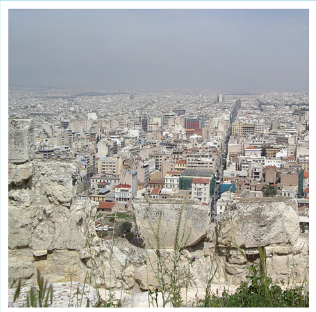
EEA Report | No 10/2017

Landscapes in transition

An account of 25 years of land cover change in Europe

ISSN 1977-8449



European Environment Agency

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Luxembourg: Publications Office of the European Union, 2017

ISBN 978-92-9213-882-0
ISSN 1977-8449
doi:10.2800/81075

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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Acknowledgements

Lead authors

Andrus Meiner (EEA) and Bas Pedroli (Wageningen University & Research)

Contributing authors

Annemarie Bastrup-Birk, Eva Ivits, Silvia Giulietti, Tobias Langanke, Doris Marquardt (all EEA), Marie Cugny-Seguin and Geertrui Louwagie (both formerly EEA).

Support to framing and analysis

Ronan Uhel (EEA)

Support from European Topic Centre Urban, land and soils systems (ETC/ULS)

Jaume Fons-Esteve and Roger Milego Agrás (Autonomous University of Barcelona), Stefan Kleeschulte and Mirko Gorban (space4environment), Gebhard Banko and Andreas Littkopf (Environment Agency Austria), Ece Aksoy, Dania Abdul Malak (University of Malaga), Miroslav Kopecky, Tomas Soukup (GISAT), Gerard Hazeu (Wageningen University & Research), Barbara Kosztra, Gergely Maucha and Robert Pataki (FÖMI/Government Office of the Capital City of Budapest), Cristina Garzillo (ICLEI)

Support from European Commission DG ESTAT GISCO team

Michael Harrop and Hannes Reuter

EEA production support

Brendan Killeen, Pia Schmidt, Irune Axpe Martinez and Carsten Iversen.

Report greatly benefitted from the feedback by

- EEA Scientific Committee
- European Commission (DG ENV and DG REGIO)
- The European Environmental Information Observation Network (Eionet), comments by National focal points received from Albania, Germany, Hungary, Malta, Poland, Slovenia, United Kingdom
- EEA colleagues including Anita Pirc-Velkavrh, Markus Erhard, Jan-Erik Petersen, Gorm Dige.

Glossary and abbreviations

7th EAP	Seventh Environment Action Programme
CAP	EU common agricultural policy 2014-2020
Copernicus	European system for monitoring the Earth, previously known as GMES (Global Monitoring for Environment and Security)
CLC	Corine Land Cover
Corine	CoORdination of INformation on the Environment Land Cover inventories
EC	European Commission
Ecological focus area	Farmers with arable areas exceeding 15 ha must ensure that at least 5 % of such areas is an 'ecological focus area', dedicated to ecologically beneficial elements
EEA	European Environment Agency
ETC/ULS	European Topic Centre on Urban, Land and Soil systems
GIS	Geographic information system
GMT	Global megatrend
HNV	High nature value (farmland)
HR	High resolution
HRL	High-resolution layer (of satellite imagery)
JRC	European Commission Joint Research Centre (Ispra, Italy)
Land take	Land (generally agricultural or forest land) taken by artificial (man-made) land cover types
LC	Land cover
LCF	Land cover flow (change of land cover from one type to another)
LRTAP	Convention on Long-range Transboundary Air Pollution
LU	Land use
LUCAS	Land Use/Cover Area frame Survey (Eurostat)
MMU	Minimum mapping unit
NUTS	EU Nomenclature of territorial units for statistics
RZ	Riparian zone
SDG	Sustainable development goals
SOC	Soil organic carbon
Total turnover	Formation plus consumption in terms of land cover
UA	Urban Atlas
UNCCD	United Nations Convention to Combat Desertification
UPU	Urban permeation units
Urbanisation	Increase in population in urban areas
Urban expansion	Land taken by built-up area (often as urban sprawl)
VHR	Very high resolution
WUP	Weighted urban proliferation (measure of urban sprawl)

Executive summary

Land is the foundation of our society and a source of economic growth. On land we build our homes, transport goods, grow our food and produce our energy. We expect land to filter our water and host the biodiversity that provides essential aspects of our livelihood.

Landscape is one of the most precious assets contributing to Europe's cultural identity. As landscape is determined to a large extent by land use, the study of land use changes, especially through changes in the land cover, provides clues to the drivers of the transitions that landscape is currently going through.

New data on land cover change in Europe up to 2012 show that total land cover change increased from the 2000-2006 period to the 2006-2012 period. There are indications that land use is changing even faster, e.g. through changes in agricultural practices, with a time lag of several years before the change is reflected and discernible in the land cover and landscape. Almost all trends in land cover change in Europe have been consistent throughout the 1990-2012 period and show persistent conversion of agricultural land into man-made surfaces, such as urban areas and infrastructure facilities. Land cover changes related to forest management remain largest in terms of total turnover.

The main trends observed and their environmental impacts are:

- Urban and infrastructure expansion continues to consume land with productive soil and to fragment existing landscape structure. Of all land cover categories, artificial areas increased the most in terms of both net area and percentage change. This is a constant trend that has been observed since 1990, although the increase in the 2006-2012 period was less than in the 2000-2006 period.

- Europe's agricultural land, often of good quality and in favourable locations, continues to decrease at an average rate of 1 000 km^2 per year (latest 2006-2012 for EEA-39). The fine grained structure and associated biodiversity of traditional rural landscapes in Europe continues to be affected by land take, agricultural intensification and farmland abandonment.

- The forest area remains stable, but forest land cover flows indicate an intensification of forest land use. This may lead to declining quality of forest ecosystems and needs to be balanced by conservation measures.

To observe such trends and to understand the impacts of the driving forces behind these changes, it is crucial to monitor land cover and land use change through land monitoring and surveying tools that combine Earth observation, statistical sampling of ground truth and thematic land inventories. Established data sources, such as Corine (Coordination of Information on the Environment) Land Cover, LUCAS (Land Use and Land Cover Survey) and the Farm Structure Survey can provide much evidence, while new high-resolution Copernicus land-monitoring products increase the precision and relevance of these data.

Land use shapes our environment in positive and negative ways. Most scenarios for global economic and societal development show a strong territorial polarisation of land functions in Europe in the near future. Although multifunctional land use is widely seen as a promising solution for the liveability of the European landscape and for balancing the provision of ecosystem services, there are not many pro-active policy alternatives to set the boundaries for such use and at the same time address environmental management that invariably requires system- and place-based adaptation (Buckwell et al., 2017).

