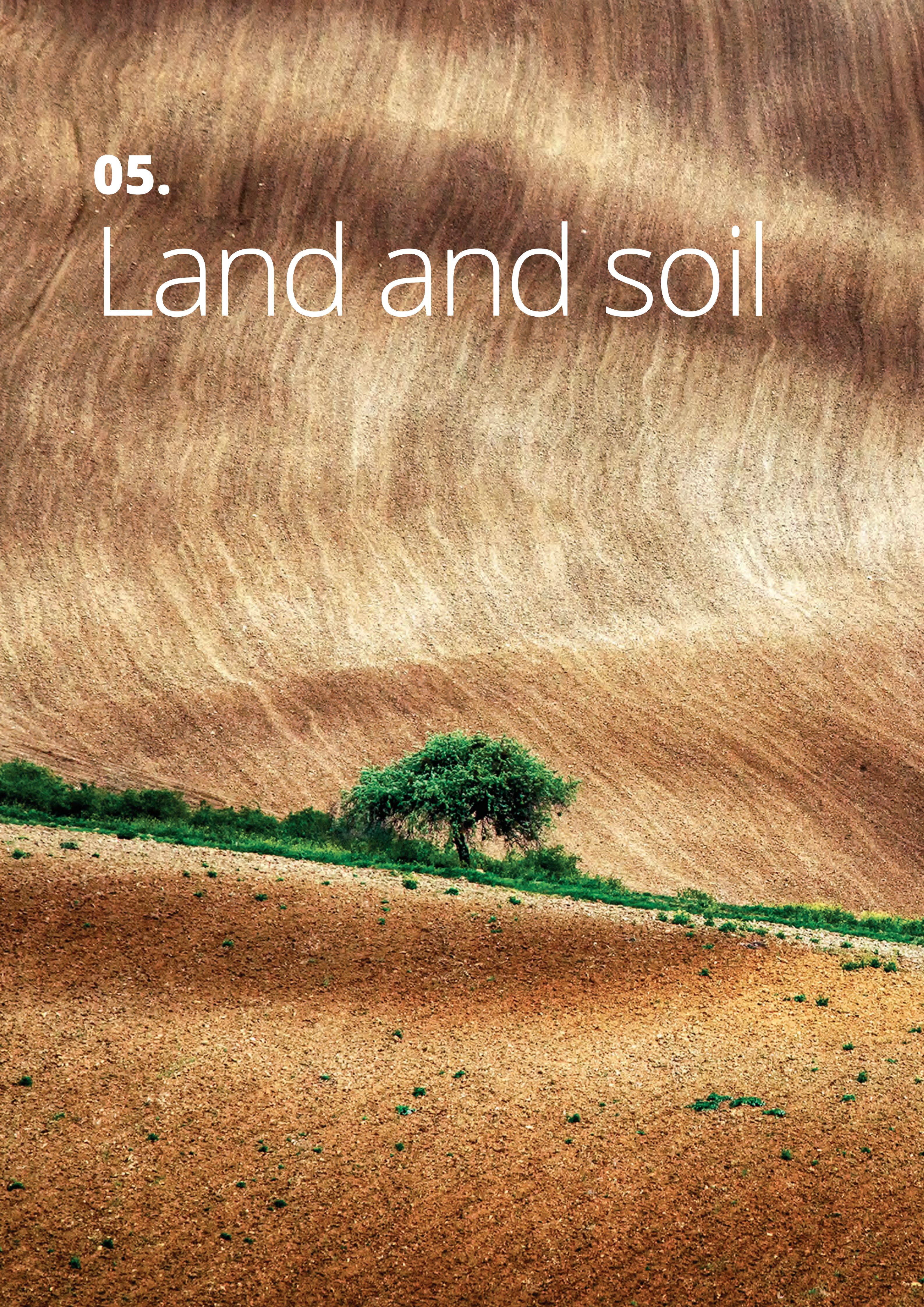
05.
Land and soil



Key messages

- Land and its soils are the foundation for producing food, feed and other ecosystem services such as regulating water quality and quantity. Ecosystem services related to land use are critical for Europe's economy and quality of life. Competition for land and intensive land use affects the condition of soils and ecosystems, altering their capacity to provide these services. It also reduces landscape and species diversity.

- Land take and soil sealing continue, predominantly at the expense of agricultural land, reducing its production potential. While the annual rate of land take and consequent habitat loss has gradually slowed, ecosystems are under pressure from fragmentation of peri-urban and rural landscapes.

- Land recycling accounts for only 13 % of urban developments in the EU. The EU 2050 target of no net land take is unlikely to be met unless annual rates of land take are further reduced and/or land recycling is increased.

- Soil degradation is not well monitored, and often hidden, but it is widespread and diverse. Intensive land management leads to negative impacts on soil biodiversity, which is the key driver of terrestrial ecosystems' carbon and nutrient cycling. There is increasing evidence that land and soil degradation have major economic consequences, whereas the cost of preventing damage is significantly lower.

- European policy aims to develop the bioeconomy but while new uses for biomass and increasing food and fodder consumption require increasing agricultural output, land for agricultural use has decreased. This leads to growing pressures on the available agricultural land and soil resources which are exacerbated by the impacts of climate change.

- The lack of a comprehensive and coherent policy framework for protecting Europe's land and soil resources is a key gap that reduces the effectiveness of the existing incentives and measures and may limit Europe's ability to achieve future objectives related to development of green infrastructure and the bioeconomy.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets	
	Past trends (10-15 years)	Outlook to 2030	2020	2050
Urbanisation and land use by agriculture and forestry	Deteriorating trends dominate	Deteriorating developments dominate		☒ Not on track
Soil condition	Deteriorating trends dominate	Deteriorating developments dominate	☒ Not on track	

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 5.3, Key trends and outlooks (Tables 5.2 and 5.4).

05.
Land and soil

5.1
Scope of the theme

Productive land and fertile soil are part of our shared natural capital. The management of land by owners and users is therefore fundamental for sustainable resource use and delivery of ecosystem services. These services include the provision of food, nutrient cycling, supporting all terrestrial biodiversity, water regulation and purification, and mitigating climate change by carbon sequestration. While the demand for food and the pressures on land and soil are increasing globally, biodiversity is visibly declining (UNEP, 2014; IPBES, 2018).

> Land-use management is vital for sustainable resource use and delivery of ecosystem services.

Current land use practices and observed land cover changes put significant pressure on the land system (EC DG AGRI, 2015; EEA, 2018c). The condition of land and soils is affected by loss of productive land because of land take and the type and intensity of land management. Europe's soils suffer from sealing, erosion, compaction, pollution, salinisation and carbon loss. Additional pressure on the land system comes from climate change. Shifting spring phenology, droughts, fires, storms and floods impact the condition of ecosystems and the food chain.

A complex pattern of pressures results from socio-economic drivers, expressed as the need for settlements, transport, clean water, food and fibre production, and tourism. Future scenarios and projections point to intensification of agriculture in northern and western Europe and extensification and abandonment in the Mediterranean region (Holman et al., 2017). More intensive land use will lead to a gradual decline in the levels of (soil) biodiversity (Schneiders et al., 2012; Tsiafouli et al., 2015).

5.2
Policy context

Prevention and restoration of land and soil degradation are addressed broadly in the European policy framework. Table 5.1 presents an overview of selected relevant policy targets and objectives. More details on policies related to agriculture and forestry are available in Chapter 13.

Regarding land and soil policies, binding targets are lacking at European level. The Seventh Environment Action Programme (7th EAP) and the EU Roadmap to a resource efficient Europe promote 'no net land take' in the EU by 2050, aiming to mitigate the effect of urban sprawl. 'No net land take' supports the land degradation neutrality target of the United Nations Convention to Combat Desertification (UNCCD), aiming to maintain the amount and quality of

TABLE 5.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Land and soil			
EU policies help to achieve no net land take by 2050	7th EAP (EU)	2050	Non-binding commitments
Reduce soil erosion, increase soil organic matter, and promote remedial work on contaminated sites	Roadmap to a resource efficient Europe (EU)	2020/2050	
Prevent further degradation of soil, preserve its functions and restore degraded soil Integrate soil protection into relevant EU policies	Thematic strategy on the protection of soil	N/A	Non-binding commitment
Restore at least 15 % of degraded ecosystems; better integrate biodiversity into agriculture and forestry	EU biodiversity strategy to 2020	2020	Non-binding commitments
Targets 2.4 (food security), 3.9 (soil pollution), 15.2 (sustainable agricultural and forest management), and 15.3 (land degradation neutrality) Combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification	Global policies: SDGs, United Nations Convention to Combat Desertification	2030	Non-binding commitments
Sustainable management of natural resources and climate action: to ensure the long-term sustainability and potential of EU agriculture by safeguarding the natural resources on which agricultural production depends	Common agricultural policy (CAP)	N/A	Non-binding commitments
Ensure the monitoring of negative impacts of air pollution upon ecosystems (Article 9) (includes soils)	National Emission Ceilings Directive (Article 9)	2030	Binding commitment
Identify and assess sites contaminated by mercury, and address risks (includes soil contamination)	Minamata Convention on Mercury (Article 15)	N/A	Non-binding commitment
Ensure that emissions do not exceed removals in the LULUCF sector (no-debit rule)	LULUCF regulation (2018/841)	2025, 2030	Binding commitment

Note: 7th EAP, Seventh Environment Action Programme; LULUCF, land use, land use change and forestry; SDGs, Sustainable Development Goals; N/A, non-applicable.

land resources. Land degradation neutrality is promoted by Target 15.3 of the UN Sustainable Development Goals (SDGs), which, by 2030, strives to combat desertification and to restore degraded land and soil. SDG 2 (to eliminate hunger) connects soils, food production and healthy living. Land and soils are also bound to goals that address poverty reduction (SDG 1), health and well-being through reduced pollution (SDG 3), access to clean water and sanitation (SDG 6), the environmental impact of urban sprawl (SDG 11) and climate change (SDG 13).

