and shrub	69%	41%		
Sparsely vegetated land	54%	53%		
Wetlands (extended wetlands) Table 3.4.16	96%	41%	44%	16%
Rivers and lakes (22% refers to extended definition including riparian areas)	64% / 22%	37%	100%	Not applicable
Marine ecosystems	9%	11%	6%	100%

Table 6.4 summarises the ecosystem condition data per ecosystem type which are reported by the different thematic ecosystem assessments of Chapter 3. We remind that Table 6.1 and table 6.2 summarise the area of each ecosystem type that is subject to reporting under the HD, WFD and MSFD.

In general, the conclusion is that, based on the reporting of status data (3rd cycle of reporting under the HD for the period 2013-2018 and the 2nd cycle of reporting under the WFD for the period 2010-2015) **the actual condition of ecosystems in the EU-28 remains largely unfavourable.**

In principle urban ecosystems and cropland have no reporting obligations under any of the four environmental directives. One can argue that the chemical and ecological status of rivers, lakes and coastal areas that intersect with cities and farmland reflects to some extent the condition of these ecosystems. To this end, the database with spatially explicit information about the status of water bodies needs to be filtered for urban areas and farmland but this assessment was not done for this study.

For the other terrestrial ecosystem types, only the data on habitat conservation status are included in this report. This is because there is a reasonably straightforward relationship between the habitat types under Annex 1 of the Habitats Directive and the MAES ecosystem types (see also table 2.2 Chapter, 2). Only dune and coastal habitats have not been assigned to a single ecosystem type. The general conclusion on ecosystem condition is that only a small share of habitats achieve a favourable conservation status. It varies from 10.7% for wetlands to circa 14.3% for grasslands, heathlands and shrub and forests, and to 25.4% for sparsely vegetated land.

In rivers and lakes the share of freshwater habitats reaching a favourable conservation status is 18.4%. The share of water bodies achieving at least a good chemical or a good ecological status is 36.0% and 39.0%, respectively.

Marine ecosystems are mostly covered by the MSFD but an assessment of environmental status is still pending while the data reported under the HD and WFD are only valid for marine inlets, transitional waters and the coastal zone (and thus excluding vast areas of the marine realm). Habitat conservation status data have been grouped over all the regional seas (although statistics are available per regional sea). However, only 1 habitat assessment out of 34 (or 2.9%) results in a favourable conservation status. The share of marine water bodies reaching good chemical and ecological status under the WFD varies between 4% and 65%.

As already noted above for urban ecosystems and cropland, the ecosystem condition data that are regularly reported under the four directives are in fact underused. For example, the data on the conservation status of non-bird species and the population status of bird species have not been considered in this ecosystem assessment, although they are highly relevant to assess the condition of ecosystems. This is in first instance due to a lack of a detailed crosswalk between these species and the MAES ecosystem types. There is currently no key to assign species to ecosystem types, which also reflects scale issues that arise when assessing ecosystem properties or characteristics. The distribution of many species is not confined to certain ecosystem types, in particular for migratory species. Instead, many species use more than one ecosystem type in their life history which complicates the assignment of species to ecosystem types. The question is how to correctly translate the favourable or unfavourable status of a species into a condition metric for one or more ecosystem types. Assessment of biodiversity across these scales is imperfectly nested, and hence cannot simply be upscaled or aggregated. Agreeing on an allocation key or look-up table between species and ecosystems or between conservation status and ecosystem condition also requires finding scientific and policy consensus and needs testing. Still, the presence and abundance of keystone species, specialist species, of species vulnerable to pressures is key information that deserves a better integration into the assessment of ecosystem condition.

The same problem was encountered to assess chemical and ecological status of wetlands. As already highlighted for cropland and urban areas, it is possible to select monitoring stations that are part of the monitoring network used to report under the WFD and that overlap with the wetlands layers used in chapter 3.4 to calculate the average chemical and ecological status. In a similar way, environmental status recorded under MSFD could be assessed for coastal wetlands, provided that data are available. These data extractions and ecosystem specific assessments have not been done but we recommend to use these data in follow up work needed to support the EU Biodiversity Strategy to 2030.

Table 6.4. Ecosystem condition of terrestrial, freshwater and marine ecosystems in the EU-28 and the EU marine regions.

Realm	Ecosystem type	Indicator	Share of ecosystem in favourable or good status
Terrestrial ecosystems	Urban ecosystems	-	-
	Agroecosystems (cropland)	-	-
	Agroecosystems (grassland)	Share of grassland habitats in favourable conservation status	14.3%
	Forests	Share of forest habitats in favourable conservation status	14.1%
	Heathlands and shrub	Share of heath and scrub habitats in favourable conservation status	14.3%
		Share of sclerophyllous scrubs habitats in favourable conservation status	21.2%
	Sparsely vegetated land	Share of rocky habitats in favourable conservation status	25.4%
	Wetlands	Share of bogs, mire and fens habitats extent in favourable conservation status	10.7%
Freshwater ecosystems	Rivers and lakes	Share of freshwater habitats in favourable conservation status	18.4%
		Share of water bodies in good chemical status	36.0%
		Share of water bodies in good or high ecological status	39.0%
Marine ecosystems (only marine inlets, transitional waters and the coastal ecosystems)	All marine regions	Share of marine habitats in favourable conservation status	2.9%
	North-east Atlantic	Share of water bodies in good chemical status	55.3%
		Share of water bodies in good ecological status	51.5%
	Baltic Sea	Share of water bodies in good chemical status	56.2%
		Share of water bodies in good ecological status	20.3%
	Black Sea	Share of water bodies in good chemical status	4.2%
		Share of water bodies in good ecological status	15.3%
	Mediterranean	Share of water bodies in good chemical status	32.8%
		Share of water bodies in good ecological status	63.6%

Data sources: Chapter 3 (Thematic ecosystem assessments; condition indicator tables). Colours only for illustration purposes to highlight percentiles (red: 0-20%; orange: 20-40%; yellow: 40-60%; green: 60-80%).

As for the use of conservation status of habitats to assess ecosystem condition, the option was to ensure that the data reported in this report reflect the official reporting in the State of Nature Report (EEA, forthcoming, 2020). Therefore table 6.4 reports the percentage of habitats in favourable conservation status using the EU level data, which are based on an aggregation of assessments carried out by each Member State. The advantage is that both this report and the State of Nature report use the same data. However, this choice also sets a limitation on an alternative use of the Art.17 reports submitted by the Member States. For instance, the correspondence between Annex 1 habitat types and MAES ecosystem types can be used to infer the conservation status of all habitats within an ecosystem type. In addition, Member States also submit area based information on the condition of habitats in order to calculate the structure and function parameter, one of four parameters used to derive a conclusion on conservation status. Also here we recommend to better investigate how habitat data collected under HD can be used to evaluate the condition of ecosystems.

Another important concern warrants discussion. Even if the above mentioned issues are addressed by streamlining definitions and developing cross walks among the different typologies, it remains difficult to infer EU level trends based on the different reporting cycles. Reporting under the habitats directive suffers from the use of different approaches among countries which probably has an impact on the EU based conclusion for conservation status. Also the analysis of trends is complicated and it is often discouraged to simply compare the status information stemming from the different reporting cycles. Reporting by Member States under the WFD has benefitted from an EU wide intercalibration exercise but changing assessment approaches from one reporting cycle to another makes it difficult to report and interpret trends. Reporting under the MSFD still suffers from many obstacles with respect to data collection and coverage. The result is that the status data presented in table 6.4 are the best available evidence we have to make a conclusion on the condition of ecosystems in Europe but that it remains difficult to track the changes in condition over time. Hence the effort of this ecosystem assessment to look beyond the reporting obligations and to use European wide, harmonised data sets to infer trends in pressures and condition based on an indicator approach.

6.3 Trends in pressures and ecosystem condition

The main objective of this report was to analyse the changes in pressures on ecosystems and ecosystem condition relative to the baseline year 2010. This analysis is based on a set of ecosystem-specific indicators which are underpinned by harmonised data that cover the EU-28 and the EU marine regions and for which at least two points in time were available in order to assess trends.

6.3.1 General statistics on trends in pressure and condition across the different ecosystems

In total the thematic ecosystem chapters on urban ecosystems, agroecosystems, forests, heathland and shrub, sparsely vegetated land, wetlands, rivers and lakes, and four marine regions are based on **132 unique indicators** (**51 unique pressure indicators and 81 unique condition indicators**). Most indicators are ecosystem-specific which means that they are only used to indicate pressures or condition of a single ecosystem type. A few indicators are crosscutting and have been used by more than one thematic ecosystem assessment. Cross-cutting pressure indicators include land take, climate indicators such as temperature, effective rainfall and extreme drought events, nutrient balance (of nitrogen and phosphorus) and deposition or exceedance of critical loads. Cross-cutting ecosystem condition indicators include landscape fragmentation, water quality related indicators, and the share of ecosystem that is managed as a protected area.

Taken together, the 132 indicators have been used in **378 short-term trend assessments** (129 short-term pressure assessments and 249 short-term condition assessments) and **378 long-term trend assessments** (129 long-term pressure assessments and 249 long-term condition assessments). Each trend assessment delivered one of four possible conclusions: improvement, no change, degradation or unresolved. A significantly downward trend in pressure or a significantly upward trend in condition are in this study associated with improvement. In contrast, a significantly upward trend in pressure or a significantly downward trend in condition are associated with degradation. No changes reflect a trend over time that remains constant relative to the baseline. The category unresolved has been used to label dynamic trends often due to high interannual variability which made is difficult to define the direction of the trend. Unresolved can also refer to data deficiencies (no data are available, only baseline data are available, or data are available but needed further post-processing and were therefore not used in this study).

Table 6.9 (Annex) breaks down the 378 short-term pressure and condition assessments over the four assessment conclusions (improvement, no change, degradation, unresolved) per ecosystem type. Table 6.10 (Annex) contains the same information but for the 378 long-term assessments.

A first important observation is the **large number of unresolved trend assessments**. Across all the ecosystem types (including the four marine regions), 170 short-term trends and 210 long-term trends (of 378) were unresolved (for the reasons mentioned above). The large share of unresolved trends corresponds to data deficiencies. Mostly time series data (indicators for which there is information for at least two points in time) are unavailable or data exist but it was not possible to rescale them to specific ecosystem types (for instance by spatial aggregation or disaggregation).

The remaining trends (or resolved trends) are more or less equally distributed over the three other assessment conclusions: 73 short-term trends suggest improvement, 72 short-term trends conclude no-changes, and 63 short-term trends suggest degradation. For the long-term trends 64 suggest improvement, 53 resulted in no change, and 52 indicated a degradation.

There is a high correspondence between short-term and long-term trends: 65% of the trend assessments (244 out of 378) reached the same conclusion for the short term and the long term. The most frequent combination of the remaining fraction is that either the short or long term assessment has a conclusion (improvement, no change, degradation) while the other trend is unresolved. This happens in 27% of the cases. Only three assessments flipped from sign between short and long term (improvement on the short term and degradation on the long term or vice versa). In sum, this means that **short-term trends from 2010 onwards largely have the same direction as the long term trend in pressure and condition** (since 1990 or 2000). For this reason the following discussion is basically limited to a description of the long-term trends in pressures and condition.

6.3.2 Trends in pressures and condition based on the core set of policy relevant indicators for ecosystem condition

A key outcome of the summary statistics presented in section 6.4.1 is that 38% of the 168 resolved long-term trends in pressures and condition suggests a significant improvement while 32% is stable (no change relative to the baseline) and 30% is degrading. In other words, at first glance, there is no clear picture towards either clearly improving or clearly deteriorating conditions of ecosystems in the EU.

During the data analysis phase of this ecosystem assessment, a number of approaches for aggregation of the pressure and condition indicators per ecosystem type have been discussed and explored but no consensus could be reached on the question if the aggregation of trends can be performed in a way that is meaningful or relevant for policy. Therefore, this report does not present an aggregated index or an aggregated presentation of the trend assessments.

Instead of aggregation, this chapter focusses on the trends of a core set of key indicators which have been presented in the fifth MAES report. The report sets an analytical framework for measuring pressures and ecosystem condition and is the foundation of this assessment. The core set consists of indicators with high policy relevance and many of them are instrumental to measure progress to targets under various policy frameworks. The advantage of working with this core set to synthesise the outcomes of the ecosystem assessment is that it represents an unbiased and agreed set of indicators. Unbiased because the core set has been chosen well before the start of this ecosystem assessment, so it is not subject to a possibly biased addition of indicators; agreed because the selection of ecosystem pressure and condition indicators that are proposed in the fifth MAES report is based on predefined indicator criteria (table 2.1 of the fifth MAES report) and have been commented and reviewed by Member States and EU services (see Figure 3.1 of the fifth MAES report for a road map).

Tables 6.5, 6.6 and 6.7 correspond to the Tables 5.1, 5.2 and 5.3 of the fifth MAES report which describe the core set of pressure and condition indicators for different MAES ecosystem types. The main difference is that the tables are now completed with the trend assessments and indicate the trend using one of the four assessment outcomes: improvement, no change, degradation or unresolved. The tables report the long-term trend (unless indicated otherwise below the table). Cropland and grassland have been combined to agroecosystems. Cases where the core indicator is approximated by another indicator used in this assessment report are indicated below the tables. A notable addition to the core set of indicators presented in the fifth MAES report are climate indicators. This knowledge gap has been addressed in this report and we included three climate indicators which have been used in the chapters on forests, agroecosystems and wetlands to assess pressures from climate change. So strictly speaking, the comment that the core set of pressure and condition indicators is unbiased and agreed does not hold for these three climate indicators.

Using the tables 6.5, 6.6, and 6.7 with trends for the core indicators, along with additional trend information stemming from the thematic and cross cutting ecosystem assessments of chapters 3 and 4, the following, major trends with respect to pressures and ecosystem condition occur in the EU-28.

6.3.2.1 Habitat conversion and degradation

Land take is decreasing in forests, agroecosystems, heathlands and shrub and sparsely vegetated areas but not in wetlands and in floodplains or riparian areas along rivers and lakes (Table 6.5). The decreasing trend in land take also reflects the relatively low changes in land cover change (Figure 6.4). These findings are corroborated by the analysis of landscape mosaic presented in chapter 4.3. Landscape mosaic measures the degree of land use intermix between agricultural, urban and natural areas. At EU level, the relative share of these three classes remains unchanged since 2000 (Table 4.3.1). Despite the lowering rate of land take, regional increases are apparent on specific locations in the EU. Urban and industrial land cover in central Europe, the southern UK and around Madrid is significantly increasing (Chapter 4.3). Agriculture land use is significantly increasing in the south-western part of the Iberian Peninsula at the cost of natural areas (Chapter 4.3). In addition to these changes, soil sealing in wetlands is increasing (Table 3.4.8). The urban ecosystem assessment shows that imperviousness of the soil is significantly increasing (Table 3.1.4) and that land in urban areas is inefficiently used (Table 3.1.5). Tree cover loss in forests increased by 26% per decade in the period 2001-2012, and by 74% per decade in 2009-2018 (Table 3.3.4). The continuation of this trend could lead to degradation and reduction of the delivery of key ecosystem services.

6.3.2.2 Climate change

Pressures caused by climate change are significantly increasing (Table 6.5). On land the average air temperature is rising with a rate of +0.325 °C per decade between 1960 and 2018 (Table 4.1.1). Of specific concern are the decrease in effective rainfall and the increase of extreme drought events in forests and agroecosystems (Table 6.5). The effective rainfall is the difference between the amount of precipitation and potential evapotranspiration. It is an indicator of the degree of water deficiency. Effective rainfall has, on average, decreased with 12 mm per decade between 1960 and 2018 (Table 4.1.1). Water is a limiting factor for forests and agroecosystems and essential for delivering ecosystem services such as food, timber, or carbon sequestration. The number of fires (Table 3.3.4) is increasing although the total area burnt has decreased on the long term. The total area of wildfire in heathlands and shrub, which are particularly vulnerable (Fagúndez, 2012), is increasing at an alarming rate (Table 3.5.6). Sea surface temperature and sea level are significantly increasing and marine ecosystems are acidifying (Table 6.7). Chapter 4.1 mapped the severity of climate change based on 15 bioclimatic variables. The impact of climate change is omnipresent in the EU but it is most pronounced in an area spanning from Portugal to Romania, including south France, the entire Mediterranean, and the Danube river basin (Figure 4.1.22). Also north Sweden and north Finland are experiencing increased climate impacts in comparison with areas in Western Europe, and the European plains between Brittany in France and Southern Finland (Figure 4.1.2.22).