Land management largely determines the diversity and specific character of Europe's landscapes. Fertile land is a critical resource for food and biomass production, and land use strongly influences soil erosion rates and soil functions such as carbon storage. The 2006 EU Soil Thematic Strategy set the basis for action for the protection and management of soil resources. The vision of land and soil as part of our natural capital that is subject to resource efficiency objectives was confirmed in 2013 by the EU Seventh Environment Action Programme to 2020 (7th EAP) entitled 'Living well, within the limits of our planet'. A recent study by the European

Commission (EC, 2017a) mapped the policy instruments for soil protection at EU and national level. It is evident that, despite the absence of a consolidated EU environmental policy approach, as in the case for water, biodiversity or air, soil protection is addressed indirectly or within sectoral policies for agriculture and forestry, energy, water, climate change, nature protection, waste and chemicals. However, the consequence of such a fragmented policy approach is the scarcity of harmonised soil data at EU level.

Policy responses are needed to help resolve conflicting land use demands and to guide land use intensity to support sustainable land management, thus contributing to achieving the EU's objectives under the 2030 Sustainable Development Goals (SDGs). In particular, Goal 15, to 'protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss' is closely related to sustainable land management and much depends on ongoing reform of CAP.

The balanced development of cities and rural land is a precondition for providing quality of life and meeting the different needs of Europe's citizens across a multitude of multifunctional territories with different social and environmental qualities. Another of the SDGs, to make cities and human settlements inclusive, safe, resilient and sustainable, confirms this. Europe's landscape deserves a well-developed consolidated vision for future land use.

Land is a fundamental issue in European policy development, as expressed in many concepts related to land:

Land systems — representation of the terrestrial component of the Earth system, encompassing all processes and activities related to human use of land (Verburg et al., 2013).

Land cover — the ensemble of physical characteristics of the land discernible by Earth observation.

Land use — the activities, arrangements and inputs undertaken in making use of the land.

Land management — the way the land is being used, including management intensity.

Land degradation — deterioration in the quality of land, its topsoil, vegetation and/or water resources, usually caused by excessive or inappropriate exploitation. According to the United Nations Convention to Combat Desertification (UNCCD), 'land degradation refers to any reduction or loss in the biological or economic productive capacity of the land resource base. It is generally caused by human activities, exacerbated by natural processes, and often magnified by and closely intertwined with climate change and biodiversity loss.' (UNCCD, 2015).

Land take (also referred to as *land consumption*) — a measure of how much land covered by agriculture, forests and semi-natural land, wetlands and water is converted to land cover for urban, commercial, industrial, infrastructure, mining or construction purposes. Note that *urban sprawl* is permeation of a landscape by urban development or solitary buildings.

Land recycling — redevelopment of previously developed land (brownfield) for economic or environmental purposes.

1 Land as part of natural capital

Today the European landscape is in transition even more strikingly than it has been throughout history. It still exhibits the traits of the historical evolving land use systems and ownership patterns (Photo 1.1), but current land use is rarely in equilibrium with the inherited landscape. In other words, current land use would never have led to the landscape in which it is practised today. There is thus a compelling need for reflection and debate about current landscape transitions, about the value of European land as a resource, and about the ways in which we can create the proper boundary conditions and governance approaches to ensure a sustainable future for this impressive asset of European culture and identity.

Land systems provide not only food, feed and fibre, but also building materials, bioenergy and, increasingly, a broad range of other products. Moreover, ecosystem services such as cultural and social landscape values are closely connected to the functioning of land systems, whereas regulating services such as flood regulation and carbon sequestration, ecosystem functioning, pollination and biocontrol of pests play an equally crucial role (Foley, et al., 2005).

Land is therefore an essential component of society's natural capital. Land has never been static, but the changes have generally been gradual and slow. Today the pace of change is accelerating. This is perhaps most visible in the rural areas of Europe, but it is the urban life style — associated with high mobility and consumption patterns detached from the immediate environment — that has an increasingly dominant influence on land use both in the urban and in the rural areas. To be able to develop efficient and effective policies for land management, it is fundamental to know what changes occur in land cover and land use and identify the drivers of these changes and where these changes predominantly occur. This report describes the results of important land cover and land use change monitoring for all EEA member and cooperating countries.

Photo 1.1 Traits of the age-old history of evolving land use systems: a landscape near Ascoli Piceno, Marche region, Italy

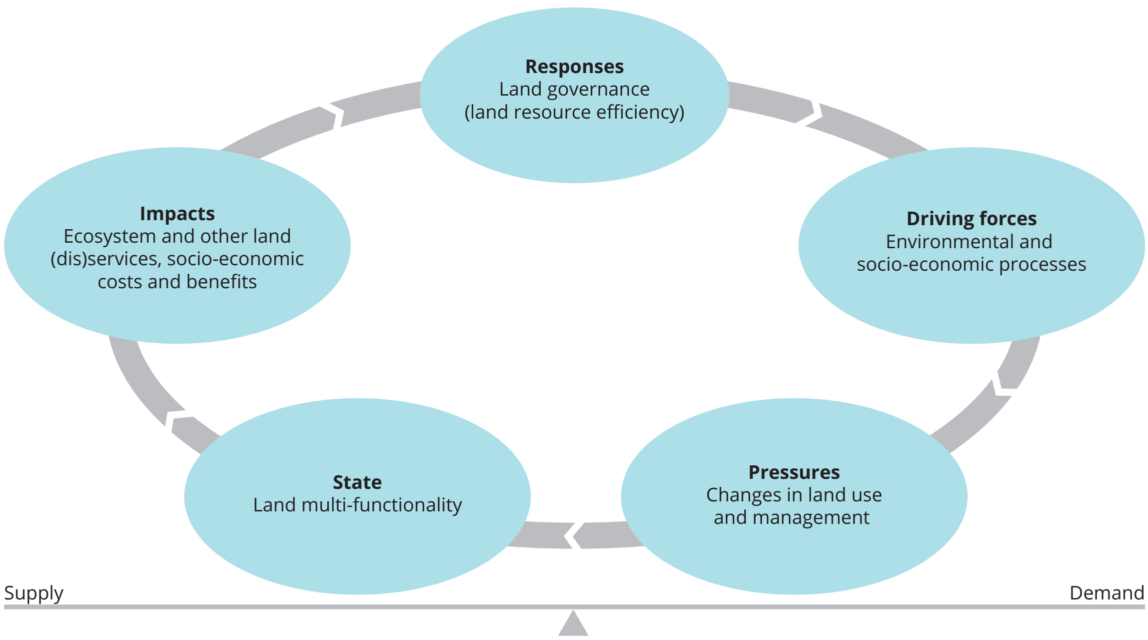
1.1 Drivers of land use change

Across Europe and the world, accelerating rates of urbanisation, changing demographic and diet patterns, technological changes, deepening market integration, and climate change place unprecedented demands on land (EEA 2015d). Yet, the availability of land is finite. This imbalance is unsustainable. Land must therefore be 'governed' in a way that preserves its potential to deliver goods and services. These services are lost or weakened (due to disrupted water and nutrient cycles) when land is sealed for the development of housing, industry, commerce or transport infrastructure. Some forms of land use and management, e.g. those driven by agricultural intensification and farmland abandonment, result in degradation processes, such as soil erosion, soil organic matter decline, habitat loss or reduced nutrient cycling (Photo 1.2). Landscape fragmentation exacerbates these effects.