The EU biodiversity strategy to 2020 calls for restoring at least 15 % of degraded ecosystems in the EU and to expand the use of green infrastructure, e.g. to help overcome land fragmentation. The UN Resolution on Soil Pollution (UNEP, 2017) requests countries to set norms and standards to prevent, reduce and manage soil pollution.

Although specific soil protection legislation is not in place in the EU, the 2006 soil thematic strategy promotes the inclusion of soil protection measures in various policy areas.

According to a study by Frelih-Larsen et al. (2017), 671 policy instruments related to soil protection exist in the 28 EU Member States (EU-28), and 45 % of them are linked to EU policies. For example, the National Emission Ceilings Directive aims to reduce the impact of emissions of acidifying substances (Chapter 8); the Industrial Emissions Directive seeks to prevent emissions from entering the soil (Chapter 12); several directives target avoiding soil contamination from waste disposal and chemicals (Chapters 9 and 10); and the Water

Framework Directive seeks to identify and estimate water pollution originating from soils (Chapter 4). Nevertheless, binding instruments and targets are mostly lacking, and not all soil threats and soil functions are covered.

5.3 Key trends and outlooks

5.3.1 Land cover change

Land use modifies the quality and quantity of ecosystem services (EEA, 2018c) by conditioning the potential of land and soil to provide these services. Unsustainable agricultural and forestry practices, urban expansion and climate change are the main drivers of land degradation, which according to the recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report (Scholes et al., 2018) have already resulted in loss of ecosystem services in many parts of the world. Accounting for the changes in land stocks, and for the processes driving these changes, may shed light on some pressures on Europe's land use (see the interactive land accounts viewer ([1])) that are impacting ecosystem services and our natural capital.

The 2018 mapping of Europe's land cover by the Copernicus Land Monitoring Service, recorded in the Corine Land Cover ([2]) data sets, indicates that the proportion of Europe's main land cover types are relatively stable (e.g. 25.1 % arable land and permanent crops, 16.6 % pastures, 34.4 % forests in the EEA's member countries and cooperating countries). The long-term changes over the period 2000-2018 show that the area of artificial surfaces has changed the most, increasing by 7.1 % (Figure 5.1). Although the latest period, 2012-2018, had the lowest increase, during the entire period 2000-2018, 921 km²/year of land was turned into artificial surfaces.

7.1 %

increase in the area of artificial surfaces between 2000 and 2018.

While the areas of arable land and permanent crops became smaller during the period 2000-2018 (by 0.5 %, 402 km²/year), in 2012-2018 there was no significant change in their extents. Firstly, the sprawl of economic and commercial sites decreased substantially in several countries (-91 % in Spain, -45 % in Germany, -35 % in France). Secondly, withdrawal from farming activities decreased (-87 % in Hungary) and so did the conversion from arable land into non-tilled agricultural land (-97 % in Germany, -93 % in Czechia, -79 % in Hungary). The small decrease in pastures and mosaic farmland mainly arose from a few countries, such as in Ireland as a result of afforestation and in France, Germany and Spain as a result of sprawl of urban and industrial areas. The loss of wetlands amounted to around 1 % over the last two decades. During 2012-2018 the most prominent decline was observed in Romania and Finland due to conversion to agriculture, to a lesser extent in the United Kingdom due to conversion to industrial sites and in Ireland due to afforestation. Forests and transitional woodlands (less than 0.1 % change) and natural grassland (less than 0.3 % change) had most stable land cover extents in Europe between 2000 and 2018.

5.3.2 Urban expansion and land use change

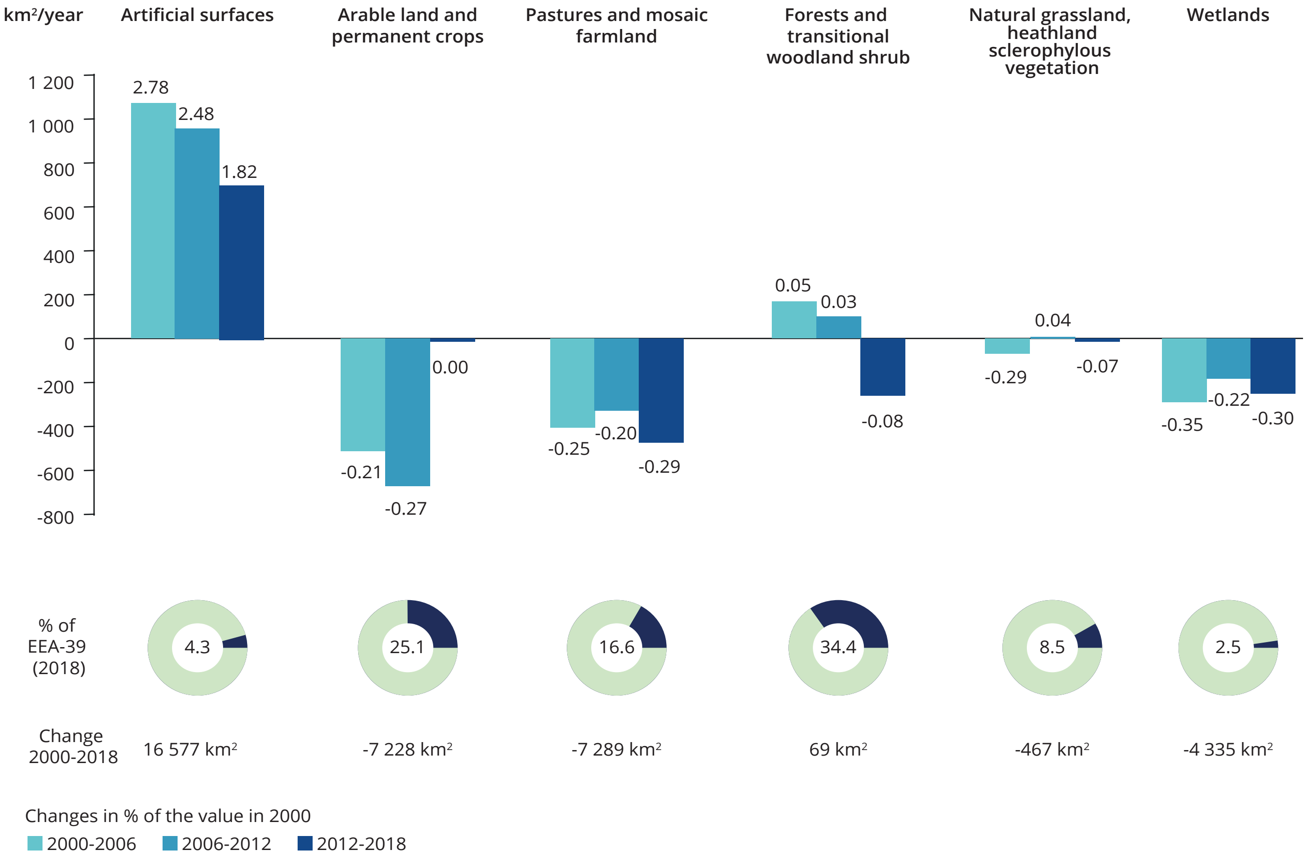
Seventy-two per cent of Europe's population lives in cities, towns and suburbs (Dijkstra et al., 2016). Urban agglomerations in the EU are expected to grow by 11 % (corresponding to 34 million people) by 2050 (Kompil et al., 2015), and artificial surfaces are predicted to increase by 0.71 % by 2050, leading to increasing land take and fragmentation (Lavalle and Barbosa, 2015; Lavalle and Vallecillo, 2015). Urban expansion is accompanied by a greater need for infrastructure (transport, water, waste and electricity), which decreases the long-term availability of productive land resources. Loss of fertile land caused by urban development decreases the potential of land to produce bio-based materials and fuels to support a low-carbon bioeconomy.