6.3.2.3 Pollution and nutrient enrichment

Pressures caused by emissions of pollutants to the atmosphere or to surface waters of the nutrients **nitrogen and phosphorus** are significantly declining (Table 6.5). The result is a decreasing nitrogen deposition, decreasing exceedance of critical loads on forests, agroecosystems, heathland and shrub and sparsely vegetated ecosystems (Table 6.5). In agroecosystems, the gross phosphorus balance is improving but the gross nitrogen balance remains equal to the baseline value for 2010 (Table 6.5). In terms of ecosystem condition, air quality in urban areas is improving and tropospheric ozone in forests (a secondary pollutant caused by nitrogen emissions) is decreasing (Table 6.6). The concentration of nutrients and the associated biological oxygen demand of rivers and lakes (and in ground water) is decreasing (Table 6.6). The bathing water quality in both freshwater (Table 3.6.4) and marine ecosystems (Table 6.7) is improving. On the short term, there is no change in chemical or ecological status of surface waters (Table 6.6). The impact on marine water quality of these positive trends is insufficiently understood and trends in marine water quality remain largely unresolved. Data on pesticides are limited to sales only and only a short term trend has been calculated. Pesticide sales remain stable at around 380 thousand tonne per year at EU-level (Table 3.2.4) so that concentrations in the environment are likely to remain unchanged or increasing with respect to the baseline year 2010.

Although marine litter causes a huge impact on the ecosystems, trends in pressure from litter are still difficult to assess reliably. Recent progress in data availability seems to cover mostly beach litter, while seafloor litter and micro litter are still largely unknown.

6.3.2.4 Overexploitation

Trends for overharvesting of natural resources are available for timber delivered by forests (Table 6.5) and for marine fisheries (Table 6.7). The long-term ratio of annual fellings to net annual increment of timber in forests remains constant over time.

Fishing mortality of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{msy}) is decreasing in the Baltic Sea and in the North-east Atlantic Ocean (Table 6.7) and fish mortality is close to F_{msy}. This decrease is not observed in the Mediterranean Sea and the Black Sea (Table 6.7) where fish mortality remains more than double the sustainable yield.

Water abstractions pose heavy pressure on freshwater ecosystems, especially where water availability is limited. In 2010 around 204,490 million m^3 of water was abstracted in the EU-28 zone as off-stream. About 39% of these gross abstractions was used and 61% was returned back to the environment with a certain level of physical or chemical deterioration. Water abstraction decadal change was -7% for 2000-2015, but no significant change occurred between 2010 and 2015. Despite the improvements, the important reductions in water abstractions from 1990 to 2010 may not continue in the foreseeable horizon. In the light of these considerations, abstractions until 2020 are considered to remain stable and similar to 2010.

6.3.2.5 Invasive alien species

A frequently used method to assess trends of non-indigenous species is to record the number of annual introductions and add this to previous introductions to derive an indicator expressing the cumulative number of introductions over time. This assessment focused only on a subgroup of non-indigenous species: a list of 49 invasive alien species (IAS) of union concern which poses the highest risks for terrestrial and freshwater ecosystems and biodiversity (marine ecosystems are not really considered). Chapter 4.2 developed an indicator that mapped the distribution of these IAS of union concern and translates that into a (proxy for) pressure on ecosystems. Currently, there are no EU wide trends for these IAS hence the label of unresolved in Table 6.5. However, the baseline data for 2010 show that urban areas and grasslands in Europe are particularly affected by IAS of union concern, with an estimated pressure on over 60% of the total extent of these ecosystem types. For croplands, forest and freshwater the total area affected by IAS is estimated between 36% and 46%. Natural ecosystem types are less affected with 16% of the surface area.

6.3.2.6 Soil erosion

Soils are under pressure from a range of drivers, reflecting diverse competition for land. These include urban expansion (resulting in soil sealing and loss of function), intensive agriculture (resulting in compaction, loss of organic matter, loss of biodiversity, contamination, and increased soil erosion) and industrial pollution (from both local and diffuse sources). The short-term soil erosion rates in 2016 show a limited decrease of 0.4% in all lands (Table 4.4.1) and 0.8% in arable lands compared to 2010. Long-term trends (2000-2010) report a stronger decrease in soil erosion by water, falling by 9% in all lands (Table 4.4.1) and 19% on arable land (driven largely by the implementation of erosion reduction measures under the common agricultural policy). However, soil erosion by water across the EU (2.45 tonne per ha per year) is above accepted soil formation rates (between 1.4 and 2 tonne per ha per year), which means that the soil ecosystem will continue to degrade. Regions with high levels of erosion (e.g. the Mediterranean) show limited improvements, probably reflecting a combination of limited soil cover, limited implementation of control measures, increasingly erosive rainfall patterns and terrain conditions.

6.3.2.7 Ecosystem condition: abiotic quality of ecosystems

The abiotic quality of ecosystems reflects their physical and chemical state. The most relevant indicators are related to the measurements of air, soil and water quality. As already mentioned in the section on pollution, the air quality in urban areas is, on average, improving (Table 6.6). The concentration of NO2, PM10 and PM2.5 has reduced with a rate of change of about 20% per decade, on average (Table 3.1.5).

In principle, more information about air pollution on ecosystems is collected by the Member States in the framework of the National Emission Ceilings Directive. Under Article 9 of this directive, Member States have to monitor the negative impacts of air pollution upon ecosystems based on a network of monitoring sites that is representative of their freshwater, natural and semi-natural habitats and forest ecosystem types. This reporting stream started in 2019 so these data could not be included in this report. Clearly, this dataset constitutes a key source of information to assess the abiotic quality of ecosystems and it remains to be seen if the positive evolution observed in urban areas holds for other ecosystems.

The abiotic water quality of rivers and lakes is improving as well (Table 6.6). Concentrations of nitrogen, phosphorus and biological oxygen demand are declining (Table 3.6.4). Tropospheric ozone in forest is decreasing (Table 6.6). However, these improvements do not mean that a good abiotic quality is achieved. For instance, only 36% of freshwater bodies reaches a good chemical status (Table 6.4).

In marine ecosystems, bathing water quality is improving in all the marine regions. Nutrient levels and biological oxygen demand show mixed patterns with improvements in the Baltic and the North-east Atlantic and deterioration in the Black Sea and the Mediterranean Sea (Table 6.7). The changes in nutrient concentrations have likely an impact on dissolved oxygen and chlorophyll a but the trends that emerge are not always in line with the expectations based on changing nutrient concentrations. On the long term, average oxygen concentrations are increasing in the Baltic Sea, the Black Sea, and the Mediterranean Sea but there is a negative trend in North-east Atlantic Ocean (Table 3.7.6). Clearly, there is a need to better understand the interactions between nutrients, dissolved oxygen and chlorophyll-a as well as the influence of climate and physical conditions on these interactions. However, there is sufficient baseline and trend data to develop a more robust condition indicator to assess the abiotic quality of marine ecosystems and this should be part of follow up work.

6.3.2.8 Ecosystem condition: biotic quality of ecosystems

The biotic quality of ecosystems describes the condition of ecosystems as a function of their composition or species diversity, the abundance of the species, their structure (vegetation density, biomass, or trophic levels), and their functions (productivity, ecological processes). This ecosystem assessment is largely based on indicators that describe structure, and to a lesser extent, biodiversity indicators. Long-term information on functional characteristics is not readily available because it is more difficult to measure it. The trends that are available in Table 6.6 are often constant over time or deteriorating, while for forests there are improving trends.

Structural condition indicators in forests exhibit an upward trend: dead wood, forest area and biomass are increasing. Fragmentation, the abundance of forest birds, and the area of protected forest are stagnating. There is no improvement of the conservation status of forest habitats that are in unfavourable status (Table 6.6). Importantly, defoliation, a key indicator to measure the structural health of forests, is not mentioned in Table 6.6. In 2010 (the baseline year for this assessment), 1 tree out of 5 suffered from defoliation and the trend is significantly negative with an estimated rate of change between 3.4 and 16.5% per decade (Table 3.3.5). Defoliation is a natural bio-indicator and can be used as an early warning system to monitor forest's health. The negative trend contrasts with the positive trends of other structural forest indicators and illustrates the potential issues that emerge when different indicators are thematically aggregated into a single index based on equal weights. Taken together, a single composite indicator would signal a rather positive trend in forest condition, which would hide an important but deteriorating trend. Clearly, simple thematic aggregation of indicators into a single index needs to be carried out with care. An aggregation scheme should be subject to expert opinion to ensure that an index based approach is capable of detecting early warning signals or significantly negative trends of key indicators. The same observation is made for functional forest indicators (Table 3.3.5). A higher productivity might be considered as positive for forest health but the increasing trend of evapotranspiration is a reason for concern as it is related to climate stress. When added together, these trends do not cancel each other out. More work is thus needed to design a method of aggregation that is sufficiently sensitive to measure the overall forest health based on a correct and ecologically meaningful interpretation of all the trends.

The structural condition of agroecosystems is, on average, deteriorating. Although Table 6.6 reports improvements based on the share of organic farming and livestock, there remain significantly downward trends. Most critical is the condition of farmland birds and grassland butterflies. Both taxa continue to decline in the long term. The declines are alarming signals of the degradation of the condition of agro-ecosystems: farmland birds decline with almost 14% per decade (Table 3.2.5); the average decline of grassland butterflies in the EU is as much as 22% per decade (Table 3.2.5). Also fallow land, an important refuge for agricultural biodiversity, is rapidly declining with a loss of 60% per decade relative to the baseline year 2010 (Table 3.2.5). Such loss in fallow land in the EU is strongly policy-driven, as it is caused by the abolishment of the CAP set aside requirements in 2009. Mineral cropland soils exhibit the lowest soil carbon stocks of all land cover types apart from artificial areas and may already have reached a minimum equilibrium. Croplands and grassland soils exhibit a slight decrease in soil organic carbon stocks between 2009 and 2015 of about 0.06% and 0.04% respectively (Table 4.4.4), but with marked regional differences (Figure 4.4.10).

For heathlands and shrub, sparsely vegetated ecosystems and inland wetlands, information available in Table 6.6 is largely limited to data streams from reporting under the environmental legislation. Also Chapter 3.5 reports only few indicators on structural condition.

In urban ecosystems, Table 6.6 reports several unresolved trends for indicators that are based on the share of the population that is exposed to noise or to poor air quality or that is connected to waste water treatment. For noise, Table 3.1.5 reports that almost 40 percent of the population is exposed to road noise with an upward, though not significant, trend. The unresolved character of these indicators is caused by their poor spatial representativeness, which makes it challenging to disaggregate them to urban areas only. Other trends reported in Table 3.1.5 on urban ecosystems are predominately negative and urban ecosystems are further deteriorating (Table 3.1.5). Within the boundaries of the EU's functional urban areas, artificial land and natural ecosystem types such as forest are increasing at the expenses of agricultural land. However, the increase of artificial land outpaces the increase in natural land (Figure 3.1.12) which results in a loss of critical functions such as water infiltration or essential services such as recreation for urban citizens or micro-climate regulation.

The most important condition indicator of rivers and lakes is ecological status. Long term data are not available yet; the short-term trend is stable (Table 6.6). So, too, is chemical status of rivers and lakes which does not change relative to the baseline (Table 3.6.4).

Large scale trends on the structural and functional condition of marine ecosystems are not known. Data are largely limited to the reporting on the WFD but this is restricted to a coastal strip of 1 nautical mile only. The biomass index of commercially-exploited species remained stable for all marine regions except for the North-east Atlantic Ocean where it increased (Table 6.7). A positive trend is the extent of marine protected areas (covering marine ecosystems) (Table 6.7) but it is noted that data on the effectiveness of marine protected areas are lacking.

Table 6.5. Long term trends of pressures in terrestrial and freshwater ecosystems based on a selection of policy relevant indicators (fifth MAES report).

Pressure class	**Indicator**	Urban ecosystems	Agroecosystems	Forest	Wetlands	Heathland and shrub	Sparsely vegetated land	Rivers and lakes
Habitat conversion and degradation	Land take	?	↑	↑	→	↑	↑	→
	Intensification / extensification		?					
	Change in forest extent			→				
Climate change	Mean temperature		↓	↓				?
	Extreme drought events		↓	↓	↓			
	Effective rainfall		↓	↓				
Pollution and nutrient enrichment	Emissions of NO2, PM10, PM2.5	↑						
	Formation of tropospheric ozone (ground level ozone)			↑				
	Gross nitrogen balance		→					→
	Critical load exceedance of nitrogen*		↑	↑	↑	↑		↑
	Gross phosphorus balance		↑					↑
Over-harvesting in forests	Long term ratio of annual fellings to net annual increment			→				
Invasive alien species	Number of annual introductions of invasive alien species	?	?	?	?	?	?	?

↑ improvement; → no changes, ↓ degradation; **?** unresolved (see also Chapter 2 for definitions); This table is based on the summary tables presented in Chapter 3. Cropland and grassland are considered together in agroecosystems; * for rivers and lakes the matching indicator is Atmospheric nitrogen deposition

Table 6.6. Long term trends of ecosystem condition in terrestrial and freshwater ecosystems based on a selection of policy relevant indicators (fifth MAES report).

Condition class	**Indicator**	Urban ecosystems	Agroecosystems	Forest	Wetlands	Heathland and shrub	Sparsely vegetated land	Rivers and lakes
Environmental quality	% population exposed to noise	?						
	% population exposed to air pollution above the standards	?						
	Concentration of air pollutants	↑						
	% population connected to urban waste water collection and treatment plants	?						
	% built up area	↓						
	Tropospheric ozone			↑				
	Concentration of nitrogen, sulphate, sulphur, calcium and magnesium			?				
	% forest under management plan or equivalent			?				
	Nutrient and BOD concentration in surface water	?						↑
	Water Exploitation Index							?
	Artificial land cover in the drained area or floodplain							↓
Structural ecosystem attributes (general) (Abbreviated to SEA)	Fragmentation**	↓	?	→	↓	?	?	?
	% area of urban green space	→						
	% High Nature Value farmland in agricultural area		→					
	% organic farming in utilised agricultural area		↑					
	Nitrogen in groundwater***		↑					
	Deadwood			↑				
	Forest area			↑				
	Biomass volume (growing stock)			↑				
	Ecological Status****							→
SEA based on species diversity and abundance	Farmland Bird Indicator		↓					
	Abundance and distribution of common forest birds			→				
SEA monitored under the EU nature directives and national legislation	% covered by Natura 2000 or by Nationally Designated Areas	?	→	→	→	→	→	→
	Conservation status and trends of species of CI		?	?	?	?	?	?
	Conservation status and trends of habitats of CI****		↓	→	↓	→	→	→
	EU Population status and trends of bird species of CI		?	?	?	?	?	?
Structural soil indicator	Soil organic carbon	?	→	?	?	?	?	

↑ improvement; → no changes, ↓ degradation; **?** unresolved (see also Chapter 2 for definitions); * based on the dominant trend of unfavourable; ** wetland connectivity used as a proxy; *** this indicator replaces livestock;**** based on short term trend; CI: community interest

Table 6.7 Long term trends of pressures and ecosystem condition in marine ecosystems based on a selection of policy relevant indicators (fifth MAES report).

Class	**Indicator**	Baltic Sea	Black Sea	Mediterranean Sea	North-east Atlantic
Climate change	Acidification	↓	↓	↓	↓
Pollution and nutrient enrichment	Chemical loads	?	?	?	?
	Nutrient loads	?	?	?	?
	Fishing mortality of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield	↑	→	→	↑
Introductions of invasive alien species	Number of annual introductions of invasive alien species	?	?	?	?
Environmental quality	% area under good chemical status*	↓	↑	↑	↑
	Nutrient and BOD concentrations**	↑	↓	↓	↑
	Bathing water quality	↑	↑	↑	↑
Structural ecosystem attributes (general)	% marine water bodies in good ecological status*	↓	↓	↑	↑
Structural ecosystem attributes based on species diversity and abundance	Spawning stock biomass or biomass index of commercially exploited species	→	→	→	↑
	Age and size distribution of commercially-exploited species	?	?	?	?
	Population abundance	?	?	?	?
Structural ecosystem attributes monitored under the EU nature directives	Conservation status and trends of habitats of Community interest	?	?	?	?
	Conservation status and trends of species of Community interest	?	?	?	?
	Population status and trends of bird species of Community interest	?	?	?	?
	% marine protected areas	↑	↑	↑	↑

↑ improvement; → no changes, ↓ degradation; **?** unresolved (see also chapter 2.2 for definitions); *based on short term trend; ** nutrients anomaly (N) used as a proxy; Fish catch is removed from this table; Contaminants are replaced by chemical loads

6.4 Ecosystem services

Both ecosystem extent and ecosystem condition determine the potential of ecosystems to provide services. When this potential is used, ecosystem services flow from ecosystems to humans and deliver benefits. When the demand for ecosystem services increases, it frequently happens at the expenses of a decrease in the ecosystem service potential. This may lead to a situation in which ecosystems cannot continue to satisfy the need for the services, declining the contribution of ecosystems to human well-being. These principles are the basis for the assessment of ecosystem services in Chapter 5.