The land system then embodies the relationship between human activities on land, socio-economic conditions, the natural environment and the systems of governance that manage these interactions. Linking its components through cause and effect, the land system thus refers to the chain of driving forces, pressures, state, impacts and responses to which the land is subject (Figure 1.1).

Photo 1.2 Soil degradation as a result of high-intensity land use (Burren, Ireland)

Figure 1.1 The land system



Source: EEA, 2015d.

Land take for urban development, infrastructure (Photo 1.3a**) and industrial purposes (**Photo 1.3b**)** exceeds 1 000 km^2 per year in the EEA-39 (the 33 EEA member countries and six cooperating countries), which is an area three times the size of Malta. Several underlying causes of land take can be identified (EEA, 2016b), driven by societal needs and shaped by regional, sectoral and environmental policies. Almost half of the land take was at the expense of arable farmland and permanent crops (EEA, 2017a). Land take thus also puts pressure on the biomass production potential of the land resource.

Land cover change in Europe is less dominated by **agricultural demand** than it is in other parts of the world. The area of agricultural land currently shows a slightly decreasing trend. The land area for **forestry** has largely stayed the same, gaining from a limited increase in forest area, mostly due to farmland abandonment and afforestation. Trends and figures obviously differ between countries. Both sectors also include land use changes for indirect energy production: in some countries (e.g. Germany) entire landscapes have changed because of the increasing dominance of oilseed rape (*Brassica napus*) and maize (*Zea mays*) instead of wheat, rye or potatoes, or, in the case of forests, plantations.

Photo 1.3 (a) Land take by infrastructure (A4 motorway in the polder Haarlemmermeer, near Amsterdam Schiphol Airport, Netherlands)

Photo 1.3 (b) : Industrial land take in Huelva, Spain

Other economic sectors require smaller land areas, but they can be locally dominating. Energy generation by wind turbines and solar energy parks generally does not require much land; however, there can be other issues such as public resistance to windmills due to their impact on landscape values or disturbance caused by noise. Flood protection requires some space as well, e.g. by reserving certain areas for flood retention. Open pit mining (sand and gravel, lignite, shale, limestone, etc.) — although often very conspicuous in the landscape — does have relatively limited spatial impacts and normally is subject to re-cultivation (landscape restoration).

In some cases land reclamation for coastal protection or harbour development can be substantial; the latter is generally considered under land take for urban, infrastructure and industrial purposes.

In addition, recreation, tourism and nature protection do make demands on land, but these relate predominantly to landscape functions and ecosystem services rather than to a spatial extension of the land needed (Photo 1.4). Nevertheless, tourism-related land demand may be substantial, especially in specific areas such as coasts, lake shores and mountains for holiday resorts, ski areas, water sports facilities, etc. As part of this land use is generally recorded as urban land use, it is difficult to provide precise assessments.

While steering their primary target domains, several EU policies will directly or indirectly impact land use too. The four key policy areas most relevant here are (1) the cohesion policy, (2) transport policy, (3) energy policy and (4) the common agricultural policy (CAP) ([1]). These policy sectors can have major impacts on land resources and are essential for transitions to sustainability.

For all four policy areas, there is a strong interaction between EU and Member State actions, and these

([1]) See http://ec.europa.eu/regional_policy/en/faq/; https://europa.eu/european-union/topics/transport_en and https://ec.europa.eu/energy/en/topics/energy-strategy; http://ec.europa.eu/agriculture/cap-post-2013 respectively.

Photo 1.4 Extensively managed grassland in the Green Heart of Holland, with the metropolitan conurbation of Rotterdam on the horizon

policies provide an opportunity to integrate and disseminate EU land objectives much more effectively than by separate Member State action. However, it must be emphasised that the drivers of land use change are difficult to identify in terms of their exact cause–effect relationships (Plieninger et al., 2016; van der Sluis et al., 2015), because global economic developments interact closely with local political and societal trends.

More analysis of the effects of EU policies on land use is needed (Plieninger et al., 2016, p. 213). However, it is clear that, for example, land abandonment, land extensification, urban expansion and infrastructure development are drivers of land use change and are affected by their respective EU policies, although the latter do not focus primarily on influencing land management as such.

Regarding EU environmental policy, two topics — nature and biodiversity protection, and water management — are closely linked to EU objectives on land and soil (EEA, 2016b) (Photo 1.5). The Natura 2000 network protects about 18.4 % of EU territory. The EU Biodiversity Strategy to 2020 calls, among other actions, for the maintenance and restoration of Europe's ecosystems.

The European Commission Green Infrastructure Strategy (EC, 2013b) aims to ensure that the protection, restoration, creation and enhancement of green infrastructure becomes an integral part of spatial planning and territorial development. As such, the green infrastructure represents a strategically planned network of natural and semi-natural areas delivering a wide range of ecosystem services, such as water purification, air quality, space for recreation, and climate mitigation and adaptation.

The Water Framework Directive and the Floods Directive both require planning mechanisms at river basin scale. The management plans support measures that maintain soil quality and combat land degradation, including measures to put a green infrastructure in place. Both nature protection and water management require good integration of land and soil in their management plans and designation instruments because protection of habitats, species and water quality depends on land and soil.

Sustainable land and soil management also benefits from consistent implementation of environmental impacts assessments (EU, 2014) and strategic

Photo 1.5 Abandoned rice fields in the Coto Doñana, now a Natura 2000 area, Andalusia, Spain

environmental assessments (EU, 2001) that have a good potential for preventing the developments that can lead to land degradation. In 2016 European Commission proposed a Regulation establishing a clear link between EU Climate and energy policy framework and land use, land use change and forestry (EC, 2016c).

Various scenario studies have been done making different assumptions about the main land use drivers (see, for example, Ceccarelli et al., 2014; Hennig et al., 2015; Pedroli et al., 2015b; van Delden and Vanhout, 2014). Depending on the assumed economic development and the pathway to be followed, net land take could indeed be halted within the next 40 years, while in many areas of Europe, agricultural land use might continue to decrease, and forest and land for nature to increase. In particular, however, halting net land take is a major land policy challenge all over Europe because it will require progressive reduction of the land take, particularly for economic purposes (Science for Environment Policy, 2016).

Limiting land take is an important land policy target at various levels in Europe (Decoville and Schneider, 2015). In order to avoid increases in land take, incentives for 'land recycling' are worth pursuing. Land recycling refers to the regeneration of land that was previously developed but is currently not in active use or available for re-development (EEA, 2016g) (Photo 1.6).