Land take

Land take is the process in which urban areas and sealed surfaces occupy agricultural, forest or other semi-natural and natural areas (EEA, 2017). The increase in artificial surfaces often impairs or disrupts valuable ecological functions of soils such as biomass provision, acting as soil biodiversity and a soil carbon pool, or water infiltration potential. This contributes to negative climate change

([1]) https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics
([2]) https://land.copernicus.eu/pan-european/corine-land-cover

FIGURE 5.1 Change in six major land cover types in the EEA-39 during the period 2000-2018



Note: Open spaces and water bodies are not shown, which is why the percentages do not add up to 100 %.

Source: EEA.

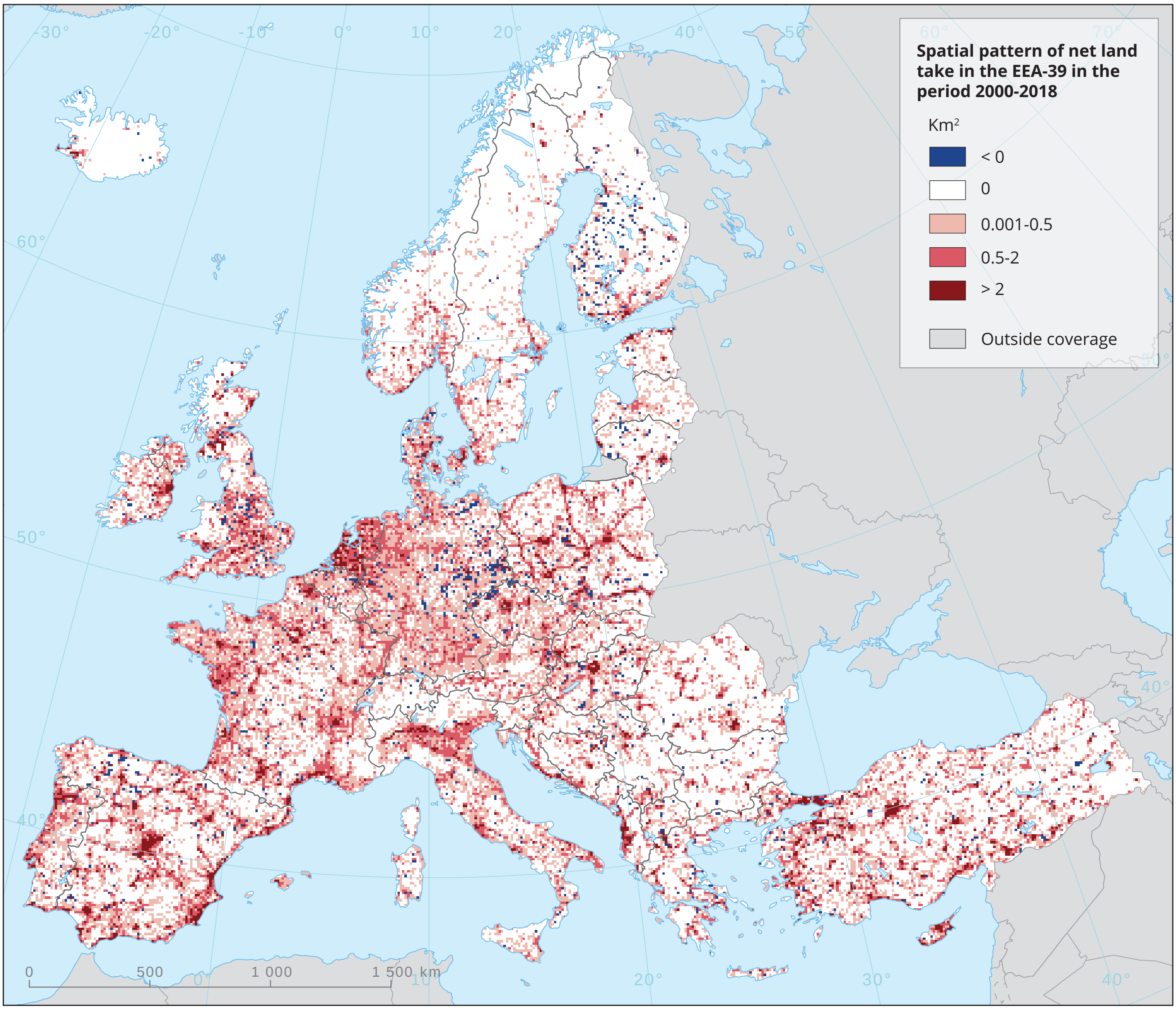
impacts by decreasing the potential for carbon storage and sequestration or increasing surface run-off during flooding (EC, 2014; Edenhofer et al., 2011).

Population and income growth have been widely reported to drive land take (Chapter 1), yet this relationship varies greatly across and within countries. In most developed countries, the demand for urbanised land grows faster than the population, or grows even without additional population, for example in Switzerland, the eastern part of Germany or the south of France (Colsaet et al., 2018). In some cases, artificial land is returned to other land categories (recultivation). The balance between taken and recultivated land is net land take — the concept behind the EU's 'no net land take' target (Map 5.1).

Calculated from the Corine Land Cover data set, annual net land take (see definition in EEA (forthcoming (a))) in the EU-28 continually decreased from 922 km²/year in the period 2000-2006 to 440 km²/year in the period 2012-2018 (see the interactive Land take data viewer ([3])). During the period 2000-2018, land take concentrated around larger urban agglomerations (Map 5.1), with 80 % of land taken at the expense of arable land and permanent crops (50 %) and of pastures and mosaic farmlands (almost 30 %). Nevertheless, while in that period some land was recultivated in the EU-28, 11 times

([3]) https://www.eea.europa.eu/data-and-maps/dashboards/land-take-and-net-land

MAP 5.1 **Spatial pattern of net land take in the EEA-39 in the period 2000-2018**



Source: EEA.

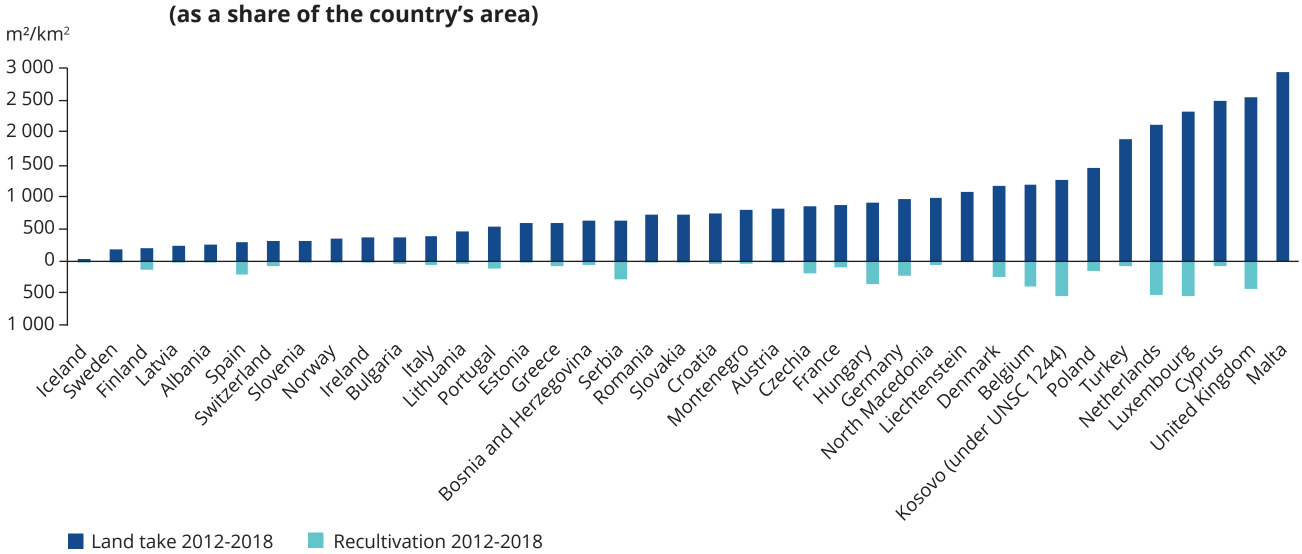
more land was taken (14 049 km² land take vs 1 269 km² recultivated land). Within functional urban areas (cities and their commuting zones) land recycling, the reuse of abandoned, vacant or underused urban land, is measured using the Copernicus Urban Atlas (4) data set. Land recycling is still low in most countries (see the Land recycling data viewer (5) — only 13 % of urban land development addressed the reuse of land in the period 2006-2012 (EEA, 2018b).

> Loss of fertile land to urban development reduces the potential to produce bio-based materials and fuels to support a low-carbon bioeconomy.

Figure 5.2 presents land take in the EEA-39 during the period 2012-2018, as the share of the country's area, which allows comparison of countries of

(4) https://land.copernicus.eu/local/urban-atlas
(5) https://www.eea.europa.eu/data-and-maps/dashboards/land-recycling

FIGURE 5.2 Country comparison — land take and land recultivation in the EEA-39 in the period 2012-2018 (as a share of the country's area)



Note: Kosovo under United Nations Security Council Resolution 1244/99.