There is a direct link between ecosystem condition and services. Condition indicators are frequently used, together with ecosystem extent and other environmental variables, to define the potential of ecosystems to provide services. Therefore, indicators of the potential to provide services can also help understand the condition of ecosystems from the point of view of the services they can provide (Palmer and Febria, 2012). Consequently, the conclusions of Chapter 5 provide an alternative and integrated approach to assess the condition of ecosystems. This is illustrated in Table 6.8, which lists the condition indicators that have been used to assess the potential of ecosystem to provide specific ecosystem services. It shows the integrative character of ecosystem service potential to also make inferences about levels and trend of ecosystems conditions.

Table 6.8. Links between ecosystem condition and the potential of ecosystems to deliver ecosystem services. The indicators in the left column represent a selection of the indicators used in this assessment to approximate the condition of terrestrial and freshwater ecosystems. The indicators in the right column are indicators that are used to describe the potential or use of ecosystem services.

Pressure of ecosystem condition indicators	Indicator for ecosystem service potential
Ratio of annual fellings to annual increment	Timber provision
Annual dry matter productivity	
Tree cover loss	
Evapotranspiration	Ecosystem contribution to crop production
Rainfall	
Soil loss	
Mineral fertilizers / plant protection products	
Gross primary production	
Ecosystem extent (pollinator habitat)	Crop pollination
Species diversity	
Climate indicators	
Ecosystem extent (ecosystems that retain runoff water)	Flood control
Imperviousness / Land take	
Extent of riparian area	
Bathing water quality	Nature based recreation
Ecosystem extent (ecosystems that provide recreation)	
Protected area	

Chapter 5 used information about the potential, the use and demand for six ecosystem services: two provisioning services (crop and timber provision), three regulating and maintenance services (carbon sequestration, crop pollination, and flood control), and one cultural service (nature-based recreation). Clearly, these services are to a large extent delivered by terrestrial ecosystem types, notably forests and agriculture (given their relative area) but also wetlands, heathlands and shrub and sparsely vegetated ecosystems are considered as service providers.

The analysis of the ecosystem services indicators at EU level shows that the potential amount of services that the above mentioned ecosystems collectively deliver varies from being stable to further eroding (Figure 6.5). The pace of this change is relatively low as it is influenced by large scale changes in land cover and land use, ecosystem condition, as well as other environmental variables that define the potential of ecosystems to deliver services. While the amount of services that ecosystems can offer is decreasing or stable, there is a growing demand from people for ecosystem services.

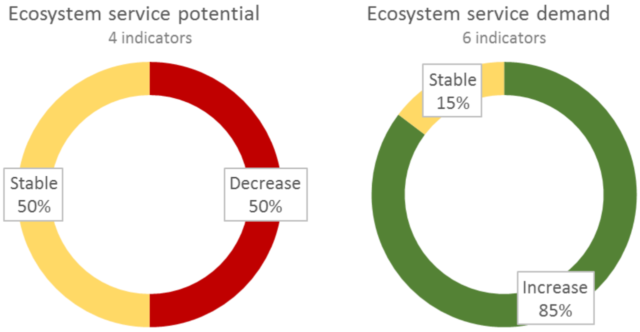

Figure 6.5. Summary of trends in the potential of ecosystems to deliver services and the societal demand for ecosystem services (same figure as Figure 5.18).

Even if based on the assessment of a few services, Figure 6.5 synthetises well the overall trends in the condition of the EU's terrestrial ecosystems. Despite several positive trends that have been highlighted in this chapter, there is no real improvement, rather a flat trend or even further deterioration. At the same time, the demand on ecosystems to deliver benefits to people is increasing. Such an increase frequently takes place at the expenses of eroding the ecosystem service potential. Bending the curve, i.e. turning stable or downward trends into upward trends by conserving and restoring ecosystems, is essential to continue meeting the demands of people.

6.5 Next steps

In May 2020, the European Commission adopted the EU Biodiversity Strategy for 2030. The Strategy has the ambition to strengthen the EU legal framework for nature restoration. As already pointed out in this Chapter, significant implementation gaps are evident (Table 6.3). There are not always clear or binding targets and timelines and no definition or criteria on restoration or on the sustainable use of ecosystems. There is also no requirement to comprehensively map, monitor or assess ecosystem services, health or restoration efforts (European Commission, 2020). The Strategy commits the Commission to put forward a proposal for legally binding EU nature restoration targets in 2021 to restore degraded ecosystems, in particular those with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters. An essential next step is therefore to agree on an EU methodology to map, assess and achieve good condition of ecosystems.

This report is a first but necessary step to better describe and understand the condition and trends of ecosystems. It delivers a baseline for future assessments based on available European datasets. All indicators for which trends have been analysed are delivered with an indicator fact sheet and with the option to use the data for further work.

Subsequent work needs to build on this report. The following steps are essential in the development of a robust methodology for mapping good ecosystem condition:

1. Derive a minimum set of key indicators which capture the full breath of ecosystem condition and which can be used to monitor ecosystems over long time period. This will allow the impact assessment of policies linked to changes in environmental pressures (or pressures on ecosystems) and are also essential to understand the potential to deliver ecosystem services. A minimum indicator set should reduce redundancy which is still present in this assessment (e.g., air and water quality indicators, indicators of protected areas). A more detailed mapping of different ecosystem types, including a level 3 typology for MAES ecosystem types, can facilitate the selection of this minimum set. A more detailed ecosystem typology, which for instance delineates also ecosystem types that are situated on ecotones between land and water, implicitly captures ecosystem characteristics that are important to assess ecosystem condition. So the changes and conversions between ecosystem extent, if measured at more detailed level, can be used to assess the condition of ecosystems at a higher hierarchical level and reduces the number of indicators that is needed to quantify ecosystem condition. For instance, assessing the forest area based on a more detailed classification of forest ecosystems into different forest sub-types or forest habitats provides implicitly information about ecosystem properties or characteristics such as productivity, wetness, or presence of species as these indicators can be used to delineate the sub-types or habitats.

2. Define the reference conditions that describe the good condition of an ecosystem. A reference condition is a condition, against which the past, present or future condition can be evaluated. Many options and methods for setting a reference condition exist including the description of a reference based on an intact or pristine state of ecosystems, the least distributed state, a historical state or a baseline year or period. Also statistical methods based on contemporary data sets are available. The strengths and weaknesses of each of these methods to set a reference needs to be defined before a consensus on reference conditions can be found. Reference conditions can be quantified by the same pressure and condition indicators on which this assessment is based. In this context, an upper reference level is the indicator value measured (or modelled) at the reference condition. A lower reference level corresponds to the zero value of the indicator and indicates when an ecosystem collapses or is completely degraded. Upper and lower limits are necessary to define a measurement scale, to decide on the boundary between a favourable and unfavourable condition and to allow setting a policy target. Different approaches to setting a reference exist; the experiences and methods developed for measuring ecological status under the WFD are particularly useful in this context and can provide guidance to this step.

3. Propose a scientifically robust aggregation scheme or decision framework based on condition indicators to support the designation of ecosystems to a favourable or unfavourable status. This assessment shows that

changes in pressure and condition are not necessarily following the same direction. Decreasing pressures are not always followed by changes in condition due to time lags and non-linear responses of ecosystems. Differences in policies for different ecosystem types, variation in the occurrence and magnitude of different pressures on ecosystems or in the level of protection of ecosystems often increase the complexity of the assessment and of interpretation of trends. This study shows that certain pressures such as climate change continue to increase while others remain stable or decrease (e.g., nutrient enrichment). The interpretation of trends in ecosystem condition and their aggregation into a single index therefore requires expert opinion. Consequently, a decision framework to support ecosystem restoration based on an aggregation of ecosystem condition indicators needs to consider the complex interactions between pressures and ecosystem condition and should be able to detect deterioration of ecosystems in due time and based on the precautionary principle.

These steps can be taken using this ecosystem assessment as a scientific basis and data foundation. In addition, there is an urgent need to agree on crosswalks between different ecosystem, land cover, and habitat typologies and on look up tables to make better use of environmental reporting under the Birds and Habitats Directives, under the Water Framework Directive, and under the Marine Strategy Framework Directive. In first instance, final crosswalks between Corine Land Cover, LULUCF (Land Use, Land-Use Change, and Forestry), and Annex 1 Habitats (Habitats Directive) are needed, including information on overlapping areas and how data can be aggregated or disaggregated. Of equal importance is an agreement on the principle that data streams collected by Member States under the above mentioned directives can be reassigned to different ecosystem types. This is particularly relevant for the reallocation of habitat conservation status data to ecosystem types. But also data on species conservation status can be assigned to ecosystems to help define ecosystem condition. The exclusion of the assessments on species conservation status is a major limitation of this assessment; however reported data were not suitable enough for our purpose.

Clearly the capacity of the EU to monitor biodiversity and ecosystems needs to be enhanced. A better biodiversity and ecosystem monitoring system is essential not only to support possible legislation on ecosystem restoration but also to help implement existing legislations and actions that are dependent on knowledge about key biodiversity and ecosystem parameters. The EU is already putting many efforts in the in-situ monitoring of land, freshwater and European regional seas and the respective ecosystems (LUCAS, monitoring under the CAP), freshwater (WFD) and marine (MSFD), air quality (NEC directive), habitats (HD), species (HD, BD), SEBI indicators, and Copernicus services. These existing schemes are likely to be complemented with other schemes like EMBAL (agricultural biodiversity) or the monitoring of pollinators. However, more integration of these initiatives is urgently needed to avoid overlaps as well as streamlining of the reporting of the environmental directives.

More and better monitoring of biodiversity and ecosystems requires a data infrastructure that allows access to a wide variety of information sources that produces regular updates on pressures, ecosystem condition and ecosystem services. An international framework for organizing ecosystem data is currently under revision. The System of Environmental Economic-Accounting – Experimental Ecosystem Accounting (SEEA EEA, United Nations et al. 2014) defines an integrated statistical framework for organising biophysical data, tracking changes in ecosystem extent, condition and services and linking this information to economic and other human activities. The SEEA EEA framework consists of four core accounts. The ecosystem extent accounts organise information on the extent (total area) of different ecosystem types within an accounting area (e.g., country, region, catchment). The ecosystem condition account measures the overall quality of an ecosystem. Ecosystem service accounts measure the supply of ecosystem services, as well as their use by beneficiaries. The monetary asset accounts record the monetary value of ecosystem assets. Next to these core accounts, thematic accounts provide more detailed, quantitative data on, for example, land, water, carbon or biodiversity. This framework for ecosystem accounts was formally adopted by the United Nations in March 2013 (United Nations et al. 2014) and technical recommendations are available to set up and present accounts in a standardised way (United Nations 2019). The SEEA EEA is presently under revision, with the aim of adopting a revised standard for ecosystem accounting in 2021 (Maes et al., 2020).

6.6 Conclusions

This report presents for the first time an EU wide ecosystem assessment covering the total area of EU Member States and marine regions. The strength of this report is that it analyses terrestrial, freshwater and marine ecosystems with a single, comparable methodology based on European data on trends of pressures and condition relative to the baseline year 2010. The report presents a methodology that is able to detect changes in ecosystems on both the short and long term at EU level. In addition, the assessment is rooted in a spatially-explicit data foundation, which provides the cartographic basis for hotspot analysis and delineation, mapping critical areas for conservation, design of green infrastructure and nature-based solutions. This facilitates the monitoring in a more transparent way by pointing to the locations (grid cells) where degradation is occurring and can occur. This exercise is unparalleled. The report constitutes a knowledge base which can support the evaluation of the 2020 biodiversity targets. It also provides a data foundation for future assessments and policy developments, in particular with respect to the ecosystem restoration agenda for the next decade.

There are large gaps in the legal protection of ecosystems. On land, a vast area of forests, agroecosystems and urban ecosystems is largely excluded from a legal designation under the EU's nature directives. In contrast, wetlands, heathlands and shrub, and sparsely vegetated ecosystems in coastal zones and in mountains are better protected but also for these ecosystems gaps in legal protection remain, in particular with respect to their soils. As a principle, all freshwater and marine ecosystems are subject to specific protection measures under the Water Framework and Marine Strategy Framework directives, which means that they are fully covered. This principle could be extended to terrestrial ecosystems with an objective to bring all terrestrial ecosystems in a good ecosystem condition.

Despite differences in legal coverage, the condition of most ecosystems is unfavourable. This conclusion is based on recent reporting on the conservation status of habitats, and the chemical and ecological status of water bodies. An aggregated ecological condition index that measures the overall quality of ecosystems integrating pressures, condition and conservation status is still to be developed. This requires finding agreement on a reference condition first.

The analysis of trends in pressures on ecosystems shows a mixed picture. Based on the available data, it is concluded that land take and pollution (but in particular nutrient enrichment) are generally declining. The most recent values for indicators that approximate these pressures are below the baseline value measured in 2010. However, the absolute values indicate that the level of these pressures remain high and further reductions are needed. The reference for pressures should be zero or not higher than the capacity of ecosystems to cope with these pressures. Impacts from climate change on ecosystems are increasing. Of specific concern are the rising of land and sea surface temperatures, decreased effective rainfall, a higher incidence of extreme drought events and ocean acidification relative to the baseline values. Time series recording the impact of invasive alien species (IAS) of union concern are not yet available but the assessment shows that IAS are now present in all ecosystems. In particular urban ecosystems and grasslands are highly penetrated with these harmful species. Despite downward trends of emissions of nitrogen and phosphorus to the environment, the combination and possible interaction of climate change and the seemingly unstoppable spread of invasive alien species represents a serious risk for the EU's biodiversity and ecosystems. These pressures continue to impact ecosystems at a slow but persistent rate of change. This is a reason for concern as we don't know how resilient ecosystems are to these changes.

The analysis of trends in ecosystem condition delivers also a mixed outcome. On the long term, air and water quality is improving but this does not imply that good quality is already achieved. In forests and agroecosystems, which represent over 80% of the EU territory, there are improvements in structural condition (biomass, deadwood, area under organic farming) relative to the baseline year 2010 but some key bio-indicators such as tree-crown defoliation or the area under fallow land continue to move in a negative direction and are signs that ecosystem condition is not improving. Species-related indicators show no progress or show declines, in particular in agroecosystems. The number of habitats that are in poor conservation status remains stable or further decreases.

The analysis of trends in ecosystem services concluded that the current potential of ecosystems to deliver timber, protection against floods, crop pollination, and nature based recreation is equal to or lower than the baseline value for 2010. The potential of ecosystems to deliver services is defined by the extent and the condition of the ecosystems. The decrease in ecosystem service potential at EU level is a consequence of land cover changes that are detrimental for the delivery of services assessed, together with a general decline in ecosystem condition. At the same time, the demand for these services has significantly increased. This means that there is fundamental risk to further erode the condition of ecosystems. The analysis of ecosystem services and the interactions between potential, use and demand are essential to guide restoration efforts so that also people benefit from ecosystem restoration.

Increasing impacts of climate and IAS and the downward trends of specific condition indicators are not simply cancelled out by positive trends of the abiotic quality and structural condition of ecosystems. Significant progress towards healthier ecosystems means that most of these indicators show clear and consistent upward trends. This is not the case yet, and more efforts are needed to bend the curve and put ecosystems on a recovery path. The progress that is made in certain areas such as pollution reduction, increasing air and water quality, increasing share of organic farming, the expansion of forests, and the efforts to maintain marine fish stocks at sustainable levels show that a persistent implementation of policies can be effective. These successes should encourage us to act now and to put forward an ambitious plan for the restoration of Europe's ecosystems.

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Annex

Table 6.9. Total number of short-term trend pressure and condition assessments per ecosystem type broken down over the different assessment conclusions.