1.2 Land use and the environment

According to the United Nations Convention to Combat Desertification (UNCCD), land is a complex resource composed primarily of soil, water and biodiversity. The product of their interactions, ecosystem goods and services, is the foundation for sustainable livelihoods, social cohesion and economic growth. Therefore, economic activities that have a long-term negative impact on land resources are not in the interests of the human race.

Photo 1.6 Example of land recycling: redevelopment of an office block site in Tallinn, Estonia

Agriculture and **forestry** in Europe are facing global environmental and economic challenges in common with many other regions of the world. The extent of these challenges and the impact they will have on currently existing land systems are likely to lead to a change in overall conditions (Costanza et al., 2014). These changes will have spatially differentiated impacts, but will certainly affect many regions of Europe (Metzger and Schröter, 2006; Plieninger et al., 2016).

Agriculture is a major driver of land use and land cover change, which is itself a component of land surface processes influencing climate regulation. Therefore, changes in agriculture also have an impact on climate change (Bessou et al., 2016). Significant land cover change modifies the surface albedo and, thus, surface-atmosphere energy exchanges, which have an impact on the regional climate. Terrestrial ecosystems act as sources and sinks of carbon and, thus, land use change leads to global climate changes through the carbon cycle. Subsequently, local evapotranspiration plays an important role in the water cycle, and it also depends on land cover and has an impact on the climate at the local to regional scale (Lambin and Geist, 2006).

A key element and a crucial limiting factor that determines the sustainability of farm systems is the soil (Vanslembrouck and Van Huyenbroeck, 2005). However, soil is subject to ongoing, often conflicting, demands from society. Despite technological progress, agriculture on farmland with good soils will continue to be favoured over farmland with shallow soils, a low level of nutrients and steep slopes. The same good soils are best in terms of their ability to deliver ecosystem services — for food production, as a biodiversity pool and as a regulator of gases, water and nutrients. Observed rates of soil sealing, erosion by water and wind, decline in organic matter and contamination all reduce the resilience or capability of the soil to absorb the changes it is exposed to.

Although, in general, forests in Europe are managed as semi-natural systems (plantations cover around 9 % of the forest area in the EEA region (EEA, 2016c)), afforestation, and plantations and intensification of forestry practices can have large impacts on biodiversity both above ground and in the soil (Barbati et al., 2011), and on carbon sequestration (Marchetti et al., 2012) (Photo 1.7).

Photo 1.7 Forest in Lapland, northern Finland

The long history of land use in Europe has resulted in a specific interaction between human uses and **biodiversity** (Photo 1.8). This co-evolution through time has created cultural landscapes that are valued for their ability to generate income as well as for their aesthetic, biodiversity and cultural values (Pedroli et al., 2007). Longstanding agriculture and forestry land use systems are generally the sources of the most valued landscapes and habitats (Hodge et al., 2015).

As farming and forestry systems became progressively more specialised and intensive, habitats and biodiversity came under increasing pressure. The threats to nature that result from such changes in land use systems have been acknowledged for decades now (Stanners and Bordeaux, 1995). However, land abandonment is also leading to the disappearance of former landscape patterns, or a change in their components, so that their associated nature value is declining (Renwick et al., 2013).

These changes have recently been well documented in terms of the variation in dominant land use systems across Europe in the past 200 years (Jepsen et al., 2015), and also in terms of land cover change in the past 100 years (Fuchs et al., 2015). The latter stress that the main land use change processes were cropland/grassland dynamics and afforestation, and also deforestation and an increase in artificial areas. When counting all land changes that occurred during the period 1900–2010 (gross changes, Fuchs et al., 2015, p. 311), on average 0.5 % of the land cover in the EU-27 + Switzerland has changed each year, which is much more than generally assumed, and about twice the area of the net area difference between two time steps (Fuchs et al. 2013, p. 1549).

Land use processes that act as the main drivers of changes in biodiversity are habitat loss, habitat deterioration and eutrophication, which are the result of land conversion, soil contamination or nutrient enrichment, and overharvesting of resources. All these factors can be exacerbated by other biodiversity drivers such as climate change impacts and invasive alien species. In view of the second target of the EU Biodiversity Strategy (EC, 2011b) to restore at least 15 % of degraded ecosystems by 2020, close monitoring of the land-related drivers is crucial.

Examples of habitat loss can be found in almost all situations of land cover change, but they are associated in particular with urban sprawl and infrastructure developments or with land reclamation or consolidation for improved agricultural use. However, land abandonment, especially of extensively managed grazing land, can also lead to the loss of niche habitats for species characteristic of agricultural landscapes.

Spontaneous forest encroachment onto abandoned land is occurring in many areas across Europe, especially in the Mediterranean (Tomaz et al., 2013), but also in Boreal semi-natural meadow systems, the existence of which depends on a well-defined sustainable grazing and mowing pressure (Berninger et al., 2015). This often has negative effects on farming-related biodiversity in the short term (Moreira

Photo 1.8 Co-evolution of agriculture and nature (Eschede, Lower Saxony, Germany)

and Russo, 2007), while the overall benefits for biodiversity will be realised only after several decades.

Examples of habitat deterioration are often related to land degradation, in particular via soil sealing, which tends to result in a reduction in the infiltration capacity and soil biodiversity. Other land degradation processes include soil erosion, the loss of organic matter, the decline of the surface and groundwater regime and eutrophication (nutrient enrichment). The latter is the result of a high land use intensity and a surplus of nutrients, affecting the nutrient status of soil and groundwater and surface water quality, often over large distances. Land take and soil sealing and degradation thus seriously affect the delivery of ecosystem services, such as water regulation, food production and carbon retention. Land can also suffer from airborne deposition of nutrients, as measured by critical load assessments, particularly nitrogen (EEA, 2015a).

Despite expected adaptations in local and regional policy, the current market mechanisms are generally pushing towards further territorial polarisation of the European landscape: at one end is a capital-intensive, production-oriented specialised agricultural land use, and at the other end is a more multifunctional land use. The biodiversity values associated with traditional farming practices will inevitably decline further, because the socio-economic factors enabling these practices are disappearing under the current globalised market conditions.

The concept of high nature value (HNV) farming systems was put forward at the beginning of the 1990s (see Beaufoy et al., 1994; Paracchini et al. 2008). It focuses on the extensive and small-scale land use systems of Europe's silvopastoral systems (Photo 1.9) and extensive grazing. The HNV farming concept exemplifies how nature values are dependent on certain farming practices, which adds a new societal value to these production systems, beyond the production of food and fibre (Almeida et al., 2013; Oppermann et al., 2012).