Source: EEA.

different sizes. Land take was highest in Malta, the United Kingdom, Cyprus, Luxembourg and the Netherlands. The large proportion of land take in Malta was mainly due to mining and urban sprawl. In the United Kingdom, Cyprus and Luxembourg, the main drivers were industrial and commercial activities and construction sites, the latter being the main reason in the Netherlands as well. Whereas in Malta there was no recultivation, and in Cyprus there was very little, in the Netherlands, Luxembourg and the United Kingdom, together with Kosovo (6), recultivation was the highest in the EEA-39 (see the interactive Land take data viewer (7)).

Landscape fragmentation

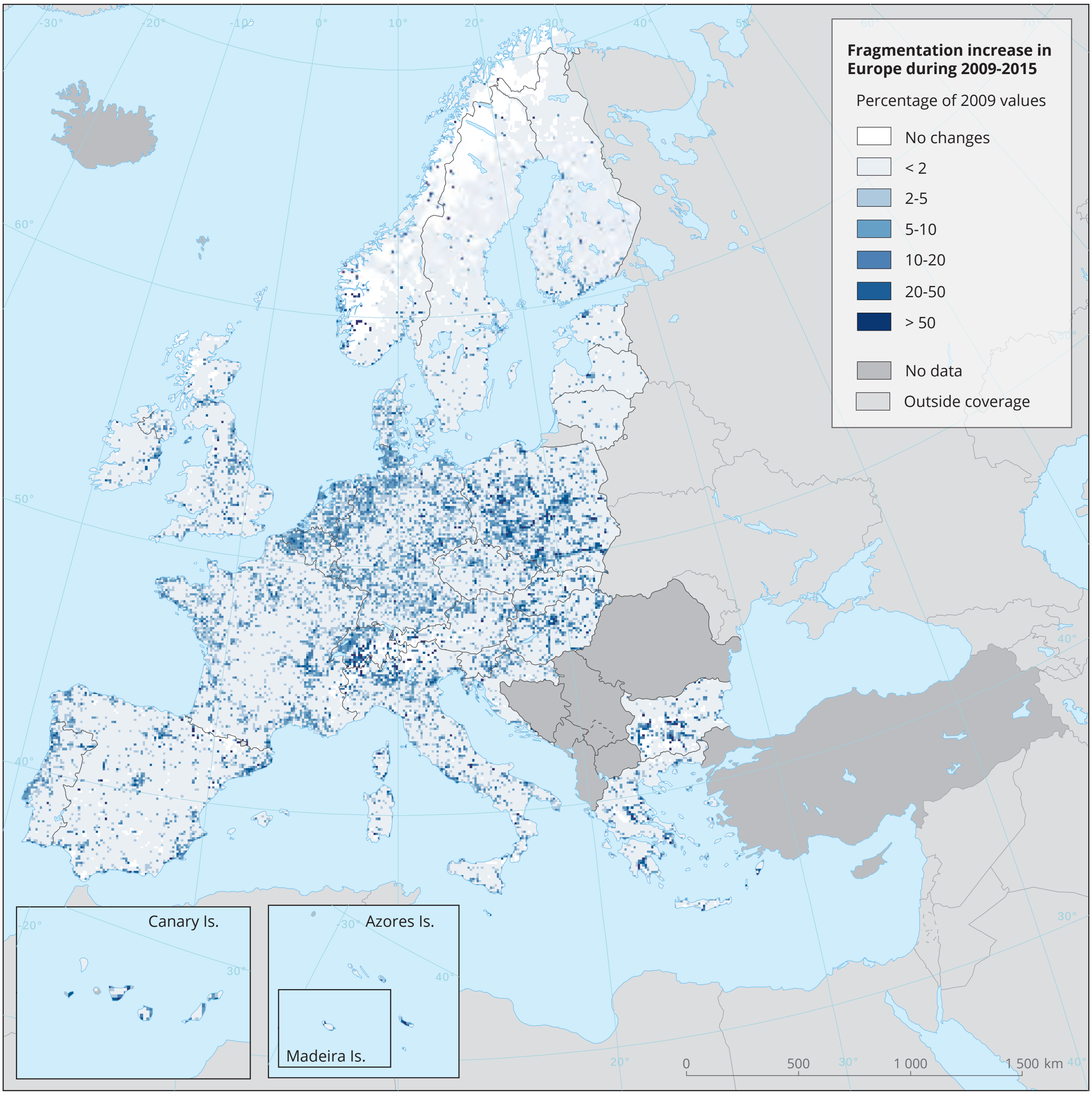
The expansion of urban areas and transport networks transforms large habitat patches into smaller, more isolated fragments, leading to habitat fragmentation. Fragmentation often jeopardises the provision of many ecosystem services and affects the stability and resilience of habitats. Although the EU biodiversity strategy to 2020 has a target to 'restore at least 15 % of degraded ecosystems in the Union and to expand the use of Green Infrastructure', there are only a few signs that pressure of land fragmentation has reached its peak.

> A 2.6 % increase in land fragmentation occurred in the EEA-39 territory between 2012 and 2015, compared to a 6.2 % increase in the period 2009-2012.

Landscape fragmentation can be measured as the number of continuous, unfragmented areas (i.e. meshes) per 1 000 km² (Moser et al., 2007; EEA, 2018d). It increased by 6.2 % in the EEA-39 territory (8) between 2009 and 2012 but slowed down to a 2.6 % increase in the period 2012-2015 (EEA, forthcoming (b)). Compared with 2009, in 2015 the most rapid increase in fragmentation was observed in Poland (18 %) due to construction of motorways. Bulgaria, Greece and Hungary also showed rapid increases in fragmentation pressure (around 14 %). In absolute terms, indicating the highest density of meshes per 1 000 km², Switzerland and the Benelux states became the most fragmented in Europe (Map 5.2). In both measurement periods, mostly uninhabited areas and dispersed rural areas became more fragmented (more than a 5 % increase); these are areas with a relatively higher potential to

(6) Under United Nations Security Council Resolution 1244/99.
(7) https://www.eea.europa.eu/data-and-maps/dashboards/land-take-and-net-land
(8) Excluding Albania, Bosnia and Herzegovina, Cyprus, Iceland, Kosovo, North Macedonia, Romania, Serbia and Turkey because of poor data coverage for transport infrastructure elements for this period.

MAP 5.2 **Increase in landscape fragmentation in Europe between 2009 and 2015**



Note: Landscape fragmentation as a result of an expansion in urban and transport infrastructure is monitored using the Copernicus Imperviousness ([9]) and the TomTom Multinet EUR (reference years: 2009, 2012, 2015) road network data sets ([10]). Data for Albania, Bosnia and Herzegovina, Cyprus, Iceland, Kosovo, North Macedonia, Romania, Serbia and Turkey are not available.

Source: EEA.

([9]) Under United Nations Security Council Resolution 1244/99.

([10]) Excluding Albania, Bosnia and Herzegovina, Cyprus, Iceland, Kosovo, North Macedonia, Romania, Serbia and Turkey because of poor data coverage for transport infrastructure elements for this period provide ecosystem services because of their lower degrees of urbanisation.

Fragmentation within Natura 2000 sites increased by 5.9 % in the period 2009-2012 and slowed down to a 1.6 % increase in the period 2012-2015 (EEA, forthcoming (b)). Urban and road infrastructure expansion may occur in Natura 2000 sites — depending on, if necessary, an assessment of their impacts in accordance with Article 6 of the EU Habitats Directive. This explains why fragmentation pressure was observed in the sites despite their protected status. Nevertheless, in all EU-28 countries, the increase in fragmentation was lower within Natura 2000 sites than in areas not protected by the EU nature directives.

5.3.3 Land use by agriculture and forestry

►See Table 5.2

Sectoral trends (Chapter 13) and high societal demand for agriculture and forestry outputs lead to pressures on land and soil. This has a range of negative environmental impacts, such as loss of biodiversity (Chapter 3), eutrophication pressures in freshwater ecosystems (Chapter 4) or air pollution (Chapter 8). Loss of arable land due to, for example, land abandonment in many cases causes loss of habitats for farmland species (Chapter 3). At the same time droughts, forest fires and floods are increasing threats, in particular in southern Europe. Sustainable management of our land and soil resources helps to maintain agricultural and forest productivity (e.g. Brady et al., 2015) while improving the potential of land and soils as a carbon sink, supporting biodiversity and storing and filtering water and nutrients.

Urban land take continues, consuming mostly agricultural land. There is however a slowing trend in urbanisation and the expansion of transport infrastructure.