Ecosystem type		Improving	No change	Degrading	Unresolved	Total
Urban ecosystems	Pressure	5	1	2	1	9
	Condition	6	5	5	13	29
Agroecosystems	Pressure	3	5	4	5	17
	Condition	3	8	2	6	19
Forest	Pressure	5	2	6	7	20
	Condition	5	4	0	4	13
Inland wetlands	Pressure	1	2	1	4	8
	Condition	0	3	0	0	3
Heathland and shrub	Pressure	2	0	1	2	5
	Condition	0	2	0	1	3
Sparsely vegetated land	Pressure	1	0	0	0	1
	Condition	0	2	0	1	3
Rivers and lakes	Pressure	1	6	0	6	13
	Condition	0	3	0	20	23
North-east Atlantic	Pressure	1	1	3	9	14
	Condition	14	3	6	16	39
Baltic sea	Pressure	0	2	3	9	14
	Condition	11	5	7	16	39
Black sea	Pressure	0	4	1	9	14
	Condition	7	9	7	16	39
Mediterranean Sea	Pressure	1	0	4	9	14
	Condition	7	5	11	16	39

Table 6.10. Total number of long-term trend pressure and condition assessments per ecosystem type broken down over the different assessment conclusions.

Ecosystem type		Improving	No change	Degrading	Unresolved	Total
Urban ecosystems	Pressure	5	1	0	3	9
	Condition	8	7	8	6	29
Agroecosystems	Pressure	4	3	5	5	17
	Condition	4	7	3	5	19
Forest	Pressure	5	5	5	5	20
	Condition	5	4	2	2	13
Inland wetlands	Pressure	1	5	2	0	8
	Condition	0	2	1	0	3
Heathland and shrub	Pressure	2	0	1	2	5
	Condition	0	2	0	1	3
Sparsely vegetated land	Pressure	1	0	0	0	1
	Condition	0	2	0	1	3
Rivers and lakes	Pressure	4	3	0	6	13
	Condition	6	5	1	11	23
North-east Atlantic	Pressure	1	0	4	9	14
	Condition	6	1	1	31	39
Baltic sea	Pressure	1	0	4	9	14
	Condition	5	1	1	32	39
Black sea	Pressure	0	2	3	9	14
	Condition	3	1	3	32	39
Mediterranean Sea	Pressure	0	1	4	9	14
	Condition	3	1	3	32	39

Table 6.11. Main legal instruments that share the objective to maintain or enhance the sustainable use or ecosystems, the conservation of habitats and species, or more in general the condition of ecosystems.

Ecosystem	**Policies**
Urban ecosystems	EU Biodiversity Strategy to 2030, Invasive Alien Species Regulation
Agroecosystems	Common Agricultural Policy (CAP) and rural development policies; EU Biodiversity Strategies to 2020 and to 2030; Birds and Habitats Directives (grasslands); Invasive Alien Species Regulation, LULUCF regulation
Forest	EU Biodiversity Strategies to 2020 and to 2030; EU Forest Strategy 2014-2020; Birds and Habitats Directives; Timber Regulation, Invasive Alien Species Regulation, LULUCF regulation; Common Agricultural Policy (CAP) and rural development policies regarding forest; EU's 2030 climate and energy framework
Wetlands	Birds and Habitats Directives, Water Framework Directive, Marine Strategy Framework Directive; EU Biodiversity Strategies to 2020 and to 2030; Invasive Alien Species Regulation, LULUCF regulation
Heathlands and shrub	Birds and Habitats Directives, EU Biodiversity Strategies to 2020 and to 2030; Invasive Alien Species Regulation
Sparsely vegetated ecosystems	Birds and Habitats Directives, EU Biodiversity Strategies to 2020 and to 2030; Invasive Alien Species Regulation
Rivers and lakes	Water Framework Directive, Nitrates Directive, Bathing Water Directive, Urban Waste Water Treatment Directive, Birds and Habitats Directives, Groundwater Directive, Floods Directive, Directive on Environmental Quality, EU Biodiversity Strategies to 2020 and to 2030; Invasive Alien Species Regulation
Marine ecosystems	Marine Strategy Framework Directive; Water Framework Directive, Birds and Habitats Directives; EU Biodiversity Strategies to 2020 and to 2030; Invasive Alien Species Regulation
Soil	Soil Thematic Strategy; EU Biodiversity Strategies to 2020 and 2030

Table 6.12. Break down of ecosystem types over extended ecosystem layers (data of Figure 6.3).

	Total area (1000 km²)	**Urban ecosystems**	**Cropland**	**Grassland**	**Forest**	**Heathland and shrub**	**Sparsely vegetated land**	**Inland wetlands**	**Rivers and lakes**	**Marine inlets and transitional waters**
Functional urban area (core cities and commuting zone)	992	11.17%	43.10%	12.22%	28.03%	1.94%	0.51%	0.81%	1.99%	0.22%
Functional urban area (core cities)	169	29.28%	32.74%	9.87%	20.88%	2.00%	0.50%	0.94%	3.25%	0.54%
Potential floodplains	367	6.95%	41.11%	12.81%	14.02%	0.81%	0.42%	2.31%	20.59%	0.98%
Riparian areas	297	7.02%	35.10%	12.19%	16.07%	0.97%	0.49%	2.23%	24.98%	0.95%
Extended wetlands	370	0.03%	1.83%	3.65%	13.27%	3.58%	0.80%	25.88%	28.81%	22.16%

7 Integrated narratives

This chapter contains four story lines or integrated narratives. These narratives illustrate how policy questions can be addressed using the knowledge that is collected in this EU ecosystem assessment. They are meant to present an easy reading for a non-technical audience telling a story based on the data, maps, and conclusions presented in the Chapters 3 (thematic ecosystem assessments) and 4 (crosscutting ecosystem assessments).

Four narratives are included:

Co-benefits of wetland restoration as key nature-based solution: The condition of wetlands in the EU is, on average, very poor and the outlook is particularly negative. Pressures on wetlands are increasing and the condition is on a declining path. Urgent action on wetlands is needed to safeguard what remains. It would entail reducing all pressures and ensuring long-term restoration strategies for wetlands through rewetting. More research and monitoring of wetlands is needed to understand their role in the carbon cycle. Wetlands that are restored and sustainably managed are important carbon sinks and could contribute more than now to climate change mitigation.

Closing the pollination gap in farmland through local restoration: The capacity of agroecosystems to support populations of wild pollinators is declining resulting from the use of pesticides and the disappearance of landscape elements where bees and butterflies find shelter and food. In 2018, the grassland butterfly index was almost 40% lower than it was in 1990. Meanwhile, the demand for pollination services is increasing as farmers grow more fruits and vegetables that depend on pollination. An analysis of supply versus demand revealed that 50% of the land cultivated with pollinator-dependent crops faces a pollination deficit. This means that the suitability of the land is insufficient to meet the demand for pollination. Such a deficit entails costs for farmers. Restoring the condition of ecosystems through creation of pollinator friendly habitats in agricultural landscapes should be encouraged by agricultural policy to ensure that the full potential of ecosystems to deliver pollination services is used.

Primary and old-growth forests: Humans have modified forests in Europe since the mid-Holocene by clearing for cropland and pasture, and as a source of fuel wood and construction materials. After a long history of forest use, currently only between 2% and 4% are primary forest undisturbed by man in the EU. These areas that are exposed to increasing pressures, represent the “pearls” of EU forest ecosystems because of their irreplaceability and unique qualities. Protecting primary forests is a global and EU concern for which robust and validated information is required.

Connecting nature to facilitate the response of species to climate change: Species respond to the impacts of climate change by moving to areas that are more favourable for their living conditions. This requires that protected areas and natural ecosystems are sufficiently connected to facilitate the movement of species between protected areas along the climatic gradients. An analysis of the landscape mosaic, which describes how landscapes in Europe are composed was used to identify the major nature networks in the EU. This is important to evaluate the coherence of the Natura 2000 network, to define the key corridors for conservation (which cannot be cut) and to locate new corridors that increase the connectivity while delivering EU added value (e.g., linking networks between different member states).

7.1 Co-benefits of wetland restoration as key nature-based solution

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7.1.1 Policy question

Wetland ecosystems cover a wide range of habitats, which fall under the scope of different EU environmental legislations (e.g. Habitats Directive, Water Framework Directive, Marine Strategy Directive). The most comprehensive approach is from the Convention on Wetlands, an intergovernmental treaty ratified by 171 parties (but not the EU) that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. In 1995 the Commission adopted a Communication to the European Parliament and the Council on the wise use and conservation of wetlands, which recognised the important functions they perform for the protection of water resources (EC, 1995).

Wetlands are key ecosystems, rich in biodiversity and carbon, which also play an important role to prevent and reduce the impact of natural disasters.

The degraded condition of wetlands in Europe both in terms of area and quality is a big concern (cf. IPBES, 2018) as it is influenced by several factors which are mainly linked to the lack of an all-inclusive European policy framework targeting wetland ecosystems.

Authoritative science suggests that forward-looking policies need to find a more comprehensive approach to promote European wetland conservation and restoration and their wise-use (in the sense of the Ramsar Convention), respecting their hydro-ecological characteristics and ensuring their integrity in management (sectoral policies), conservation and protection (environmental policies).

Advancing the future agenda for wetland ecosystems in Europe needs to ensure bending the curve for wetland ecosystem condition, through prioritising restoration plans that safeguard and restore their sensitive habitats function, guaranteeing multi-functionality and co-benefits and increasing socio-ecological resilience facing the climate crisis.

Wetland ecosystem definition and extent in Europe

Wetlands, as defined by the Convention on Wetlands of International Importance (Ramsar), include a wide variety of inland habitats such as marshes, wet grasslands and peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, intertidal mudflats and seagrass beds, and coral reefs and other marine areas no deeper than six meters at low tide, as well as human-made wetlands such as dams, reservoirs, rice paddies and wastewater treatment ponds and lagoons (Ramsar Convention Secretariat, 2016).

This wide variety of wetland habitat types shown in Table 7.1.1 together with the percentage of their extent covered by the most relevant European legislative instruments, highlights the patchy treatment of wetland habitats and their underlying biodiversity by European legislative and regulatory tools. At the ecosystem level, less than 44% of wetlands are covered by both the Habitats Directive and the Water Framework Directive while around 16% of the wetland habitats present within the marine ecosystem (marine waters less than 6 meters of depth at low tide) are covered by both the Habitats and the Marine Strategy Framework Directives.

In the framework of the EU MAES assessment of wetland ecosystem condition, wetlands have been considered and assessed according to the definitions summarised in box 7.1.1.

7.1.2 Wetland assessment in the MAES framework

Despite the broad range of services, especially regulating ones, that healthy wetland habitats provide to human livelihoods, historically, wetlands in Europe have been suffering from a continued loss and degradation of their habitats from unprecedently increasing multiple pressures since the middle of the twentieth century.

The IPBES regional assessment of biodiversity and ecosystem services in Europe and Central Asia, 2018, is stressing that marine and freshwater biodiversity is particularly threatened in Europe. We are still losing wetlands, semi-natural grassland and old-growth forest in Europe, which are key for carbon retention, flood protection and pollination; and the majority of regulating services are decreasing in Europe (1960-2016).

Table 7.1.1. Percentage coverage of the extent of wetland ecosystems by relevant EU directives

Wetland habitat	Habitats Directive[127]	Water Framework Directive	Marine Strategy Framework Directive
Beaches, dunes, sand	89.9		
Coastal lagoons	91.9	100.0	
Coastal saltpans (highly artificial salinas)	99.8	100.0	
Inland marshes	87.4		
Intertidal flats	99.9		
Lakes, ponds and reservoirs	93.3	100.0	
Managed or grazed wet meadow or pasture	94.8		
Marine waters less than six meters deep at low tide	95.1	82.6	100.0
Natural seasonally or permanently wet grasslands	94.7		
Open mires	98.7		
Rice Fields	84.1		
Riparian, fluvial and mixed forest	98.6		
Riparian, fluvial and swamp broadleaved forest	94.1		
Riparian, fluvial and swamp coniferous forest	99.3		
River estuaries and estuarine waters of deltas	99.8	100.0	
Riverine and fen scrubs	96.6		
Salt marshes	99.0		
Water courses	88.9	100.0	
Wet heaths	98.6		
Total	**95.5**	**44.3**	**15.5**

Box 7.1.1. Definitions

Inland wetlands habitats are defined in the MAES typology under "Terrestrial" (level 1) and "Wetlands" ecosystem types (level 2). They are defined in the first MAES report, page 24 (Maes et al, 2013), as "predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites". This ecosystem corresponds to the CORINE Land Cover class 4.1 "Inland wetlands" while, in the EUNIS classification system, peatbogs habitats correspond to the class D "Mires, bogs and fens" and inland marshes habitats are classified as habitats of the classes C "Inland surface waters" or E "Grasslands and lands dominated by forbs, mosses or lichens".

Coastal wetlands habitats are defined in the MAES typology under "Marine" (level 1) and "Marine inlets and transitional waters" ecosystem types (level 2). The Marine inlets and transitional waters ecosystem types are defined in the first MAES report, page 24 (Maes et al, 2013), as "ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5 ‰" which, beside coastal wetlands, also include "lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments". In CORINE, these habitats correspond to the class 4.2 "Coastal wetlands" and the Marine waters classes 5.2.1 (Coastal lagoons) and 5.2.2 (Estuaries). In EUNIS, these same habitats are covered under several classes: salt marshes habitats belong to groups A ("Marine habitats") and B ("Coastal habitats"); lagoons and estuaries to the class X ("Habitat complexes"); coastal saltpans to the class J ("Constructed, industrial and other artificial habitats"); intertidal flats to the class A ("Marine habitats").

The **extended wetland** habitats are defined according to the Ramsar Convention, ratified by all EU-28 Member States, which defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six meters". Furthermore, wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands.

[127] Croatia not included

The ecosystem condition assessments (Chapter 3) confirm these facts, through underpinning evidence, and concludes that European wetland ecosystems are in a dire condition. Based on the latest data on habitat conservation status, wetlands are the ecosystems with the worst condition among all assessed ecosystems that have been assessed in this study. This alarming evidence suggests that, despite being very poor, the condition of wetlands is showing no improvement over time, and future trends of their condition is showing either no change in the situation or yet further degradation over time. Moreover, climate change related pressures such as changes in precipitation, rising temperatures and rising sea-level are exacerbating the condition of their habitats and biodiversity and consequently compromising their long-term ecological functioning, which in turn will impact the climate system.

European inland wetlands are still being lost showing decreasing trends in their extent between 2000 and 2018, due to land conversion to agricultural, forest and semi-natural areas. Based on the reported data of Annex 1 of the Habitat Directive, all habitats associated to inland wetlands are among the habitat types showing the worst conservation status among all European ecosystems, with 87.5% of the habitats in poor or bad conservation status: among them, only the 4% is showing improving trends.

While for the same time period, the extent of coastal wetlands remains substantially stable, the trends in the conservation status of habitats show that the 91% of these habitats are in an unfavourable status while only less than 3% are in good conservation status. Of the habitats that are in an unfavourable status, only 15% is showing improving trends. Despite the efforts in research and conservation, there is a major degree of lack of knowledge (Unknown) about the trends of the condition of coastal wetlands in Europe.

When considering the extent of wetland habitats based on their hydro-ecological boundaries (as defined by Ramsar, Box I), the extent of European wetland habitats (see Chapter 3.4) is up to three times larger than an extend defined according to the definitions set by European reporting schemes and instruments (CLC, LULUCF, MAES,...). The ecological extent of wetland ecosystems is of around 370,000 km^2 at EU-28 level (Figure 7.11).