The future land use effects on biodiversity will depend very much on the basic environmental conditions to be maintained in the agricultural and forestry production areas that undergo intensification. These effects will also depend on additional measures to improve biodiversity values, e.g. by targeting conservation funding in both the multifunctional peri-urban lands and nature reserves, such as the Natura 2000 areas (Gamero et al., 2017; Waldron et al., 2013). In some suitable marginal areas, the approach to improving biodiversity could be rewilding and natural habitat regeneration, although the diverse effects of such measures need to be carefully considered.

Photo 1.9 Silvopastoral land use in the Alentejo, Portugal

2 Land cover change in Europe

2.1 Land cover in history

Historical land use change is important for assessment of soil carbon, biodiversity or urban quality of life, and for studies of climate change cumulative impacts on land-based features and resources. Most reconstructions have focused on the net area difference between two snapshots in time (net changes) instead of accounting for all area gains and losses (gross changes). This leads to a serious underestimation of land use dynamics, which has impacts on the biogeochemical and environmental assessments based on these reconstructions.

Fuchs et al. (2015) empirically analysed available historical land use change data and identified underlying processes causing differences between gross and net changes. Gross changes varied for different land use classes (largest for forest and grassland) and led to two to four times the net changes. In their reconstruction, gross changes led in total to a 56 % area change (approximately 0.5 % per year) between 1900 and 2010 and covered twice the area of net changes. In other words, on average, every second hectare of Europe's land has changed its land cover at least once since 1900. More detailed analysis of land changes in 1950-2010 were provided by Fuchs et al., 2013 (Box 2.1).

It is clear that the huge changes in society in the past 200 years are directly reflected in changing land use almost all over Europe. A highly diverse set of large-scale drivers have influenced the development of the countryside in Europe and thus shaped over time the heterogeneous landscape we know today. It shows that the dynamics of the landscape is an integral part of the landscape itself.

2.2 Corine Land Cover 2012

The most recent information on land use/land cover in 39 countries of Europe (EEA-39) is from 2012 ([2]) (see Soukop et al., 2016a) for the distribution over countries). A total of 34 % of Europe's land is covered by forests ([3]), 25 % by arable land and permanent crops

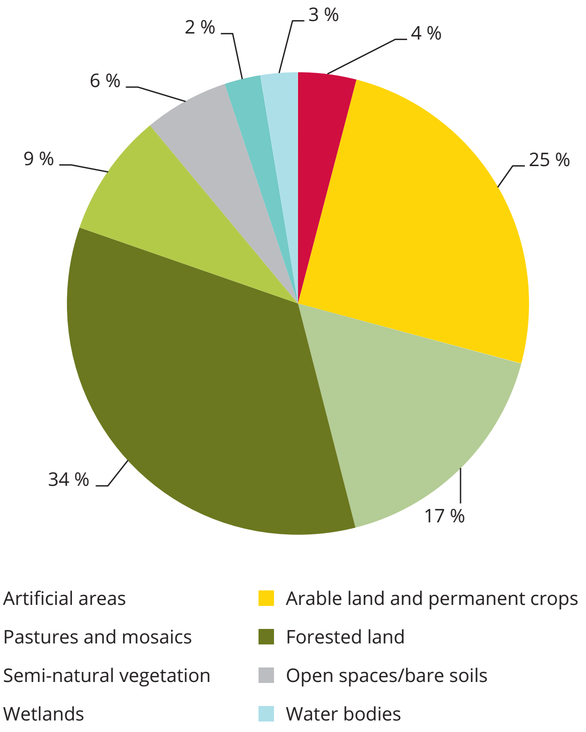
Box 2.1 Historical land changes 1950-2010

Fuchs et al. (2013) investigated the area of land affected at least once by land use changes during the 1950-2010 period (the net change between the two time steps, which is about half of the area of all land changes that have occurred in the period, the gross changes, see Fuchs et al. 2015, p. 311), which is almost 14 % of the total area of all EU-27 states plus Switzerland. On average, every year 0.26 % of the entire area is converted, an area the size of Montenegro. In southern Europe, the relative amount of land change was almost 3.5 % higher than average, while western Europe was roughly 2 % below average. An increase in settlement area of about 35 818 km^2 (+ 24.5 % of new urban area) throughout Europe since 1950 can also be noted in their results. Some of the hot spots of change are:

- Forests in Sweden increased their coverage by almost 20 % over the 60 years from 1950 to 2010.
- Coastal areas of Italy, southern Portugal and Spain experienced a considerable drop in cropland due to simultaneous conversion into mainly grassland and, to a small extent, forests.
- In Romania, while forests stayed almost constant, the main change was the drop in cropland in the Transylvanian and Moldavian regions, resulting in increasing grassland areas.
- In France, forest increased by 50 000 km^2, from 109 540 km^2 (1950) to 159 540 km^2 (2010), mainly in Provence and around Paris, which implies an increase of 45.6 % within the last 60 years.

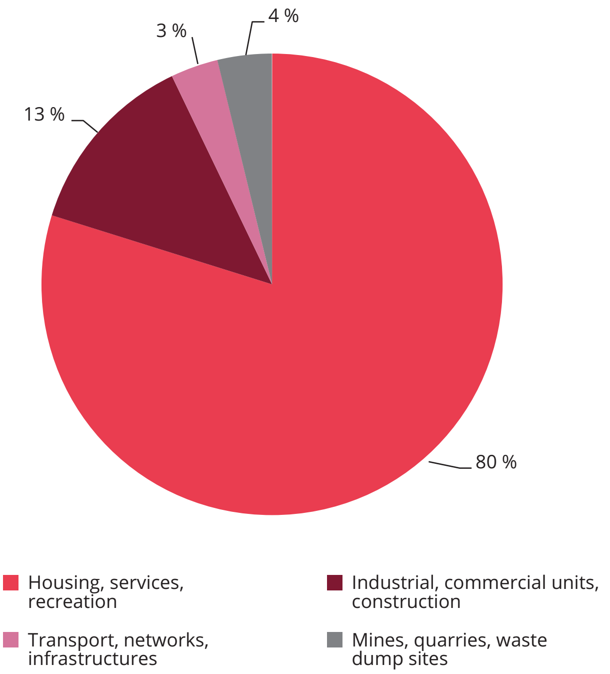
([2]) http://land.copernicus.eu/pan-european/corine-land-cover; the minimum mapping unit is 25 ha for the status layer and 5 ha for the change layer; see also Section 3.2 and Annex II.
([3]) Other definitions of forest lead to a substantially higher proportion of around 40 % (see also Section 5.4).

Figure 2.1 Proportions of land cover types in Europe (results for 39 countries in the Corine Land Cover 2012 data set)



Source: ETC/ULS, 2016.

Figure 2.2 Proportions of artificial surfaces in Europe (results from 39 countries in the Corine Land Cover 2012 data set)



Source: ETC/ULS, 2016.