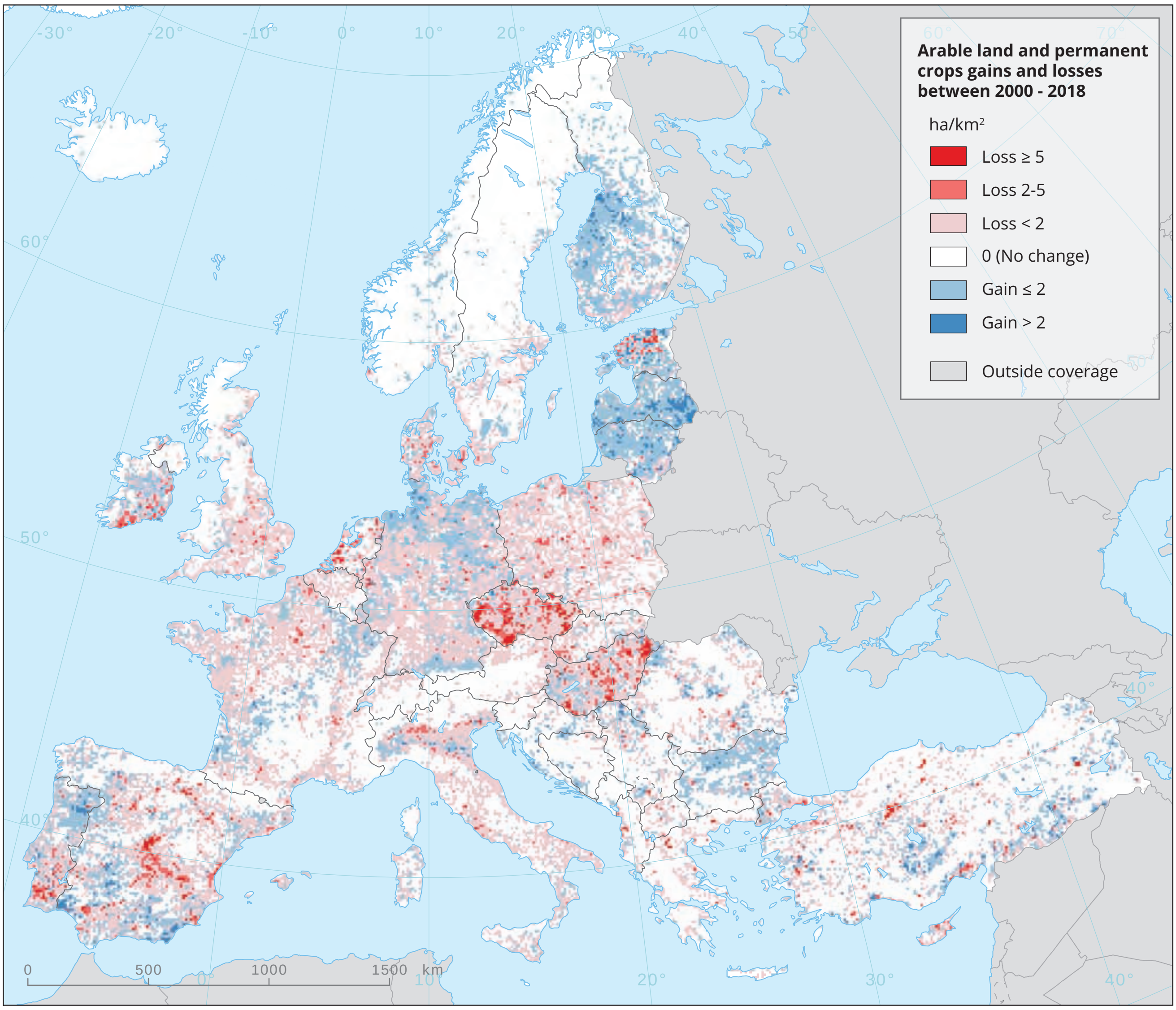
According to the Copernicus Corine Land Cover data sets ([11]), during the period 2000-2018, the largest losses of arable land and permanent crops were observed in Czechia, Hungary, the interior of Spain and southern Portugal (Map 5.3). While in Hungary and Portugal the main reason was withdrawal of farming and subsequent woodland creation, in Czechia the main driver was the extension of non-tilled agricultural land and pastures (see the interactive Land accounts viewer ([12])). In central Spain, the increase in construction and industrial sites was the main cause. The largest gains were observed in northern Portugal, the Baltic countries (in particular Latvia) and central Finland. While in Latvia and Lithuania arable land was created by converting pastures, in central Finland the gains were due to forest conversion.

Grasslands provide important ecosystem services, such as food provision, enjoyment of landscapes, storage of soil carbon, erosion control and flood regulation. They are among the most species-rich vegetation types in Europe with up to 80 plant species/m^2 (Silva et al., 2008). Grasslands are generally lost when extensive livestock farming is given up because of land abandonment or through conversion to cropland or increased fertilisation and mowing frequencies. The decline in grassland areas has negative consequences for pollinators and other insects as well as for birds (Assandri et al., 2019) (Chapter 3). Semi-natural grasslands are a core component of high nature value farmland in Europe, representing around 30 % of the EU's agricultural land (Paracchini et al., 2008). High nature value farmland exemplifies the pressures on agro-ecosystems from agricultural intensification as well as land abandonment (e.g. Henle et al., 2008; Renwick et al., 2013).

The forested area in Europe has been largely stable over the last two decades, and it only expanded because of afforestation programmes in some European countries and through spontaneous regeneration on abandoned agricultural land. Changes in forest land cover are now locally concentrated in a few European countries (Forest Europe, 2015). Despite the stable area and sustainable use of timber resources, forest ecosystems are subject to pressures (Section 13.4.2 in Chapter 13) and changes in their condition, which raises concern over their long-term stability and health (EEA, 2016, 2018a). Although the area of protected forests has slightly increased in the EEA-39 (EEA, 2019), the fragmentation of forests increased by 8 % between 2009 and 2015 (EEA, forthcoming (b)). In eastern and southern Europe (Bulgaria, Croatia, Greece, Hungary, and Poland), the increase in fragmentation of forests and woodlands was more than 15 %, and illegal logging is increasingly reported (e.g. in the Carpathian region).

([11]) https://land.copernicus.eu/pan-european/corine-land-cover
([12]) https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

MAP 5.3 **Arable land and permanent crop losses and gains during the period 2000-2018**



Source: EEA.

TABLE 5.2 Summary assessment — urbanisation and land use by agriculture and forestry

Past trends and outlook		
Past trends (10-15 years)		Europe's land resources are exposed to intensive use at an accelerated rate. Land take continues, mostly at the expense of agricultural areas, although the yearly rate shows a tendency to slow down. The rate of reuse of developed land remains low. Landscape fragmentation has increased, impacting mostly uninhabited or dispersed rural areas and suburbs — areas with relatively greater potential to supply ecosystem services.
Outlook to 2030		Land take and resulting landscape fragmentation are projected to increase in forthcoming decades. Farming is likely to retreat further from marginal, biodiversity-rich areas and the intensive use of productive farmland is likely to increase, impacting the quality and ecosystem services of agricultural areas. Logging and consumption of wood for fuel will increase, which, together with increasing droughts, fires and storms, is expected to reduce forest ecosystem services.
Prospects of meeting policy objectives/targets		
2050	☒	Europe is at risk of not meeting the 7th EAP objective of managing land sustainably and reaching no net land take by 2050. However, slowing trends in the expansion of urban and transport infrastructure areas indicate that, if appropriate measures are taken, the targets could be reached. The increase in landscape fragmentation is lower within and in the areas surrounding Natura 2000 sites, hence protection policies seem to be effective in partially reaching the target set by the EU biodiversity strategy to 2020 to restore 15 % of degraded ecosystems.
Robustness		Data are based on regular and quantitative inventories of the Copernicus Corine Land Cover, Urban Atlas and Imperviousness data sets, using medium- and high-resolution remote sensing images. Interpretation and calibration are harmonised and quality assured and controlled by third party experts. While data quality is subject to sensor performance and weather impacts, and derived data still depend on human interpretation, remote sensing is the only tool that offers standardised and repeatable measurements on high spatial and temporal resolutions, at a large spatial scale and with continental to global coverage. The assessment of the outlook for and prospects of meeting policy objectives relies on models and on expert judgement.

Competition for land, unsustainable practices and pollution affect soil quality.

Forest Europe (2015) reports that about 8 % of the forest area is intensively managed plantations. Intensive management operations involve clear-cutting, skidding damage to remaining trees and soil compaction. A study by Schelhass et al. (2018) underlines that little is known about harvesting processes in European forests. The current fellings/growth ratio is approximately 60-65 % of the annual forest increment harvested. Recent analysis of the wood resource balance (Camia et al., 2018) shows that this ratio is expected to be about 12 % larger as a result of underestimation of reported removals.

The climate targets of the Paris Agreement and the incentives offered under new EU policies, e.g. land-based carbon accounting (land use, land use change and forestry, LULUCF) will influence forest management. Energy policies already result in an increased demand for wood products and for bioenergy (Levers et al., 2014; Pricewaterhouse Coopers EU, 2017). As a consequence, the land used for intensively managed forests may increase to maximise the provision of biomass either from Europe's forests or by importing more biomass (e.g. wood pellets from North America).