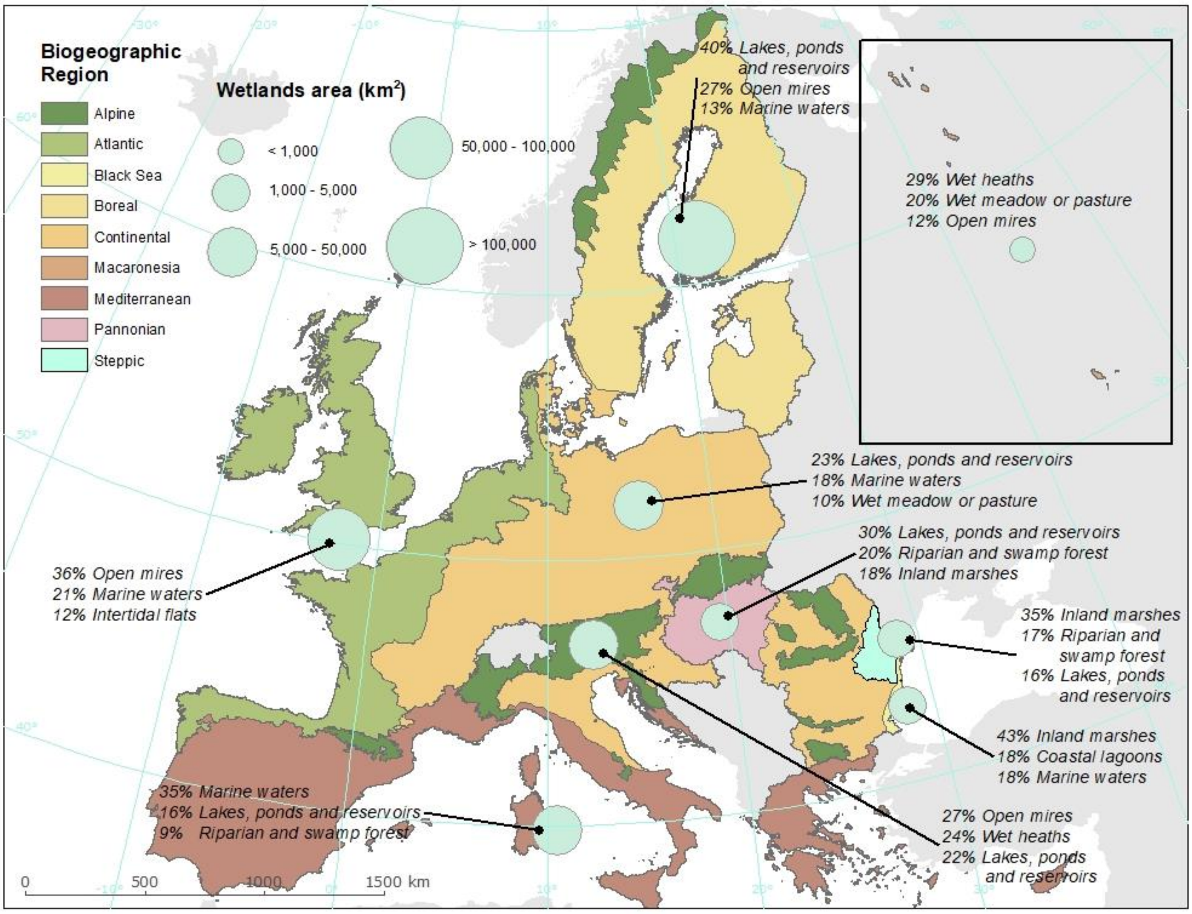

Figure 7.1.1. Delineation of the extended wetland layer for 2012 covering 370,000 km2 of wetland habitats in the EU-28.

Results of the extended wetland ecosystem layer developed for the year 2012 show a wetland coverage of which 26% corresponds to the share of inland wetlands (inland marshes and peatbogs) covered by MAES in-depth wetland assessment, 7% to the share of coastal wetlands while 67% are newly added classes matching the hydro-ecological wetlands dimension (i.e. the Ramsar definition) (Figure 7.1.2).

With exception of urban ecosystems, these extended wetland habitats connect with all the other European ecosystems under MAES, belonging either to "Rivers and lakes" assessment (26%) or to the other classes addressed within the rest of ecosystems assessed (see also Chapter 6, Figure 6.3).

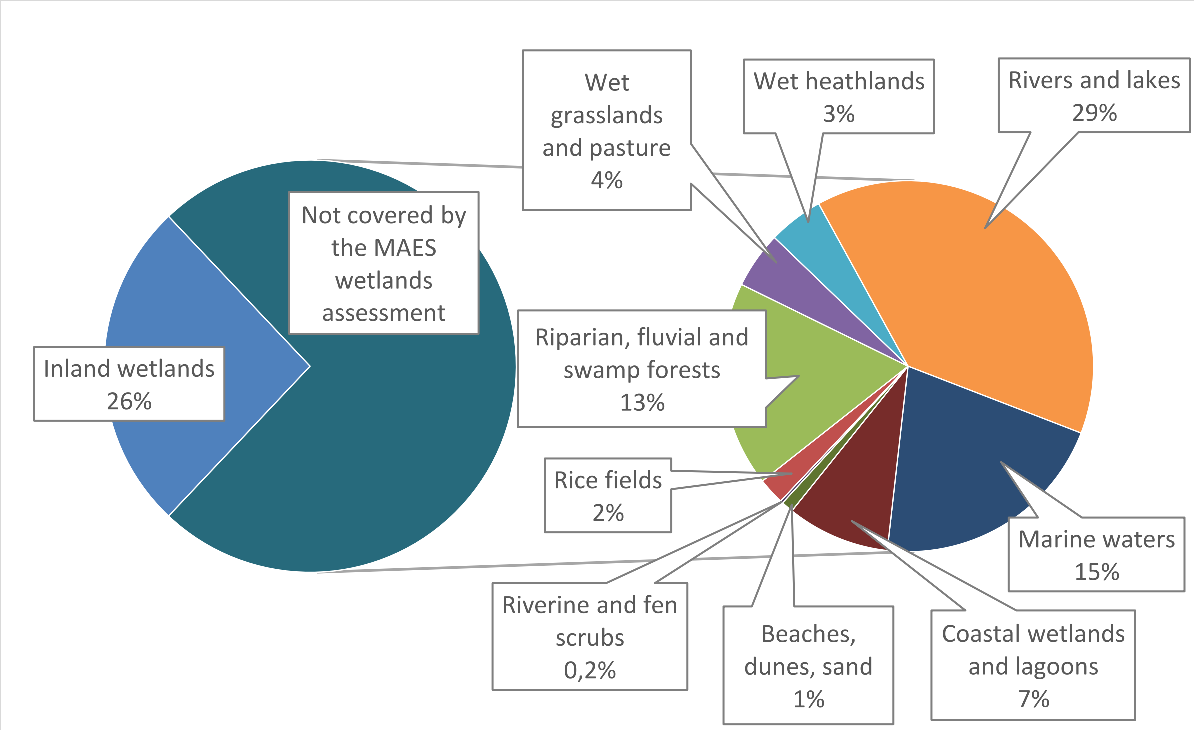

Figure 7.1.2. Wetlands defined based on an ecosystem-based approach at the EU-28 level: classes covered by the in-depth MAES inland wetlands assessment (inland wetlands) and the newly added classes matching the hydro-ecological wetlands dimension

Though major data gaps still exist to enable an in-depth assessment of condition for the whole wetland ecosystem in Europe, the article 17 reporting shows that extended wetland habitats are dominantly in an unfavourable conservation status (84% of them) and this trend tends to be mainly downward (47% of the cases), while trends of improvements are reported as negligible (7%) (Chapter 3.4 and State of Nature report, forthcoming).

7.1.3 Wetlands as an ecosystem delivering key ecosystem services

Wetlands are the living space for many species as well as migratory birds and are crucial in their role of providing habitats and a wide range of ecosystem services. Erosion control and sediment transport, water filtration and regulation, flood control and nature-based recreation are a few of the many valuable services delivered by this ecosystem. In recent times, the role of healthy vegetated wetlands as contributors to decrease climate change impacts has been emphasized, namely their capacity to capture and store carbon, and so reducing atmospheric greenhouse gases, and providing better resilience to hazards such as flooding, storm surges and coastal inundation (Ramsar Convention on Wetlands, 2018).

Ecosystem services assessed for wetlands include the regulation of greenhouse gases in the atmosphere, flood control and nature-based recreation. Despite the fact that wetlands, when properly managed, are known for their role as carbon sink, official data accounted for by Member States in their LULUCF reports estimate that managed wetlands (peatlands) are net sources of CO_2, with increasing emissions to the atmosphere by 5% between 2000 and 2012 (Figure 7.1.3). Note that emissions from drained organic soils can be reduced and even stopped. If the water table is restored to pre-drainage levels, emissions will become similar to pristine conditions again (IPCC, 2014).

In Europe, human disturbances remain as the main driver of pressures on inland wetlands through conversion to other land uses, mainly agriculture and forestry. Within this ecosystem, wetland drainage constitutes a major source of GHG emissions (Fennessy and Lei, 2018), mainly caused by the practices of peat extraction. Despite the limited extent of peatland extractions in Europe, these practices have a huge impact on the total amount of GHG emission by all ecosystems (EEA, 2019). On the other side, it is evident that the amount of GHG removals is significant, when peat bogs are left intact (EEA, 2019).

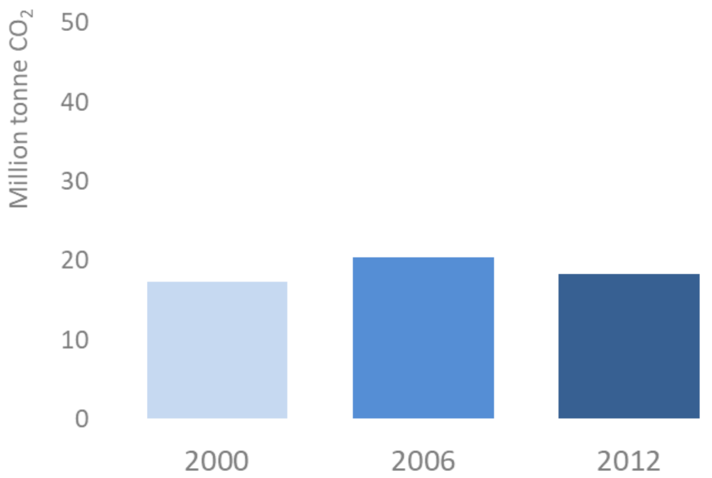

Figure 7.1.3. Net CO_2 emissions from wetlands in the EU-28 for three different years

In addition to the role of wetlands in regulating global climate, wetland ecosystems contribute to other major ecosystem services in Europe delivering significantly larger flood control service than any other European ecosystem and contributing, together with sparsely vegetated lands, to provide the highest delivery of nature-based recreation (Figure 7.1.4). However, the reduction in extent between 2000 and 2012 consequently caused a decrease in the amount of services that wetlands offer.

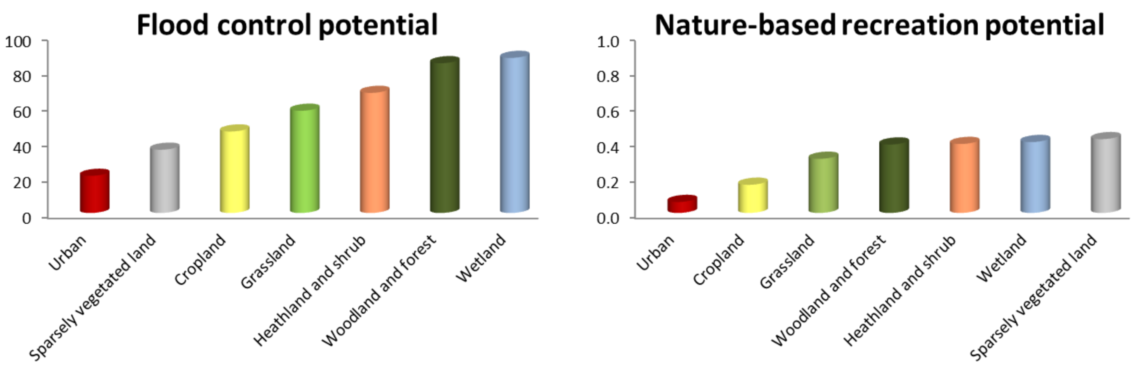

Figure 7.1.4. Average values at EU level of ecosystem service potential. MAES ecosystem types are sorted from smaller to larger values within each figure

7.1.4 Knowledge gaps to consider

The degraded condition of wetlands in Europe is influenced by several factors mostly related to:

The mis-definition and misrepresentation of wetlands in different classification systems hinders addressing wetland ecosystems holistically

1. In EU, there is no over-arching policy framework for wetlands that addresses wetland ecosystems holistically. Instead, wetland ecosystem management is partially addressed by different legislative instruments (EU Biodiversity Strategy and Nature Directives, Climate Strategy, Water Framework Directive, Flood Directive, Marine Strategy Framework Directive).

2. Though these have some synergetic effects on wetland management and conservation, they nevertheless lack the instruments to assess the wetland ecosystem integrity but rather consider habitats and species of interest; pollution control; flood risks; and/or carbon sequestration.
3. The lack of such comprehensive framework leads to fragmented classification, reporting and monitoring system of the wetland habitats and species in Europe. The incomplete definition and delimitation of wetlands and their underlying habitats is the root cause of the limited amount of underpinning data to properly assess and monitor this ecosystem integrally.

Despite efforts in research and conservation, the fragmented knowledge available for wetland habitats is underestimating the essential role wetlands play in providing key ecosystem services in Europe.

The analysis of the fragmented knowledge available on wetland biodiversity in general and more concretely on coastal wetland habitats confirms that, despite the huge efforts in research and conservation of these areas, there is currently limited available knowledge reported by the EU-28 about the status and trends of wetland related habitats and species.

There is still a very central knowledge gap at the EU level about the role of wetlands in climate regulation. Despite being a key ecosystem for regulating greenhouse gasses in the atmosphere, emissions and removals from the LULUCF sector refer only to managed ecosystems[128], which in the case of wetlands represent only 30% of the total wetland extent reported in the EU.

For around 70% of wetlands in Europe, mainly the unmanaged ones, major knowledge gaps mainly linked to flooded areas and wetland habitat reported under other ecosystems remain unsolved in the EU (Figure 7.2.1), for which most countries, although providing information on their areas do not report the associated CO_2 flows.

Limited awareness and historical low socio-cultural valuation of these ecosystems has facilitated fast changes in land uses over time in Europe.

The historical low socio-cultural values given to wetland habitats lead to overlooking the hydro-ecological character of wetland and influenced rapid human-exploitation and excessive alterations of their functioning over time. This profit-driven approach to wetland resources namely for peat extraction or dryland agriculture and forestry has overlooked the biological, hydro-ecological and socio-economic values of wetlands over time. Consequently, this ecosystem suffered fast alterations in its functioning, undervaluation of the ecosystem services it provides to people and hindered management schemes to assess and monitor its condition over time.

The limited awareness among the general public about the real extent and the social, economic, ecological and cultural values of wetlands are important constraints that need to be overcome.

7.1.5 How to bend the curve

The degraded condition of wetlands in Europe is influenced by several factors which are mainly linked to the lack of a European policy that considers wetland ecosystems, wetlands definition and their change in use and socio-cultural values in a comprehensive way.

The patchy treatment of wetland habitats and their underlying biodiversity by legislative and regulatory tools is reflected by a heterogeneous condition reported for different wetland habitats. Whereas rivers and lakes, fully covered by the WFD but also the Nitrates, Bathing Water, Urban Waste Water treatment Directives show a better condition status or somehow certain signs of improvement (Chapter 3.6), habitats such as intertidal flats, open mires, rice fields, riparian forests and wet grasslands, which, beside the Habitats Directive, are not specific targets of European policies, show a much worse status that is also deteriorating in time.

A fundamental change is essential in the way of treating wetland ecosystems to change the historical trends. This is only possible by better integrating the broad extent of wetland ecosystems in existing EU and upcoming targeted restoration policies in addition to improving the implementation of the ongoing policies and would ensure more effective conservation of these habitats.