Table 2.1 Proportions of land cover types in Europe (results for 39 countries in the Corine Land Cover 2012 data set)

Land cover type	Proportion (%)	Total (km²)
Artificial areas	4	238 610
Arable land and permanent crops	25	1 471 684
Pastures and mosaics	17	985 102
Forested land	34	2 011 979
Semi-natural vegetation	9	506 385
Open spaces/bare soils	6	346 610
Wetlands	3	147 835
Water bodies	3	152 629

Table 2.2 Proportions of artificial surfaces in Europe (results from 39 countries in Corine Land Cover 2012 data set)

Artificial land cover type	Proportion (%)	Total (km²)
Housing, services, recreation	80	187 310
Industrial, commercial units, construction	13	33 158
Transport, networks, infrastructures	3	8 459
Mines, quarries, landfills	4	9 683

Note: 39 countries included in Corrine Land Cover 2012 data set are: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kosovo (under UNSCR 1244/99), Latvia, Liechtenstein, Lithuania, Luxembourg, the former Yugoslav Republic of Macedonia, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom.

Source: ETC/ULS, 2016.

and 17 % by permanent pastures and mixed mosaics (Figure 2.1 and Table 2.1). About 4 % is covered by artificial surfaces (Figure 2.2 and Table 2.2), mostly in cities, including green urban areas. These proportions of the main land categories have remained relatively stable since the beginning of European inventories in the 1990s.

Although they cover a relatively small proportion of the land, artificial areas represent hot spots of intensive use: most of the European population lives in urban areas and most of the economic activity is also concentrated there. Transport networks account for a small proportion of the artificial areas. However, their impact should be considered not only in terms of area, but also in terms of their spatial pattern, facilitating the connection and movement of goods and services between (distant) places.

The following regional patterns can be noted:

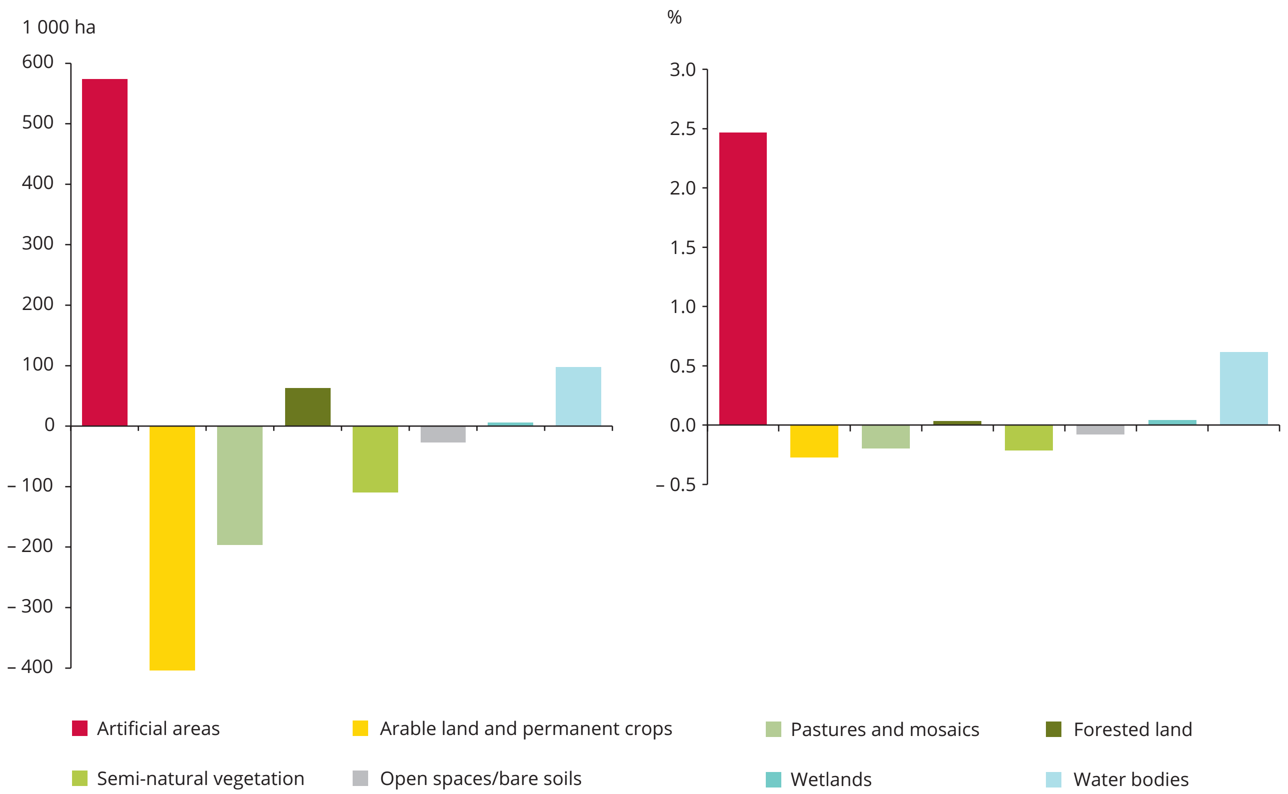
- The largest extension of forests is in the boreal forests in northern Europe.
- The main artificial areas are capital cities, in particular large metropolitan areas such as London, Paris, Milan, the Randstadt conurbation in the Netherlands and the Rhine–Ruhr metropolitan area.
- Large tracts of agricultural land can be observed, especially in eastern European countries (Hungary, Poland, Romania), but also in France and Ireland.
- Open spaces occur in relation to land use patterns in mountain massifs in south-eastern Europe and the Iberian peninsula.

2.3 Land cover changes 2006-2012

The total analysed land stocks over 39 countries covered 5.86 million km^2, and in 1.6 % of this area the land cover type changed during the 2006-2012 period, while 3.2 % of turnover (formation plus consumption) could be observed (Table 2.3). The total land cover change increased by 1.3 % compared with the previous period (2000-2006). These changes are not evenly distributed among countries: the largest changes can be seen in the Czech Republic, Estonia, France, Greece, Latvia, Poland, Portugal, Slovakia, and Sweden (see Feranec et al., 2016, especially Chapter 16; Soukop et al., 2016).

During the 2006-2012 period, artificial areas increased most among the land cover categories, in terms of both net area and percentage change (Figure 2.3), but less than in the 2000-2006 period. In 2006-2012, the development of man-made (artificial) surfaces amounted on average to 1 065 km^2 per year, which

Figure 2.3 Land cover changes, 2006-2012



Source: ETC/ULS, 2016.