Climate change, as well as economic and technological change, will continue to drive change in agricultural land management in the coming decades. Agricultural productivity in southern Europe will be particularly affected, and this is likely to involve a further retreat of farming from marginal but often biodiversity-rich areas as well as intensive use of productive farmland in central, western and northern Europe (Holman et al., 2017; Stürck et al., 2018). Europe's forests overall maintain their function as a carbon sink, but degradation of forest ecosystems may increase the risks of eroding the biodiversity and ecological condition of forests and of forest soils due to compaction, loss of nutrients and loss of forest soils (Bengtsson et al., 2000; Frelich et al., 2018). The sustainable management of ecosystems and soils under agricultural and forestry land use will continue to be an important challenge for conserving and enhancing Europe's natural capital.

85 861 km^2

of land in the EEA-39 territory was sealed in 2015.

5.3.4 Soil condition

► *See Table 5.4*

Pressures on European soils are increasing, and there is a risk that they will affect the services provided by properly functioning, healthy soils. Soil is a finite, non-renewable resource because its regeneration takes longer than a human lifetime. It is a key component of Europe's natural capital, and it contributes to basic human needs by supporting, for example, food provision and water purification, while acting as a major store for organic carbon and a habitat for extremely diverse biological communities. 'Soil formation and protection' is one of the ecosystem services known to be declining in Europe, according to the recent IPBES assessment (IPBES, 2018).

Soils are threatened by increasing competition for land, unsustainable practices and inputs of pollutants, causing their degradation in various forms. Exposure to chemicals (mineral fertilisers, plant protection products, industrial emissions), tillage and compaction, as well as soil loss through sealing from urban expansion, erosion and landslides, degrade soils physically, chemically and biologically.

Physical degradation of soils

Soil sealing causes the complete and irreversible loss of all soil functions. Urban expansion and infrastructure consume soils by physical removal or covering them with impermeable (impervious) artificial material (e.g. asphalt and concrete), though only part of the land that is defined as land take is actually sealed.

In 2015, 1.48 % of the total EEA-39 area was sealed (2.43 % of the EU-28 in 2012), totalling 85 861 km^2. The annual rate of soil sealing seems to have decreased since 2012 (annual sealing rate for the monitoring interval 2006-2009: 460 km^2; 2009-2012: 492 km^2; 2012-2015: 334 km^2). In certain densely populated countries with dense infrastructure, such as Belgium and the Netherlands, almost 4 % of the national territory is sealed.

Erosion describes the loss of soil by water (predominantly as rill or gully erosion) and by wind and harvest losses (i.e. soil adhering to harvested crops such as sugar beet and potato). Apart from the loss of productivity and soil function, erosion of agricultural soils is also critical because of their proximity to surface waters, leading to the transfer of soil material and pollutants into water systems (e.g. 55 % of soils in Switzerland have a connection to water bodies, (BAFU, 2017)).

Panagos et al. (2015) estimated the mean soil erosion rate by water to be about 2.46 t/ha per year in the EU (which is 1.6 times higher than the average rate of soil formation). Accordingly, 12.7 % of Europe's land area is affected by moderate to high erosion (soil loss rates > 5 t/ha per year). The total soil loss due to water erosion is estimated at 970 million tonnes per year (Panagos et al., 2016). The average annual soil loss by wind erosion is estimated to be about 0.53 t/ha per year (EU-28 arable land, 2001-2010; (Borrelli et al., 2017). Crop harvesting contributes to significant soil removal. Panagos et al. (2019) estimate that 4.2 million hectares of root crops (of 173 million hectares of utilised agricultural land in the EU) contribute to 14.7 million tonnes of soil loss. Although there is a declining trend due to a decrease in sugar beet cropping, crop harvesting practices may increase the overall soil loss rate in countries such as Belgium, Ireland and the Netherlands.

The annual cost of agricultural production (losses in crop yield) due to severe erosion in the EU is estimated to be EUR 1.25 billion (Panagos et al., 2018). Existing policy, in particular the cross-compliance requirements of the common agricultural policy (Chapter 13), may have reduced rates of soil loss over the past decade (Panagos et al., 2015). However, erosion rates can be expected to increase in the future as a result of more extreme rain events (Panagos et al., 2017), but sectoral changes, such as increased parcel size, heavier machinery and increased compaction, also play a role. Maintaining and/or increasing landscape features may reduce the risk of soil erosion.

Soil compaction is the result of mechanical stress caused by the passage of agricultural machinery and livestock. The consequences are increased soil density, a degradation of soil structure and reduced porosity (especially macroporosity). This causes increased resistance against root penetration and also negatively affects soil organisms, as their presence is restricted to sufficiently sized pores (Schjønning et al., 2015). Compaction is known to be a significant pre-cursor of erosion. Soil compaction may lower crop yields by 2.5-15 %, but it also contributes to waterlogging during precipitation events, which not only reduces the accessibility of fields to machinery but also negatively affects run-off, discharge rate and flooding events (Brus and van den Akker, 2018).

About 23 % of soils in the EU-28 are estimated to have critically high densities in their subsoils, indicating compaction (Schjønning et al., 2015). About 43 % of subsoils in the Netherlands exhibit compaction (Brus and van den Akker, 2018). Climate change (higher precipitation during the cold seasons), heavier machinery and increasingly narrow time windows for field operations are all factors that could increase the compaction hazard in the future. Although some countries have guidelines on access to land when the soil is wet, currently there is no European-level instrument to protect soils from severe compaction.

Chemical degradation of soils under intensive land use

Soils, with the help of various organisms, filter and buffer contaminants in the environment. Industrial activities, waste disposal and intensive land management have led to the dispersal of contaminants throughout the environment and eventually to their accumulation in soils. Sources of contaminants include the residues of plant protection products, industrial emissions, mineral fertilisers, biosolids (some composts, manures and sewage sludges), wood preservatives and pharmaceutical products.

Soil contamination can be diffuse and widespread or intense and localised (contaminated sites). Contaminants include heavy metals, persistent organic pollutants, residues of plant protection products and others. Depending on soil properties and their concentrations, contaminants in soil may enter the food chain, threaten human health and be toxic to soil-dwelling organisms (FAO and ITPS, 2017). Substances that are not readily degradable will eventually leach into surface and groundwaters or be dispersed by wind erosion (Silva et al., 2018).

There may be as many as 2.8 million contaminated sites in the EU, but only 24 % of the sites are inventoried.

According to Payá Pérez and Rodríguez Eugenio (2018), the dominating activities for contamination at local level are municipal and industrial waste sites (37 %) together with industrial emissions and leakages (33 %). In the EU-28, potentially polluting activities took place on an estimated 2.8 million sites (but only 24 % of the sites are inventoried). Currently, only 28 % of the registered sites are investigated, a pre-requisite to deciding whether remediation is needed or not (Payá Pérez and Rodríguez Eugenio, 2018). Considering the estimated extent of past and current pollution, and the uncertainties of reliable estimates, little progress has been made in the assessment and management of contaminated sites.