[128] Used as a proxy to assess anthropogenic emissions targeted in the GHG inventories. However, definitions of managed and unmanaged is highly variable across countries

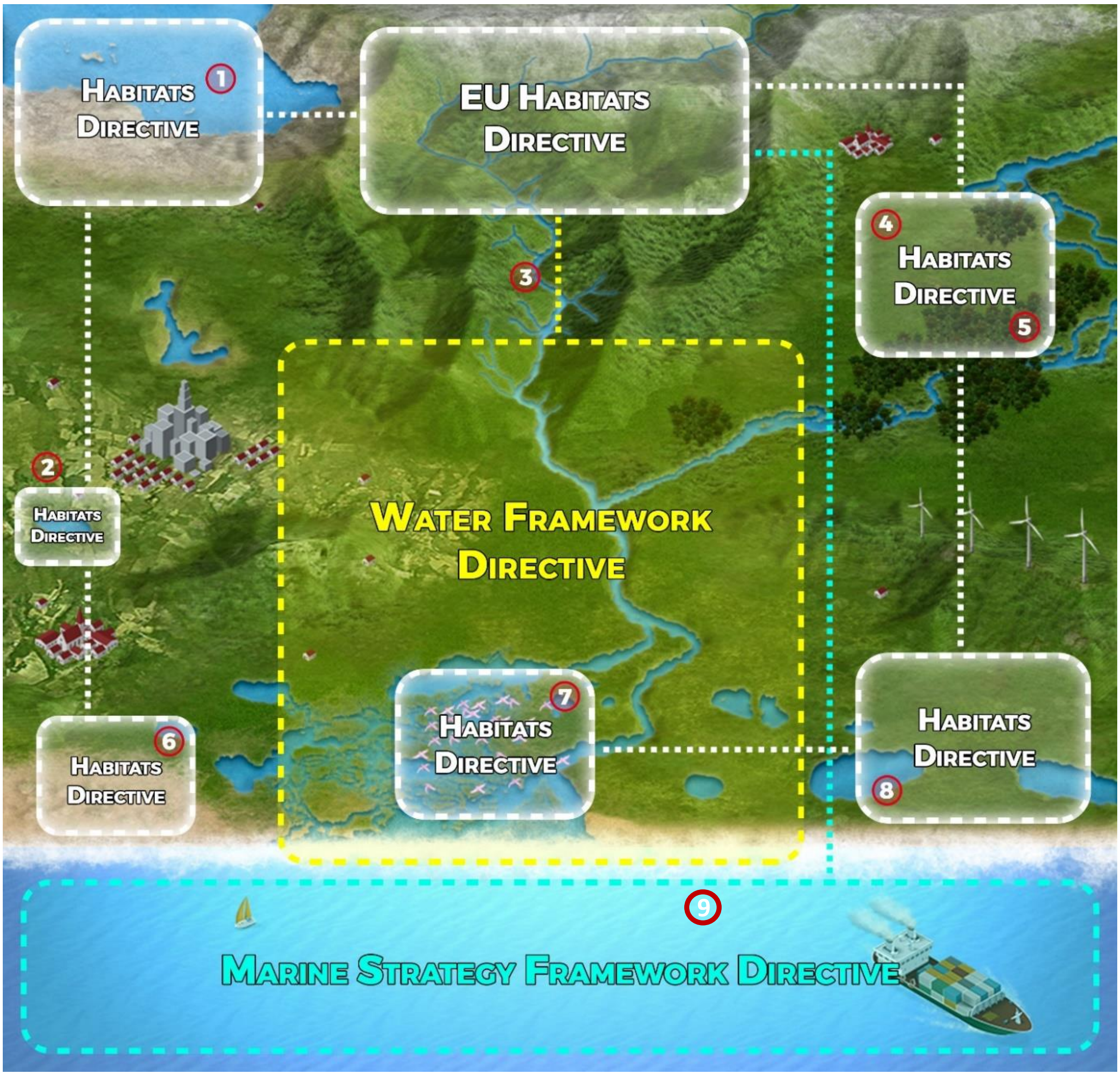

Figure 7.1.5. Wetlands and policies in the EU: examples of European habitat types belonging ecologically to wetland ecosystems and the patchy treatment of most relevant EU environmental policies in covering them: 1. Tidal mudflats, 2. Urban wetland, 3. Alluvial meadows, 4. Grasslands, wet meadows, 5. Riparian forest, 6. Dunes, 7. Deltaic areas and 8. Salt meadows and marshes, 9. Marine waters less than six meters deep at low tide

Forward-looking policies need to find a more comprehensive approach to promote European wetland conservation and their wise-use (in the sense of the Ramsar Convention), respecting their hydro-ecological characteristics and ensuring their integrity in management (sectoral policies), conservation and protection (environmental policies). Such a change in the paradigm would benefit the inclusion of a properly defined wetland ecosystem extent, condition and services accounting framework across EU post-2020 policies and so ensure more effective protection, conservation and restoration agendas.

A targeted long-term strategic plan for wetland conservation and restoration should aim to lay out the foundations for comprehensive management, enhanced conservation and restoration targets, which could halt and reverse recorded declines, perform tangible and large-scale improvements in their extent and condition re-establishing their full ecological functions and thus ensuring a combined delivery of multiple services. Such plans need to ensure shifts in societal behaviour by providing more visibility to wetland ecosystem restoration benefits among all sectors in society and increasing public information about their values to human wellbeing.

Possible options to be up taken by European policies include reaching vital agreements among scientists, practitioners and policy makers on widely used and ecologically sound definitions of wetland habitats that ensure proper delimitations, delineations and nomenclatures, as well as consistent accounting reports across policy areas (e.g. environment, climate, agriculture, finance). This would guarantee a coherent evidence-based decision-making system based on proper assessment and monitoring of wetlands that is coherent at all levels –*aligning the wide-variety of current definitions set under the Biodiversity Strategy, WFD, MSFD, LULUCF* and other European and global frameworks.

There are interesting recent developments under the EU Biodiversity Strategy for 2030, which is calling for legally-binding targets to restore degraded and resilient ecosystems, in particular those with the highest potential to capture and store carbon and to prevent and reduce the impact of natural disasters. The Climate Plan (in preparation) provides an opportunity for legislative changes in 2021, especially through the LULUCF regulation (EU, 2018); the recently adopted EU Regulation on the establishment of a framework to facilitate sustainable investment (EU, 2020), includes a delegated act on wetlands to promote restoration investment; and the new CAP may reward carbon farming of least productive but high-biodiversity and high-carbon land (EC, 2018).

More research is needed to strengthen the evidence on the co-benefits of long-term wetland management as a profitable investment for natural capital restoration (Vallecillo et al. 2019). Targeted research needs to provide knowledge on carbon fluxes in unmanaged wetlands and on targeted restoration efforts that would co-benefit biodiversity and climate change adaptation and mitigation agendas. Research priorities would include setting the understanding on transferable ways to increase a) the effectiveness of long-term restoration (re-wetting) and conservation measures of degraded wetlands and uplifting their capacities to support regulating greenhouse gasses in the atmosphere; b) the flood control function of wetlands though setting widely applicable schemes of re-naturalization of river valleys, natural-water retention measures, reconnection and restoration of floodplains; and c) improving wetland condition and restoring their nature-based recreation capacities through prioritising measures to protect and adequately manage wetlands which are also key for hotspots of biodiversity. The Biodiversity Partnership under Horizon Europe may provide opportunities to fill these knowledge gaps.

Such a strategic approach to wetland conservation, supported by on-going European policies, aim at laying out a foundation for a very much needed different future for wetlands in its broadest sense, where full/integrated management, enhanced conservation and targeted restoration can halt and reverse degradation and ensure that European wetlands play a key role in the European Green Deal.

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7.2 Closing the pollination gap in farmland through local restoration

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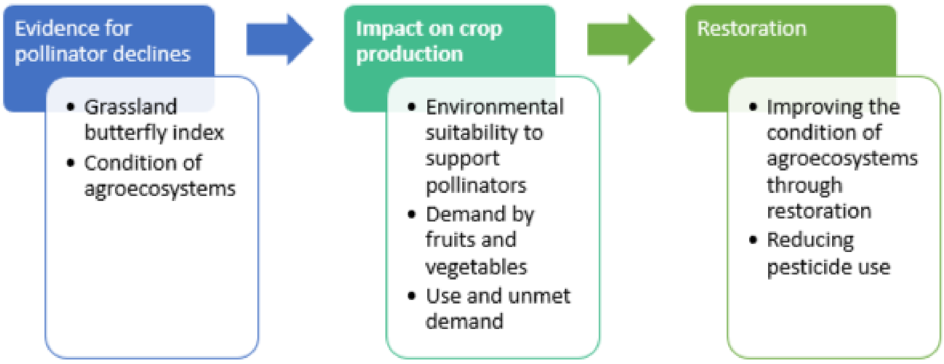
7.2.1 Policy question

Pollinators have declined in occurrence and diversity in Europe (IPBES, 2016). This puts at risk ecosystem functioning, and consequently human wellbeing which depends on pollinators. What can be done to reverse the decline of pollinators?

7.2.2 Evidence from the ecosystem assessment



At the EU level, the only consistently measured indicator that approximates the state of pollinators is the **grassland butterfly index**. This index is part of the assessment of pressures and condition in agroecosystems (Chapter 3.2). The index tells us that on the long term, **grassland butterflies are declining at a current rate of 22% per decade.**

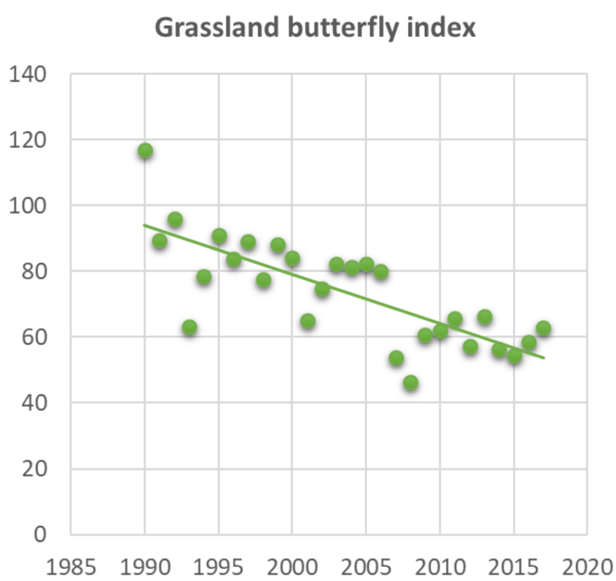


Figure 7.2.1. Grassland butterfly index between 1990 and 2017. Data source: BCE

The grassland butterfly index is symptomatic for other wild pollinators as well. Wild pollinators have declined in occurrence and diversity (and abundance for certain species) at local and regional scales in North West Europe (IPBES, 2016) and **in the EU 9.1% of all bee species are threatened with extinction** (Nieto et al. 2014). For many taxa of pollinators, there are no systematically collected and harmonized data at EU level. The **EU Pollinators Initiative** has therefore set up an action to design an EU wide monitoring network for insect pollinators. A report with a proposal for such a monitoring scheme will be ready in September 2020. Furthermore, the Commission is working on monitoring initiatives which are designed to generate good data on the quality of pollinator habitats in the agricultural landscape and pesticide use[129]. As such, these hold a great potential to improve this type of an assessment and provide even more operational knowledge to land managers.

[129] EU Pollinator Information Hive, https://wikis.ec.europa.eu/display/EUPKH/Data+and+information

The causes of this decline must be found in the high anthropogenic pressures on agroecosystems (Chapter 3.2) and in the decrease in quantity and quality of habitats for wild bee species (Chapter 5 reports the outcomes of a model on pollination using wild bees as indicator species). Of specific concern are the gross nitrogen balance and the use of pesticides. In spite of downward trends in the use of nutrients, the gross nitrogen balance remains relatively high with an excess nitrogen of 50 kg/ha, on average. Total pesticides sales in the EU take place at a quantity of 380.000 tonnes/year and this value is not changing relative to the baseline year 2010. High nutrient levels reduce plant biodiversity (Bobbink et al., 2010), and are also generally related to an intensive use of the land, which are expected to negatively impact pollinating insects. Exposure to pesticides poses an additional threat to pollinators, which can be decreased by a combination of agricultural practices, including reducing the use and risk of pesticides by applying the Integrated Pest Management and following risk management guidelines, which should ensure that authorized pesticides are used in a way not to harm non-target organisms. These are key objectives of the as requested by the EU Biodiversity Strategy for 2030 and the Farm to Fork Strategy.

7.2.3 Impact of crop production: Pollination potential and pollination demand maps.

The assessment of ecosystem services (Chapter 5) mapped the potential of ecosystems to deliver pollination services and it mapped the demand for insect pollination set by the area of pollinator-dependent fruit trees and vegetable crops. We also looked at the changes in ecosystem service potential and demand. The demand for pollination has increased by 5% per decade[130]. In contrast, the potential has dropped by 1%. Importantly, 50% of the area that requires pollination does not meet habitat needs of pollinators, resulting in an increasing pollination deficit (i.e., the unmet pollination demand) between 2006 and 2012.

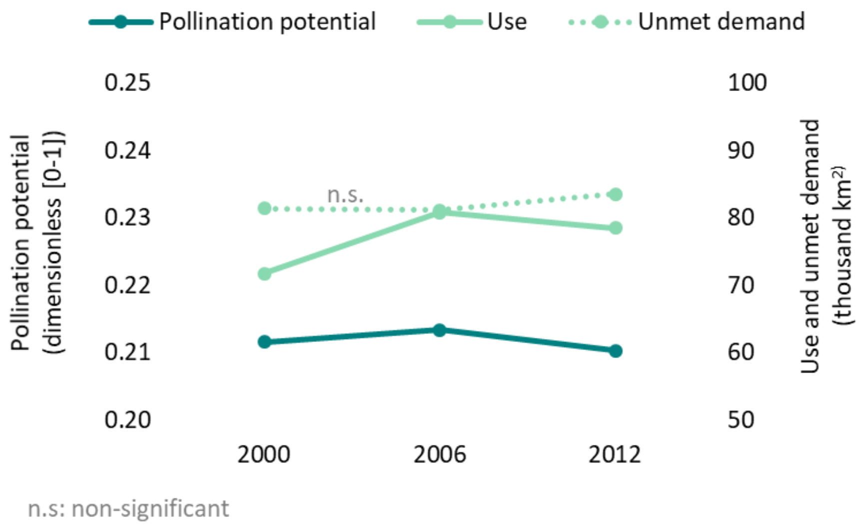


Figure 7.2.2. The changes in pollination potential (habitat quality for pollinating insects), use of the service by pollinator dependent crops, and unmet demand (extent of pollinator dependent crops where pollination potential is low).

7.2.4 How to close the gap through restoration?

Addressing this pollination deficit is possible by restoring habitats that support pollinator populations in cropland: flower-rich field margins, for instance, allow pollinators to satisfy their foraging needs during their entire period of activity; undisturbed soils, hedges, tree lines, forest edges can provide suitable nesting places to a variety of pollinators; additionally, ecological road sides can also contribute to support pollinator populations (Estreguil et al., 2016). The EU Biodiversity Strategy for 2030 couples the need for space for wild animals, plants, pollinators and natural pest regulators in farmlands to a commitment to bring back at least 10% of agricultural area under high-diversity landscape features.

The analysis in chapter 5 identifies areas in the EU where pollination deficit is higher (Figure 7.2.3); in these areas, providing (or improving the condition of) semi-natural and natural habitats in the proximity of pollinator-dependent crops can increase pollinator visitation rate, with an expected positive influence on crop yield. Aside from benefiting crop yield, pollinators play also an important role within the wider context of biodiversity maintenance, although this aspect is not included in the assessment.

[130] Based on data modelled data for 2004 and 2008 (Britz & Witzke, 2014)

This micro-scale restoration of farmlands brings additional benefits. It results, among others, in better water quality, mitigation of soil erosion, provision of habitats for pest predators, carbon storage, increased landscape amenity for recreation, and greater resilience of the social-ecological system.

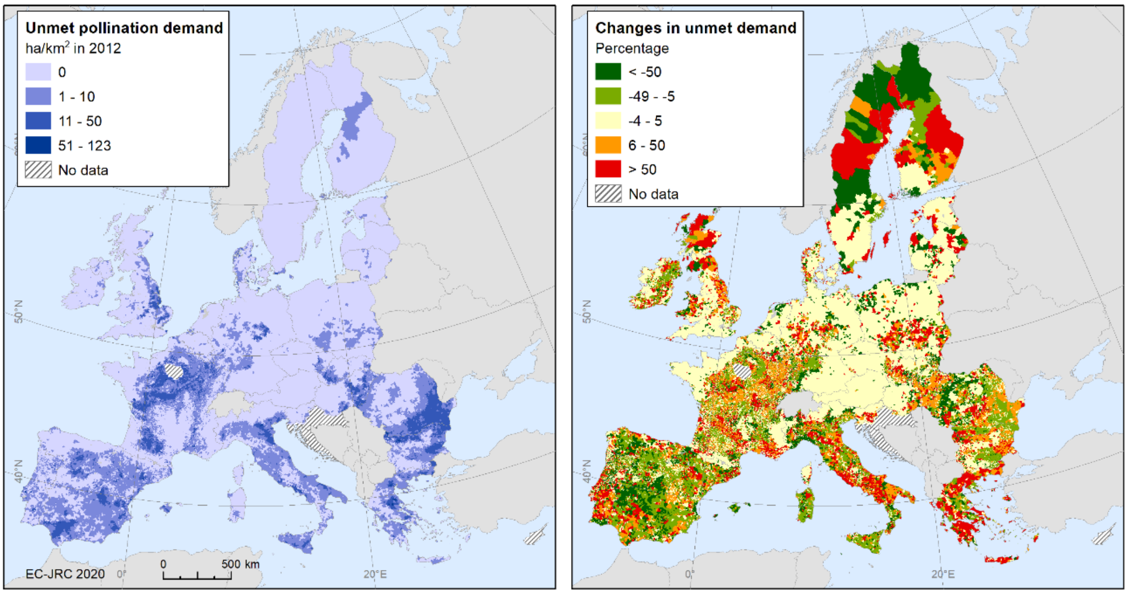


Figure 7.2.3. Unmet pollination demand (status in 2012, and change map). These maps assess the status and trends of pollination deficits in the landscape (areas where demand for pollination services exceeds the potential of ecosystems to deliver pollination). Left panel: unmet demand for pollination services expressed as hectares of land with a pollination deficit per km². Right panel: changes in unmet demand between 2000 and 2012.