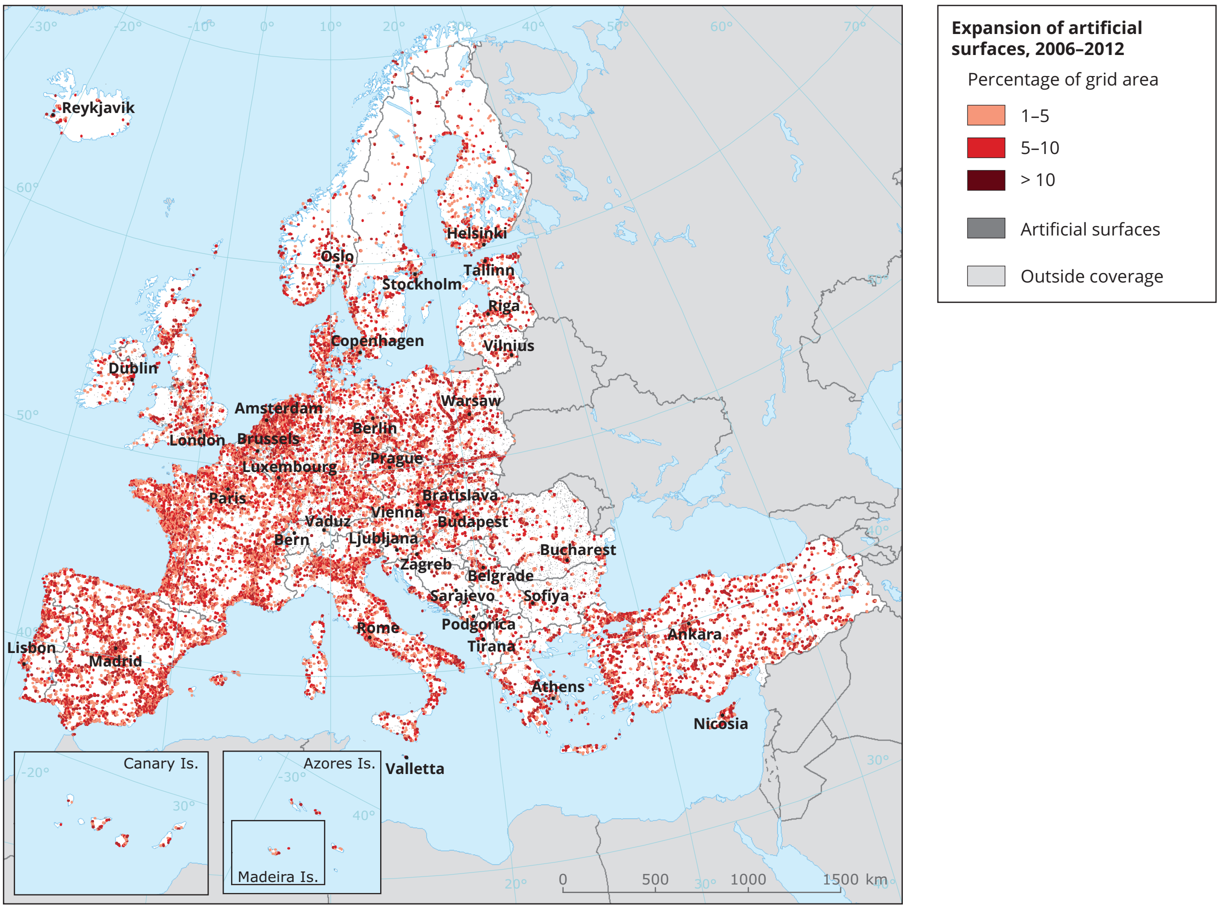
Table 2.3 **Land cover accounts 2006-2012 (km^2) for the 39 European countries in the Corine Land Cover 2012 data set**

	Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/ bare soils	Wetlands	Water bodies	Total (km^2)
Land cover 2006	232 872	1 475 722	987 066	2 011 348	507 477	346 878	147 774	151 704	5 860 842
Consumption of initial land cover	2 544	9 942	5 672	69 776	2 184	2 182	213	346	92 858
Formation of new land cover	8 281	5 904	3 708	70 406	1 091	1 914	274	1 279	92 858
Net formation of land cover	5 738 ([a])	– 4 038	– 1 964	631	– 1 092	– 268	61	933	0
Net formation as % of initial year	2.5	– 0.3	– 0.2	0.03	– 0.2	– 0.1	0.04	0.6	
Total turnover of land cover	10 825	15 845	9 381	140 182	3 275	4 097	486	1 625	185 654
Total turnover as % of initial year	4.6	1.1	1.0	7.0	0.6	1.2	0.3	1.1	3.2
Land cover 2012	238 610	1 471 684	985 102	2 011 979	506 385	346 610	147 835	152 637	5 860 842

Note: ([a]) Net formation of artificial areas during the 2006-2012 period amounts to 5 738 km^2. This is the balance between all conversions (gains and losses) in artificial areas. However, when considering only urban expansion (the gains) on previously undeveloped land (e.g. agricultural, natural or semi-natural areas), the increase in artificial areas is substantially larger — 6 391 km^2.

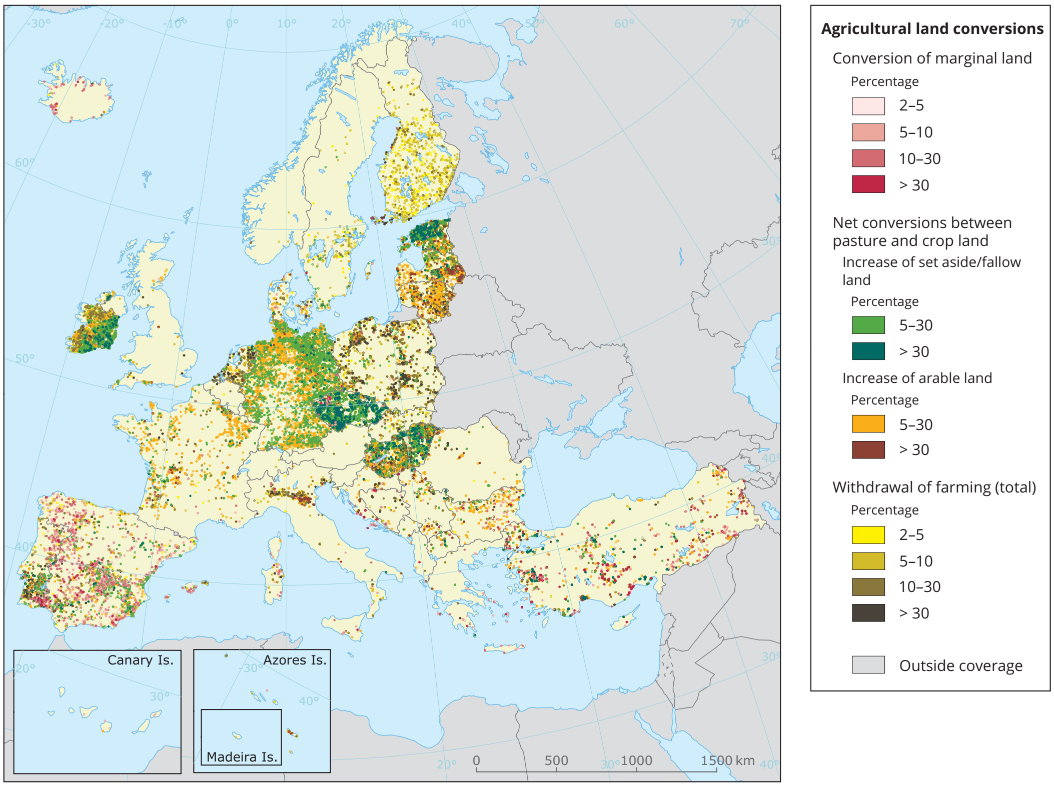
Source: ETC/ULS, 2016.