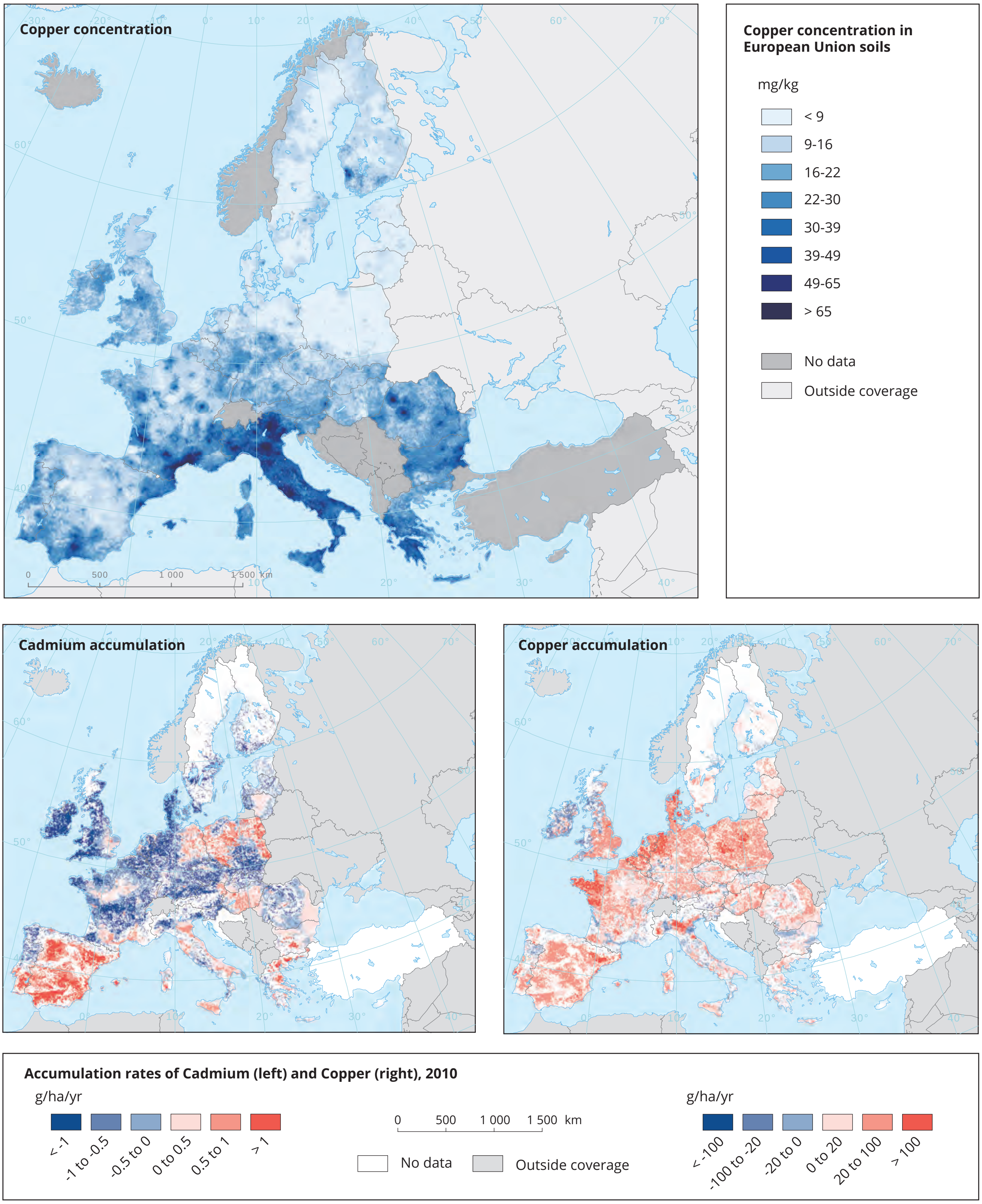
While diffuse contamination through large-scale atmospheric deposition is decreasing (lead by 87 % and mercury by 40 % since 1990, using concentrations in mosses as indicators (BAFU, 2017)), some metals such as cadmium and copper are accumulating in arable soils (Map 5.4). Once critical thresholds are exceeded, human health and ecosystem functioning is impacted, for example by the release of substances to groundwater (De Vries et al., 2007).

Cadmium — mainly originating from mineral phosphorus fertilisers — accumulates in 45 % of agricultural soils, mainly in southern Europe where leaching rates are low due to a low precipitation surplus (Map 5.4). In 21 % of agricultural soils, the cadmium concentration in the topsoil exceeds the limit for groundwater, 1.0 mg/m^3 (used for drinking water). Soils therefore need accurate monitoring of the fate of accumulating heavy metals in the seepage pathway through the soil to the groundwater.

While copper is an essential micronutrient, excess levels in soils are a source of concern. Copper has been widely used as a fungicide spray, especially in vineyards and orchards. Results from the Land Use and Coverage Area Frame Survey (LUCAS) soil sampling 2009-2012 show elevated copper levels in the soils in the olive and wine-producing regions of the Mediterranean (Map 5.4) (Ballabio et al., 2018). Animal manure is the largest source of copper in grassland, which together with zinc is added to animal feed and is introduced into the environment through manure spreading (De Vries et al., forthcoming).

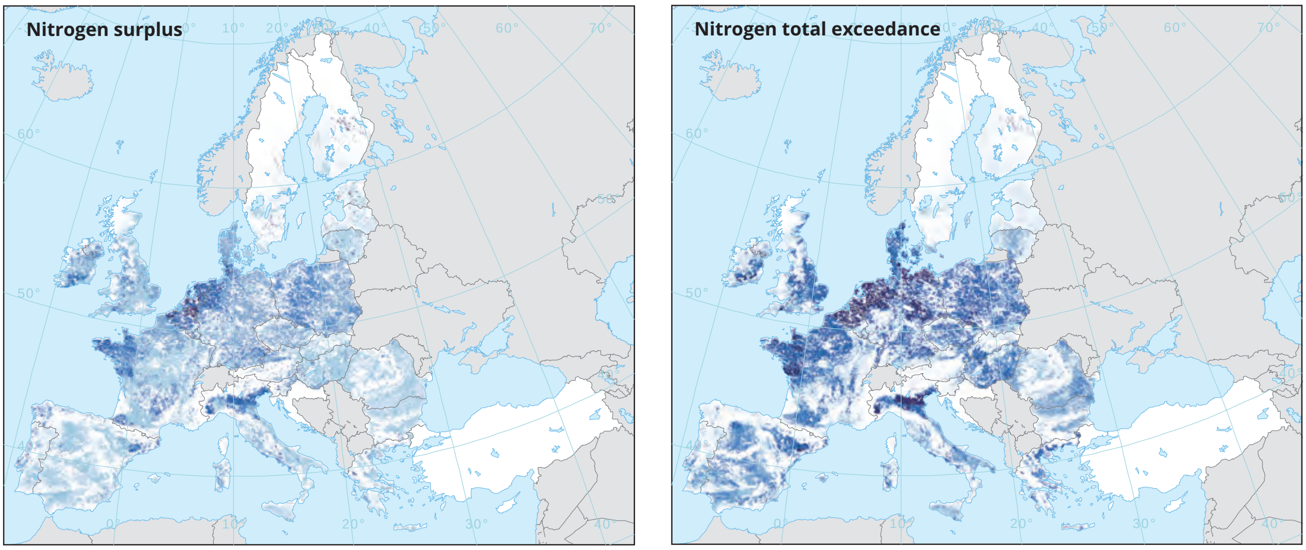
There is also increasing concern about the residence and accumulation of pesticide residues and their metabolites in soils (e.g. glyphosate and AMPA, or aminomethylphosphonic acid), and their potential release mechanisms, for example due to acidification and wind erosion (Silva et al., 2018). In the case of the Netherlands, in one third of the groundwater abstractions, pesticide concentrations can be found that exceed 75 % of the pesticide standards. Two thirds of the substances found are herbicides (Swartjes et al., 2016). In Finnish agricultural soils, 43 % of the samples contained pesticides, while quality standards were exceeded in 15 % of the groundwater bodies studied (Juvonen et al., 2017). In a pilot study with LUCAS soil samples, over 80 % of soils tested contained pesticide residues, with 58 % of samples containing mixtures of

MAP 5.4 **Copper concentration in EU soils, and accumulation rates of cadmium and copper**



Sources: Ballabio et al. (2018) (top); De Vries et al. (forthcoming) (lower left and lower right).

MAP 5.5 **Calculated nitrogen surplus (inputs vs outputs) (left) and exceedances of critical nitrogen inputs to agricultural land in view of adverse impacts on the environment (right)**



Nitrogen surplus and exceedances of critical nitrogen inputs to agricultural land in view of adverse impacts on water quality

kg/ha/year: < 25; 25 to 50; 50 to 75; 75 to 100; 100 to 200; > 200

0 500 1 000 1 500 km

No data; Outside coverage

kg/ha/year: < 0; 0 to 25; 25 to 50; 50 to 75; 75 to 150; > 150

Note: Statistical data refer to 2010 inputs; areas shown in white are non-agricultural soils.

Source: De Vries et al. (forthcoming).

Various soil contamination thresholds are already exceeded.

two or more residues in a total of 166 different pesticide combinations (Silva et al., 2019). These results indicate the accumulative effects of pollutants, and that mixtures of pesticide residues in soils are the rule rather than the exception.

In conclusion, contamination of soils is widespread, and various thresholds are already exceeded (e.g. cadmium), indicating that the filtering capacity of soils has been exceeded in some areas. However, the additive effects are still unknown for many substances in soils. In future attention needs to be paid to monitoring and investigating the effects of emerging contaminants such as microplastics, endocrine disruptors, antibiotics and flame retardants. Another source of concern is excessive nutrient inputs to soils through fertilisers, which leads to acidification and eutrophication (Chapter 1, Box 1.2 and Chapter 13). Europe is a global nitrogen hotspot with high nitrogen export through rivers to coastal waters, and 10 % of the global nitrous oxide (N_2O) emissions (Van Grinsven et al., 2013). Exceedance of critical loads for nitrogen is linked to reduced plant species richness in a broad range of European ecosystems (Dise, 2011) (see also Chapter 8, Box 8.2, for critical loads). For approximately 65-75 % of the EU-27 agricultural soils, nitrogen inputs

TABLE 5.3 Soil organic carbon by land use category in the period 2009-2015

Land use category	Number of samples	Mean SOC (g/kg)	
		2009	2015
Permanent grassland	2 230	42.0	43.8
Long-term cultivated land	5 018	17.9	17.3
Rice	5	22.8	19.2
Permanent crops	704	15.6	16.4
Natural vegetation	4 167	91.7	90.4
Wetlands	23	432.6	456.5

Source: Hiederer (2018).

through fertiliser, manure, biosolids and nitrogen-fixing crops exceed critical values beyond which eutrophication can be expected (e.g. critical ammonia, or NH_3, emissions to remain below critical loads, or 2.5 mg N/l in run-off to surface waters) (Map 5.5). On average across Europe, about a 40 % reduction in nitrogen inputs would be needed to prevent this exceedance (De Vries et al., forthcoming). Map 5.5 (left) presents the nitrogen surplus, being the difference between nitrogen inputs and uptake by plants, which is a measure of the potential pollution of air and water (De Vries et al., forthcoming).