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7.3 Primary and old-growth forests

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7.3.1 Introduction and context

Primary and old-growth forests in Europe are relict intact ecosystems persisting after millennia of forest use. In Europe forests have been modified since the mid-Holocene by clearing for cropland and pasture, and have been used as a source of fuelwood and construction materials (Kaplan et al. 2009). Currently only a minor share of forests between 2% and 4% are considered primary and old-growth forests in the EU-28 (Figure 7.3.1).

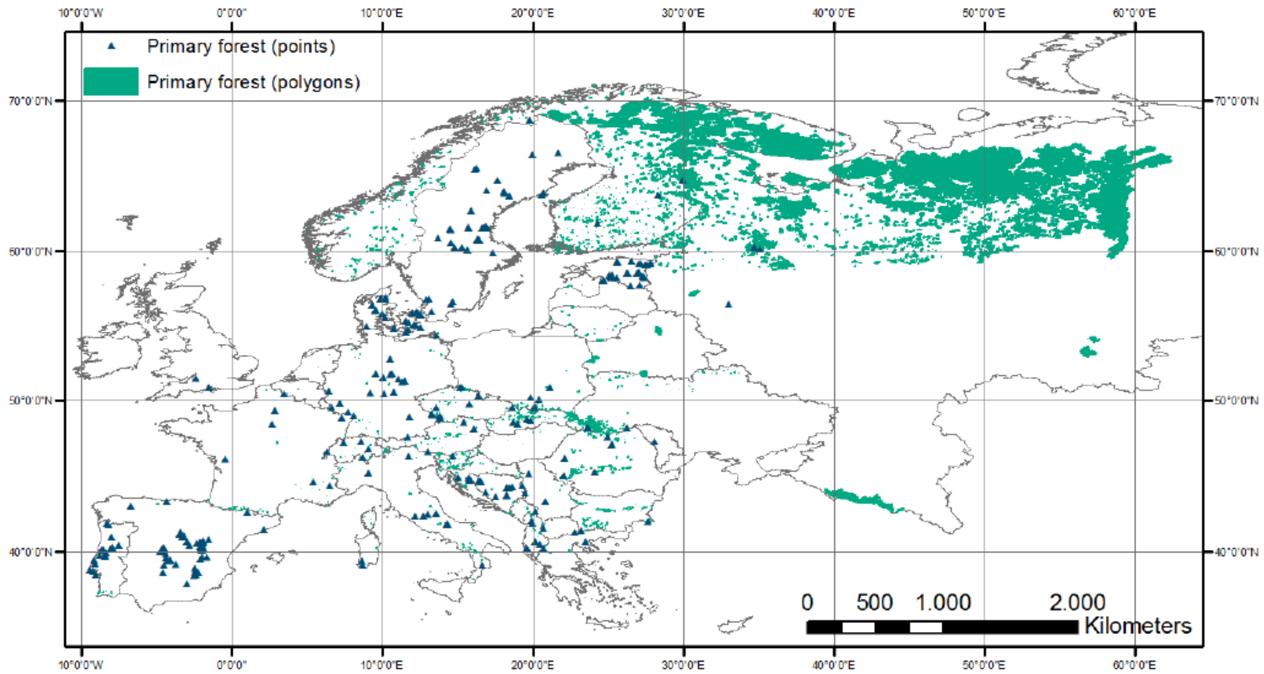

Figure 7.3.1. Distribution of primary and old-growth forests. Note that the polygons were magnified to improve readability. Source: Sabatini, F.M. & Bluhm, H. (2019). Final Report. Supervision of validating data within the framework of Griffith project. No. 03 – Data Validation. Frankfurter Zoological Society, Revision: 2.0. pp. 131.

The aim of this narrative is to provide policy-relevant information on the situation of primary and old-growth forests and the services they provide in the EU.

An operational definition primary and old-growth forests is necessary for proper policy design, implementation and monitoring. For instance, FAO is coordinating an expert consultation and a series of workshops to improve the operational methods for data collection and reporting on the extent of primary forests in the Global Forest Resources Assessment (FRA)[131].

The notions of primary and old-growth forests adopted by international initiatives share many commonalities (Buchwald, 2005; FAO, 2012; FOREST EUROPE, 2015, Sabatini et al., 2018). Some common features of the definitions of primary and old-growth forests are that they are relatively intact forest areas, show natural dynamics, are naturally regenerated and composed by native species, and especially, there are no visible indications of human activities.

Forest data comparability between countries remains an issue (Nabuurs et al. 2019). Therefore, defining, mapping, assessing, monitoring and reporting the condition of primary and old-growth forests is a key priority in the EU. Recent initiatives have provided some light regarding the identification and mapping of primary and

[131] http://www.fao.org/fsnforum/activities/discussions/primary-forest

old-growth forests in Europe. For example, Sabatini et al. (2018) created a data set mapping this type of forest, in addition they operationalised a definition of primary forest (including old-growth forests) departing from the study of Buchwald (2005). Also the UNESCO initiative on “Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe[132]” provides maps of primary and old-growth forests for a group of European countries. There is a number of other initiatives and NGOs collecting data on primary and old-growth forests in Europe. Nevertheless, despite previous efforts gaps remain regarding the mapping of primary and old-growth forests in Europe.

7.3.2 Why are primary and old-growth forests so important?

In a continent with the more pronounced human foot-print of the Earth, with profound implications for biodiversity (Venter et al. 2016), intact forest ecosystems dominated by natural processes should be considered natural treasures. Nevertheless, beyond their existence value, primary and old-growth forests provide an exceptional variety of ecosystem services in addition to their importance for biodiversity conservation. A few examples are carbon sequestration and storage, water provision, the maintenance of human health and home for imperilled biodiversity (Watson et al. 2018). Figure 2 shows the ecosystem services associated with primary and old-growth forests in Europe.

Areal information on primary and old-growth forests in Europe was collected from two sources. First, the study of Sabatini et at. (2018, 2019) mapped around 3.2 million hectares of primary forest in the EU-28 (Figure 1). This is equivalent to 2% of the area of forest in the EU-28[133]. Second, Forest Europe (2015), using data from the UNECE statistical database of forest resources[134], reports the existence of around 4 million hectares of forest “undisturbed by man” in 2015[135], which is equivalent to 2.5% of the forest area in the EU-28[136]. In total, this source reported 4.3 million hectares of forest “undisturbed by man” in forest and other wooded land together.

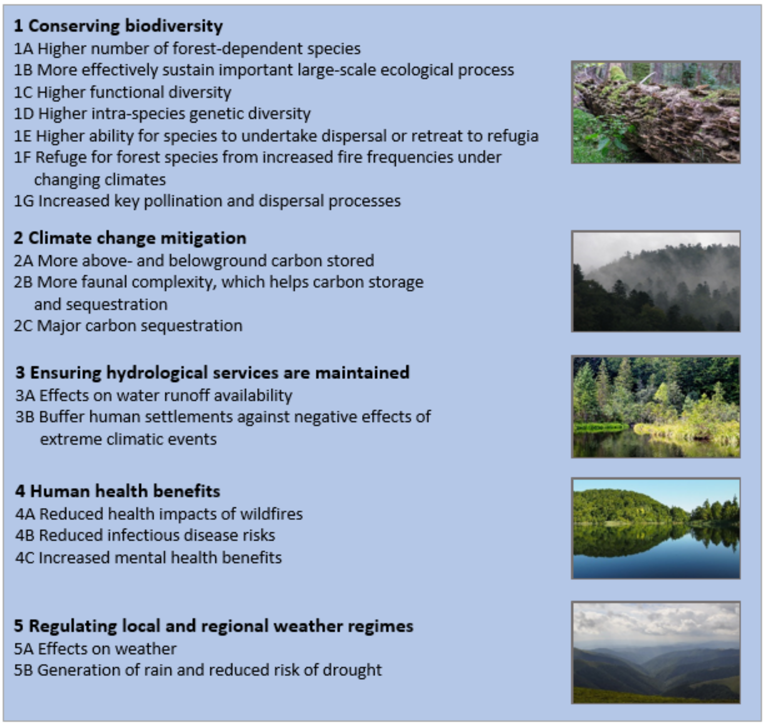

Figure 7.3.2. Key ecosystem services provided by primary and old-growth forests in relation to degraded forests in Europe. Own elaboration. Source of key ecosystem services: modified from Watson et al. (2018). Images from top to bottom by: Robert Pastryk (Bialowieza Forests, Poland), Eugen Visan (Carpathian forests), Dmitry Medved (Carpathian forests), Andreas H. (Plitvice Lakes National Park, Croatia) and Fishka1380 (Carpathian forests), all from Pixabay [https://pixabay.com].

[132] https://whc.unesco.org/en/tentativelists/6395/ and https://www.protectedplanet.net/903141
[133] According to Forest Europe (2015) the forest area in the EU-28 in 2015 was 161 million hectares.
[134] https://www.unece.org/forests/fpm/onlinedata.html
[135] Area reported: 4,020,000 ha. Notes: Data for Bulgaria as of 2010. Data for Ireland is not reported. UK reported no area of forest “undisturbed by man”.
[136] Note that Forest Europe (2015) indicates that the extent of forest “undisturbed by man” represents 4% of the forest area of the countries providing information in the EU-28. Nevertheless, the reasons of the discrepancy with the numbers above are to be investigated.

Despite previous initiatives oriented to collect and provide data on primary and old-growth forests in Europe, data gaps persist (Sabatini et al., 2018, 2019). Therefore, it is very likely that the amount of this type of forest is larger than the reported figures in the EU-28.

In a previous study, Sabatini et al (2018) indicated that of 1.4 million hectares of primary forests in a group of 32 European countries (not including Russia), 89% are protected, but only 46% are strictly protected (IUCN category I). The median size of the identified patches was only 24 ha, and only 4.3% of the patches were larger than 1000 ha. These numbers describe well the patchy character and distribution of primary and old-growth forest across Europe. This aspect represents a threat to primary and old-growth forests and its dwelling species. In addition, there is a growing number of degradation processes due to harmful activates reported in EU's primary and old-growth forests, among which illegal harvesting.

7.3.3 Policy action

The Biodiversity Strategy for 2030 calls for crucial action regarding primary and old-growth forests in the EU. The aims of the strategy in this regard are oriented to:

- **Operational definition of primary and old-growth forests**: This aim should depart from available knowledge from previous and on-going initiatives (see above).

- **Mapping**: Previous and on-going initiatives provide baseline georeferenced data for mapping. However, remaining gaps need to be filled for achieving a comprehensive assessment and monitoring system of primary and old-growth forests.

- **Monitoring**: The integrated use of ground-level data and remote sensing is necessary for an up-to-date and systematic monitoring system. Moreover, exploiting the potential of citizen science, volunteer monitoring and open access repositories would facilitate a transparent and robust system. In addition, a monitoring system should explore the potential of current reporting systems to provide information on primary and old-growth forests, e.g. LULUCF (EU, 2018).

- **Strictly protect all the EU's remaining primary and old-growth forests**. This is a fundamental first step for the integral conservation of this type of forests. Then, restoration and biodiversity-oriented management of the patches and its buffer zones are crucial due to the small size of most patches. In fact, even after protection, the patches should be included in networks of natural forests for restoration, conservation and expansion where possible.

European primary and old-growth forests are our natural treasures. They have survived millennia of forest use and change, countless disturbances, two World Wars, and currently a range of human-driven pressures. The time for its conservation is now.

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7.4 Connecting nature to facilitate the response of species to climate change

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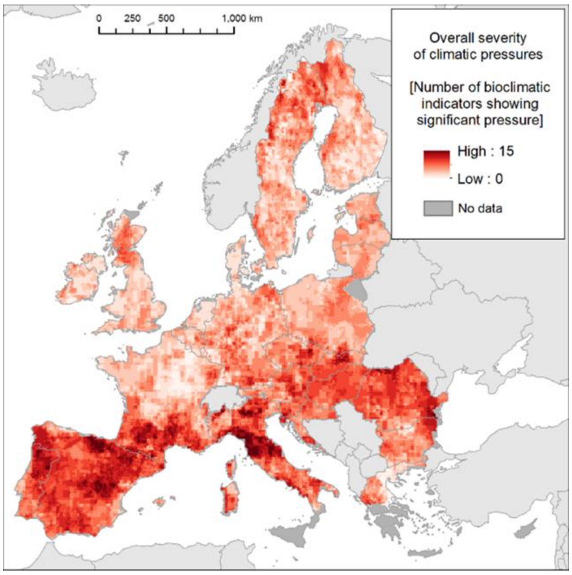
7.4.1 Policy question

Species respond to the impacts of climate change by moving to areas that are more favourable for their living conditions (Pecl et al., 2017; Saura et al., 2017). This requires that protected areas and natural ecosystems are sufficiently connected to facilitate the movement of species between protected areas along the climatic gradients (Araújo et al., 2011). So how can we enhance or restore the coherence of the network of natural areas and nature reserves in the EU.

This narrative combines findings of the crosscutting thematic assessments in Chapter 4 (Climate change, Landscape Mosaic, and Invasive alien species) to argue for an increased connectivity of the EU's natural areas (including Natura 2000) to create a climate-proof nature network.

7.4.2 Climate change impacts on ecosystems

Climate change is already taking a toll on Europe's ecosystems. Almost the total EU-28 area is now subject to increasing average, winter and summer temperatures. Roughly half of the area is experiencing an increase in extreme climate events. One third of the EU land area is going through a longer growing season and one fourth of the area undergoes changes in precipitation or available water. The climate stress on ecosystems is unequally distributed across the EU. Figure 7.4.1 maps the number of indicators representing significant climate pressure mapped on 10 km grid cells. Whereas changes in climate means are evident across the entire EU-28, the impacts in Southern and Central-Eastern Europe are more pronounced. Generally, the EU has longer periods of warm weather, higher temperatures, milder winters, and a higher frequency of drought events.



These changes impact species but it was beyond the scope of this report to assess how species respond to climate change. However, shifts in species distributions across latitude, elevation, and with depth in the ocean have been extensively documented in the literature (see Pecl et al., 2017). Meta-analyses show that, on average, terrestrial taxa move poleward by 17 km per decade and marine taxa by 72 km per decade. Just as terrestrial species on mountainsides are moving upslope to escape warming lowlands, some fish species are driven deeper as the sea surface warms.

Figure 7.4.1. The number of bioclimatic indicators (all indicators) that pose a significant pressure on ecosystems and biodiversity (This figure is the same as Figure 4.1.22)

7.4.3 Restoring connectivity

Climate change risks to reduce conservation value of protected areas if species are limited in their mobility to move and occupy spaces that fall within their climate tolerance. Increasing connectivity between protected areas is therefore considered a key restoration action since well-connected areas may allow species to persist for longer (Nila et al., 2019). By reconnecting fragmented natural areas and restoring damaged habitats, nature networks can also offer a socio-economically viable and sustainable infrastructure that provides multiple goods and services to human populations (Estreguil et al., 2019).