Biological degradation and the decline in soil organic matter

Soils deliver key ecosystem services such as nutrient provision, water purification, filtering of pollutants and a habitat for soil organisms. Non-degraded soils provide these functions simultaneously and to a level needed for ecosystem performance (Chapter 3). Two closely connected indicators are the basis of soil multifunctionality, the soil organic carbon (SOC) pool and soil biodiversity. Carbon is one of the primary sources of energy in food webs; losses of carbon

The increased intensity of land use has negatively affected the species richness of earthworms, springtails and mites across Europe.

(through erosion, climate change, drainage of otherwise waterlogged soils) impact the supply of ecosystem services and reduce biodiversity (Stolte et al., 2016). Biologically mediated decomposition of organic material is the fundamental process for building the soil carbon stock, which, together with clay minerals, are important for nutrient retention and cycling.

Different forms of soil degradation (SOC loss, tillage, pollution, compaction and erosion) negatively impact the habitat available for soil organisms. In all regions across Europe, the species richness of earthworms, springtails and mites has been negatively affected by increased intensity of land use (Tsiafouli et al., 2015). Healthy soils contain active microbial (bacteria and fungi) and animal (micro to macro fauna) communities (Orgiazzi et al., 2016), of which bacteria and fungi are mainly responsible for nutrient cycling, which is essential for plant growth.

The dynamics of SOC vary according to land use and specific management practices. Forest soils currently act as a strong sink for carbon (30-50 % of the current sink by forest biomass) (Luyssaert et al., 2010). In a recent assessment covering 2009-2015, carbon in mineral cropland soils in the EU-28 was shown to be broadly stable or slightly declining (albeit at much lower levels compared with other land cover categories) (Table 5.3), while carbon in grasslands showed slight increases (Hiederer, 2018); similar results were also reported from national soil monitoring (e.g. Kobza, 2015; Kaczynski et al., 2017). It should be noted that the LUCAS sampling programme has only recently started, so the currently available 6-year interval is relatively short to demonstrate significant changes in SOC stocks.

The largest amounts of SOC are found in organic soils such as peat (Byrne and et al., 2004; spatial extend of peat and mires, see Tanneberger et al., 2017). Cultivation of organic soils causes large carbon dioxide (CO_2) emissions. Such carbon losses contribute significantly to the negative greenhouse gas balance

TABLE 5.4 Summary assessment — soil condition

Past trends and outlook		
Past trends (10-15 years)		Land cover change and management intensity significantly affect soil condition and levels of contamination. Progress in the remediation of polluted soils is slow. Despite recent reductions in soil sealing, fertile soils continue to be lost by continued land take. On intensively managed land, soil biodiversity is endangered. Soil loss as a result of sedimentation through erosion is still significant. The effects of soil compaction and historical and current losses of soil organic carbon are becoming increasingly visible under climate change.
Outlook to 2030		The underlying drivers of soil degradation are not projected to change favourably, so the functionality of soils is under even more pressure. Harmonised, representative soil monitoring across Europe is needed to develop early warnings of exceedances of critical thresholds and to guide sustainable soil management.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to protect its soil resources based on the existing strategies. There is a lack of binding policy targets; and some threats to soil — compaction, salinisation and soil sealing — are not addressed in existing European legislation. There is a high risk that the EU will fail some of its own and international commitments such as land degradation neutrality.
Robustness		A consistent set of indicators and representative databases for all soil threats across Europe has not yet been established. Measurements and monitoring of soil threats are incomplete. For selected indicators, data on changes in the condition of topsoils can be derived from the LUCAS soil programme (pesticide and soil biodiversity components are currently being added). The assessment of the outlook for and prospects of meeting policy objectives relies primarily on expert judgement.

for some countries (Schils et al., 2008), and they are expected to continue to do so in the future: 13-36 % of the current soil carbon stock in European peatlands might be lost by the end of this century (Gobin et al., 2011).

5.4 Responses and prospects of meeting agreed targets and objectives

Several recent assessments consider land and soil critical yet finite natural resources, subject to competing pressures from urbanisation and infrastructure development and from increased food, feed, fibre and fuel production (FAO and ITPS, 2015; IPBES, 2018). While many European and national policies address land and soil to some extent, binding targets, incentives and measures are largely missing at the European level. The European Court of Auditors recommends establishing methodologies and a legal framework to assess land degradation and desertification and to support the Member States to achieve land degradation neutrality by 2030 (ECA, 2018).

Europe is at risk of not meeting the 7th EAP objective of managing land sustainably and reaching no net land take by 2050.

Meeting the 7th EAP objective of no net land take by 2050 would require investments in land recycling, as well as halting land take. Land recycling is one way to ensure that a growing urban population consumes less land per capita. Land recycling can be achieved by constructing between buildings (densification), by constructing on brownfield sites (i.e. already used sites, known as grey recycling) or by converting developed land into green areas (green recycling) (EEA, 2018b). Setting up green infrastructure is an important means of re-establishing and maintaining unsealed areas, thus allowing patches and networks of urban ecosystems to function in more sustainable cities (see Chapters 3 and 17 for more information on the role of green infrastructure). However, currently there is no legal framework or incentive to recycle urban land, despite funding being available for land rehabilitation under the EU cohesion policy.

Measures to halt land take vary considerably throughout European countries. Reducing land take is an indicative policy objective in Austria, whereas the target to achieve 'zero net land take by 2050' is integrated into national policies in France and Switzerland. In Germany, the national sustainable development strategy for 2020 sets a goal to limit the use of new areas for settlement and transport, whereas in Hungary the 2013 national spatial plan defines suitability zones for agriculture, nature protection and forest. The United Kingdom and Flanders (Belgium) aim to have 60 % of urban development on brownfield sites (Science for Environment Policy et al., 2016; Decoville and Schneider, 2016). However, new housing is needed in many urban conglomerates, and the 2050 objective of the 7th EAP continues to be challenging to meet.

There is currently no European legislation that focuses exclusively on soil. The absence of suitable soil legislation at the European level contributes to the continuous degradation of many soils within Europe (Virto et al., 2014; Günal et al., 2015).

Vrebos et al. (2017) found 35 different EU policy instruments that — mostly indirectly — affect soil functions, as suggested in the soil thematic strategy. Many of them have the potential to address various soil degradative processes (Frelih-Larsen et al., 2017). However, their effectiveness is unclear (Louwagie et al., 2011). For example, some of the common agricultural policy measures such as creating good agricultural and environmental conditions (GAEC) refer to only a specific set of practices, implemented in some areas for a limited period of time.

The absence of suitable EU soil legislation contributes to soil degradation within Europe.

Glæsner et al. (2014) concludes that three threats to soil, namely compaction, salinisation and sealing, are not addressed in existing EU legislation and that targets to limit soil threats are hardly defined. A coherent coordination of the different existing policies could make soil protection at EU level effective. In addition, the multifunctionality of soil cannot be properly addressed through the existing heterogeneous policy environment. In order to progress, a revision of the existing soil thematic strategy (EC, 2006) is urgently needed, as well as agreements to improve Europe-wide harmonised soil monitoring and indicator assessments.

Societal discussion on soil protection needs to expand beyond economics and include the concept of land stewardship. This would complement the production-oriented and biophysical aspects of land management and aim to achieve more systemic solutions, such as land systems that encompass all processes and activities related to the human use of land (EEA, 2018c). A key element of better land stewardship will be a focus on ecosystem services. However, the services that landowners may supply as an obligation to the common good (land and soil) will need clear specifications (Bartkowski et al., 2018). The more systemic land systems approach may provide a holistic frame, but it needs to be complemented with relevant governance or legal measures. Technical solutions already known to practitioners still need criteria, thresholds and incentives to achieve the societal goal of more sustainable land use and to make its application on the ground part of everyday practice.

Diverse policies refer to soil pollution and the need for data on pollution sources (Water Framework Directive, Industrial Emissions Directive, National Emissions Ceiling Directive, Environmental Liability Directive, Mercury regulation, Sewage Sludge Directive); however, there is a lack of binding measures, e.g. to build and publish registers of polluted sites or to assess and apply harmonised definitions and critical thresholds for contaminants in soils.

With regard to land and soil, how can more sustainable use and proper preservation of the multifunctionality of land be achieved in the absence of direct policies? The 7th EAP has not been sufficient to create a common EU vision for sustainable land and soil use. Progress towards sustainable development in Europe (and globally) is possible only if land and soil resources are properly addressed.