An analysis of the Landscape Mosaic (Chapter 4.3), which describes how landscapes in Europe are composed, was used to identify the major nature networks in the EU. This is important to evaluate the coherence of the Natura 2000 network, to **define the key corridors for conservation** (which cannot be cut) and to **locate new corridors that increase the connectivity while delivering EU added value** (e.g., linking networks between different member states). Natural and semi-natural landscape elements connecting Natura 2000 sites dominated by forest and woodland extend over 33% of the EU territory. Around 80% of those Natura 2000 sites are connected by natural and semi-natural terrestrial ecosystems outside the network (Estreguil et al., 2019; EEA, 2020). Of these 50 % are fully connected by contiguous patches of unprotected forest and woodland. Around 15 % of disconnected Natura 2000 sites are less than 1 km apart but intersected by highways limiting species movement (EEA, 2020). Conserving or restoring these corridors are found to be multifunctional and they deliver multiple ecosystem services such as erosion control, pollination and water regulation (Estreguil et al., 2016; Estreguil et al., 2019).

Landscape Mosaic provides a comprehensive view of the spatial arrangement, composition and interactions of land cover classes. It measures the degree of land use intermix between agricultural, urban and natural areas. For the purpose of this narrative, it is used to identify the main nature networks in the EU.

Figure 7.4.2 combines the Natura 2000 sites with landscape mosaic consisting of forests and semi-natural areas. This map can be used to evaluate the coherence of the Natura 2000 network. It can help detect the existing key natural corridors for conservation or identify new natural corridors for restoration.

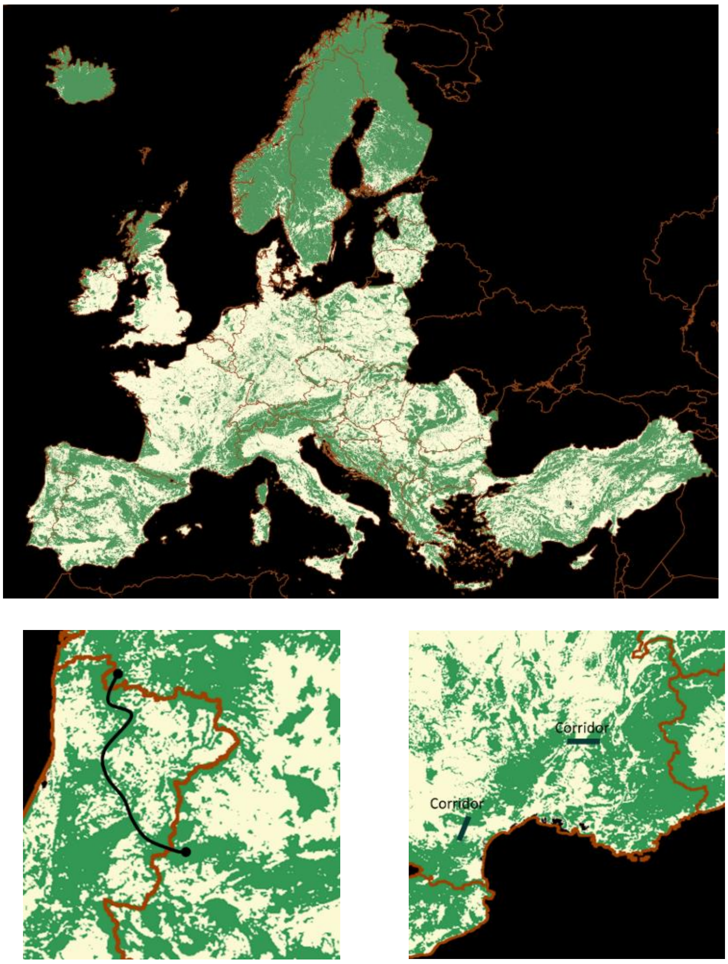


Figure 7.4.2. Map of dominant nature land types and Natura 2000 sites in Europe (data source: Corine Land Cover 2018 and Natura 2000 network, EEA).

Below the European map, the two examples illustrate how to use the data for connectivity analysis.

The map in the lower left panel zooms in on natural areas of North-West Spain and North Portugal. It demonstrates with a black line how natural areas in North-West Spain (Galicia) and West Spain (Castile and León) are connected through natural areas in Portugal. These corridors should be conserved in order to maintain the connectivity.

The map in the lower right panel zooms in on South-East France. Connecting nature between the Pyrenees and the Alps would require the creation of new natural corridors spanning a distance of about 40 km in areas.

Both cases also illustrate well how conservation and restoration projects deliver EU added value as they link networks between different member states.

7.4.4 Watch out for invasive alien species when connecting nature

Ecological networks, in particular if poorly maintained or degraded, can provide pathways for the movement of invasive alien species (IAS) although there are strong arguments that resilient ecosystems are more resistant to IAS (Monaco and Genovesi, 2014). This ecosystem assessment provides evidence for the pressures of IAS on ecosystems. In Europe, urban areas and grasslands are particularly affected by invasive alien species with an estimated pressure on over 60% of the total extent of these ecosystem types. For croplands, forest and freshwater the total impacted surface area is estimated between 36% and 46%. Natural ecosystem types are less affected (16% of the surface area), which may indeed suggest that natural ecosystems possess a stronger resilience in comparison with modified ecosystems.

Restoration projects that aim to create a functionally connected network of protected areas must thus take into account the risk of causing or facilitating further IAS invasions. This requires an integrated landscape approach to ecological restoration with a focus on restoring native species and ecological processes across entire landscapes, within and outside existing reserve networks (Glen et al, 2013)

7.4.5 Building a truly coherent Trans-European Nature Network.

The EU Biodiversity Strategy for 2030 describes the basics of an EU nature restoration plan. It recognises the need to build a truly coherent Trans-European Nature Network. At regional scales, this plan entails enlarging protected areas and set up ecological corridors to prevent genetic isolation, allow for species migration, and maintain and enhance healthy ecosystems. At more local scales, the restoration plan includes ensuring connectivity among habitats in agroecosystems or improving connections between green spaces in urban areas.

Restoration at both geographical scales needs to be complementary. Local approaches to ecosystem restoration for instance in farmland and urban systems need to contribute to large scale restoration efforts that increase connectivity within the network of protected areas. The case of climate change, which is causing the redistribution of biodiversity, makes this evident.

The Landscape Mosaic concept, applied in this EU ecosystem assessment, provides a holistic view of the spatial arrangement, composition and interactions of landscape feature classes. The synthesis allows for the assessment and monitoring of the status and trends in sustainability, ecosystem diversity, connectivity and heterogeneity of the European landscape. A future EU ecosystem assessment will capitalise on the Landscape Mosaic assessment with a dedicated restoration modelling platform aimed to provide spatial guidance for cost-efficient restoration measures. The platform is designed to directly address the restoration targets outlined in the EU Nature Restoration Plan by measuring coherence and restoration potential for Natura2000 sites as well as urban-, natural- and agro-ecosystems.

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8 Conclusions and next steps

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This report presents for the first time an ecosystem assessment for all ecosystems in the European Union. The publication of this report comes at a turning point for biodiversity policy. The report marks the end of the EU Biodiversity Strategy to 2020 and in particular of its Action 5: a common endeavour with the EU Member States to map and assess ecosystems and their services. At the same time the report coincides with the start of the EU Biodiversity Strategy for 2030 which the European Commission adopted between the presentation of the first draft report at a high-level Conference of the first EU-wide ecosystem assessment, organised by the Finnish Presidency of the Council of the EU in December 2019, and the final publication of this report in 2020. One of the ambitions of the new strategy is to strengthen the EU legal framework for nature restoration. Currently, there are no binding restoration targets. Our limited understanding about the condition of ecosystems and their levels of degradation has hindered the development of ecosystem restoration plans and priorities. This report provides an important contribution to knowledge about the condition of all ecosystems in the European Union and changes in this condition in the last decade. Building on the most recent findings about the conservation status of habitats reported under the Habitats Directive, and the chemical and ecological status of water bodies reported under the Water Framework Directive (WFD) it offers an essential assessment in support of the new EU legal framework for nature restoration.

The strength of this report is that it analyses terrestrial, freshwater and marine ecosystems with a single, comparable methodology based on harmonized European data on the trends in pressures and condition relative to the baseline year 2010.

The overall conclusion of this assessment is that the condition of ecosystems in the EU is unfavourable:

- Most habitats protected under the Habitats Directives are in an unfavourable conservation status. The share of habitats that reaches a favourable conservation status remains very low and varies between 3 and 25%.
- Most rivers and lakes do not reach a good chemical status or a good ecological status. The share of freshwater bodies reaching at least a good chemical status is 36%, the share of freshwater bodies reaching at least a good ecological status is 39%.

The analysis of trends of pressures and ecosystem condition shows a mixed picture:

- Certain pressures, in particular nutrient enrichment, trend downward. This results in improved air and water quality. However, the absolute values of these pressures remain too high and further reductions are needed.
- Climate change is causing a rising temperature, more extreme droughts, altering precipitation patterns, and ocean acidification.
- Invasive alien species are now present in all ecosystems and threaten urban ecosystems and grasslands in particular.
- In forests and agroecosystems, covering over 80% of the EU territory, there are improvements in structural condition relative to the baseline year 2010. However, key bio-indicators such as increasing defoliation in forests or eroding farmland biodiversity suggest ecosystem degradation.
- Habitats that have had a poor conservation status are stable or further decrease.
- The current potential of ecosystems to deliver ecosystem services is equal to or lower than the baseline value for 2010. This decrease is also a sign of ecosystem degradation.

A key conclusion of this report is also that there are large gaps in the legal protection of ecosystems. On land, a vast area of forests, agroecosystems and urban ecosystems remains excluded from legal protection. In contrast to terrestrial ecosystems, all freshwater and marine ecosystems are in principle subject to the Water and Marine Strategy Framework Directives (WFD and MSFD), respectively, which aim to bring these systems in good condition (good ecological status for freshwater ecosystems or good environmental status for marine ecosystems).

The analysis in this report showed an important shortcoming in the EU's data availability and reporting on ecosystem condition. The status data that are collected under the different environmental laws and reported in cycles of three to six years are not suitable for trend analysis. Due to changes in assessment and reporting methods, comparing the status data between reporting cycles is not straightforward and needs to be done with care. Furthermore, the indicators used in this report to infer trends in pressures and ecosystem condition do not have reference values that reflect the condition of a least disturbed, intact, or natural system. Reference values are needed to scale indicators and to set a target or boundary value between an unfavourable and favourable status.

An important step in this context is the adoption of a taxonomy on sustainable activities under the EU framework to facilitate sustainable investment (Taxonomy Regulation (EU)2020/852). This Regulation defines the good condition of ecosystems. “Good condition means, in relation to an ecosystem, that the ecosystem is in good physical, chemical and biological condition or of a good physical, chemical and biological quality with self-reproduction or self-restoration capability, in which species composition, ecosystem structure and ecological functions are not impaired.” The Regulation thus defines the minimum criteria that have to be met by ecosystems to reach a good condition and it outlines the basics for setting a reference condition (species composition, ecosystem structure and functions are not impaired). Clearly, the next logical step is to use the baseline data and indicators collated in this report to define the minimum criteria for good ecosystem condition.

Once these criteria are defined, the principles of the WFD can guide the work. In a first instance, the principle of complete coverage should be extended to all terrestrial ecosystems with the objective to bring all terrestrial ecosystems in a good or favourable ecosystem condition. This would cover the existing legal gaps that are not filled by the Habitats and Birds Directives. Secondly, the WFD recognizes two baselines to guide ecosystem recovery: a pristine reference condition (good ecological status), which is the target for natural rivers and lakes and a baseline, known as good ecological potential, which is the target for heavily modified water bodies. This principle can guide the setting of terrestrial ecosystem restoration targets as well, in particular for ecosystems which are currently not covered by the nature directives and where restoration to a pristine state is no longer possible (e.g., croplands and urban ecosystems).

Whereas this report is based on 132 unique pressure and ecosystem condition indicators, only a handful indicators report in a consistent and harmonized way the trends on species diversity at the European scale. This low number of species-based EU-level indicators is in sharp contrast with the ongoing big data revolution, also in the field of biodiversity. Increasingly, species data are recorded in the Global Biodiversity Information Facility or biodiversity observation platforms through citizen science. New technologies based on molecular methods or earth observation are generating massive amounts of biodiversity data. However, this report clearly demonstrates that the uptake of such data for policy and management is hampered by temporal, spatial and taxonomic gaps, lack of standardisation and integration, quality constraints, limited availability of data in publicly accessible databases, little interoperability among data and infrastructures, and few suitable knowledge products readily usable for policy and management. This needs to change. If biodiversity is becoming more central to EU strategic policies such as the European Green Deal, an EU framework for monitoring for biodiversity and ecosystems needs to be designed and become operational before the end of this decade.

List of abbreviations and definitions

BD	Birds Directive
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CDDA	Nationally designated areas
CFP	Common Fisheries Policy
CICES	Common International Classification of Ecosystem Services
CLC	Corine Land Cover
CSO	Czech Society for Ornithology
DG	Directorate General (of the European Commission)
EBCC	European Bird Census Council
Ecosystem condition	The physical, chemical and biological condition or quality of an ecosystem at a particular point in time
Ecosystem status	Ecosystem condition defined among several well-defined categories with a legal status. It is usually measured against time and compared to an agreed target in EU environmental directives (e.g. Habitats Directive, Water Framework Directive, Marine Strategy Framework Directive), e.g. “conservation status”.
EDO	European Drought Observatory
EEA	European Environment Agency
END	Environmental Noise Directive
ENV	Directorate General for the Environment
E-OBS	ENSEMBLES daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe
EQS	Environmental Quality Standards
ES	Ecosystem Services
ETCCDI	Expert Team (ET) on Climate Change Detection and Indices
EU	European Union
EUROSTAT	Statistical office of the European Union
FAO	Food and Agriculture Organization
FAWS	Forest Available for Wood Supply
FUA	Functional Urban Area
GES	Good Environmental Status (in marine ecosystems)
GHG	Greenhouse Gasses
GPP	Gross Primary Production
HD	Habitats Directive
IAS	Invasive Alien Species
IMP	Integrated Maritime Policy
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
KIP-INCA	Knowledge Innovation Project on an Integrated system of Natural Capital and ecosystem services Accounting in the EU
LUCAS	Land Use and Coverage Area frame Survey
LULUCF	Land use, land-use change, and Forestry
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MARS	Monitoring Agricultural Resources
MPA	Marine Protected Area
MS	Member States
MSFD	Marine Strategy Framework Directive
NAI	net annual increments of growing stocks
NEC	National Emissions Ceilings (Directive)
NFI	National Forest Inventories
NUTS	Nomenclature of Territorial Units for Statistics levels
PoM	Programmes of Measures
RSC	Regional Sea Convention
RSPB	Royal Society for the Protection of Birds
SEEA EEA	System of Environmental Economic-Accounting – Experimental Ecosystem Accounting

SGD	Sustainable Development Goal
TEEB	The Economics of Ecosystems and Biodiversity
UAA	Utilised Agricultural Area
UGI	Urban Green Infrastructure
UN	United Nations
UNFCCC	UN Framework Convention on Climate Change
WFD	Water Framework Directive

Abbreviations of author and reviewer affiliations

EEA	European Environment Agency
ENV	Directorate General for the Environment
ETC/BD	European Topic Centre on Biological Diversity
ETC/ULS	European Topic Centre on Urban, Land and Soil Systems
Eurostat	Directorate General for European Statistics
JRC.A.5	Joint Research Centre – Scientific Development unit
JRC.C.2	Joint Research Centre – Energy Efficiency and Renewables
JRC.C.5	Joint Research Centre – Air and Climate unit
JRC.D.1	Joint Research Centre – Bio-Economy unit
JRC.D.2	Joint Research Centre – Water and Marine Resources unit
JRC.D.3	Joint Research Centre – Land Resources unit
JRC.D.5	Joint Research Centre – Food Security unit
JRC.D.6	Joint Research Centre – Knowledge for Sustainable Development & Food Security unit
JRC.E.1	Joint Research Centre – Disaster Risk Management unit
RTD	Directorate General for Research and Innovation

The MAES glossary is available here:

https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/5th%20MAES%20report.pdf

For a glossary of ecosystem services mapping and assessment terminology:
https://oneecosystem.pensoft.net/article/27110/

Annex: List of fact sheets

Fact sheets with information of the indicators, data, and metadata used in this this report are bundled in a separate supplement. This supplement can be downloaded here:
https://publications.jrc.ec.europa.eu/repository/handle/JRC120383

List with the fact sheets and their page number in the supplement

KJ-NA-30161-EN-N

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Publications Office of the European Union

doi:10.2760/757183

ISBN 978-92-76-17833-0