Map 2.1 **Expansion in artificial surfaces, 2006-2012**



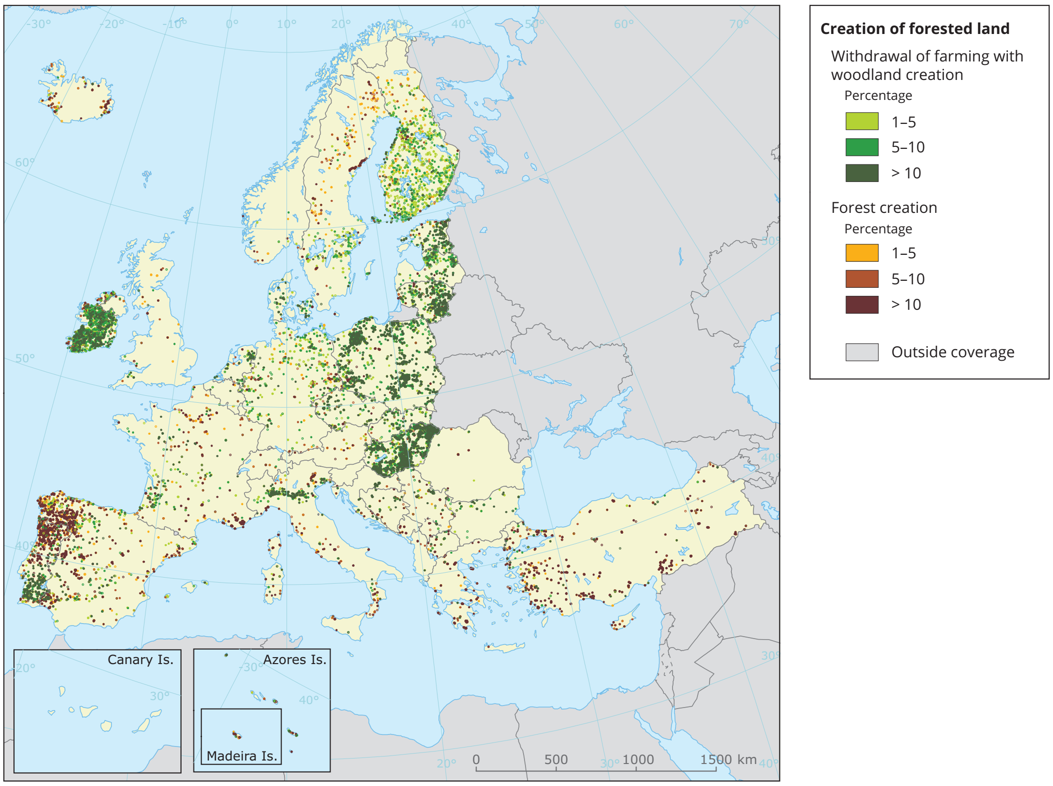
Source: ETC/ULS .

Map 2.2 Agricultural conversions, 2006-2012



Source: ETC/ULS, 2016.

Map 2.3 Creation of forested land, 2006-2012



Source: ETC/ULS, 2016.

was especially apparent in the Netherlands, France and the Po plain (Italy) (Map 2.1).

Agricultural conversions in 2006-2012 were especially marked in the Baltic countries, Ireland, Germany and Hungary (Map 2.2). Forested land was created through withdrawal of farming with subsequent woodland regeneration — which occurred mainly in Ireland and Hungary and also in Poland, the Baltic countries and Finland. A major concentration of forest creation (over dry semi-natural land) can also be observed in northern Portugal and in north-western Spain (Map 2.3).

2.4 Main land cover flows 1990-2012

Based on an analysis of the Corine Land Cover data set, the overall land cover changes in Europe between 1990 and 2012 are indicated in Table 2.4. Annex 1 gives the changes in the separate countries and an interpretation of the characteristic patterns.

Land cover data for 1990, 2000, 2006 and 2012 allow the analysis of trends over a period of almost 25 years, which includes important socio-economic and political changes: the integration of the new Member States to the European Union, the implementation of the CAP and its reform, and the economic downturn that occurred in the latest period analysed (2006-2012) (Figure 2.4). The available data allow comparison of 27 countries, which includes some non-EU countries, but does not include Finland, Norway or Sweden. Therefore these limitations should be taken into account, especially when analysing forest trends.

The main trends are as follows (Table 2.5 and Annex 1):

- Continuous increase in artificial areas, although the drivers changed slightly during the period: the component of residential sprawl has been declining since 1990, while the proportion of industrial areas and urban infrastructure has been increasing. The process was more intensive in the 1990-2000 period, while it slowed down in the 2000-2006 and 2006-2012 periods.
- There was a loss of agricultural land, at the expense of an increase in artificial areas and abandonment (often resulting in woodland regeneration) on more marginal areas. Two distinct periods can be observed:
  - Firstly, the 1990-2006 period. There is a steady pattern of land abandonment or withdrawal from farming in marginal areas. Such trends

Table 2.4 Land cover accounts 1990-2012 (km²) for 27 European countries

	Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/ bare soils	Wetlands	Water bodies	Total
Land cover 1990	197 176	1 414 434	919 646	1 281 983	368 052	167 361	68 498	61 019	4 477 186
Consumption of initial land cover	4 012	86 052	26 311	80 263	12 525	5 083	2 008	1 512	217 766
Formation of new land cover	25 131	73 387	18 183	85 872	7 930	3 787	1 260	2 215	217 766
Net formation of land cover	21 119	– 12 665	– 8 128	5 609	– 4 594	– 1 296	– 748	703	0
Net formation as % of initial year	10.7	– 0.9	– 0.9	0.44	– 1.2	– 0.8	– 1.09	1.2	
Total turnover of land cover	29 143	159 439	44 494	166 135	20 455	8 871	3 268	3 727	436 925
Total turnover as % of initial year	14.8	11.3	4.8	13.0	5.6	5.3	4.8	6.1	9.8
Land cover 2012	218 295	1 401 769	911 518	1 287 592	363 458	166 065	67 750	61 722	4 477 186

Note: Countries included are Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain and Turkey.

Source: ETC/ULS, 2016.

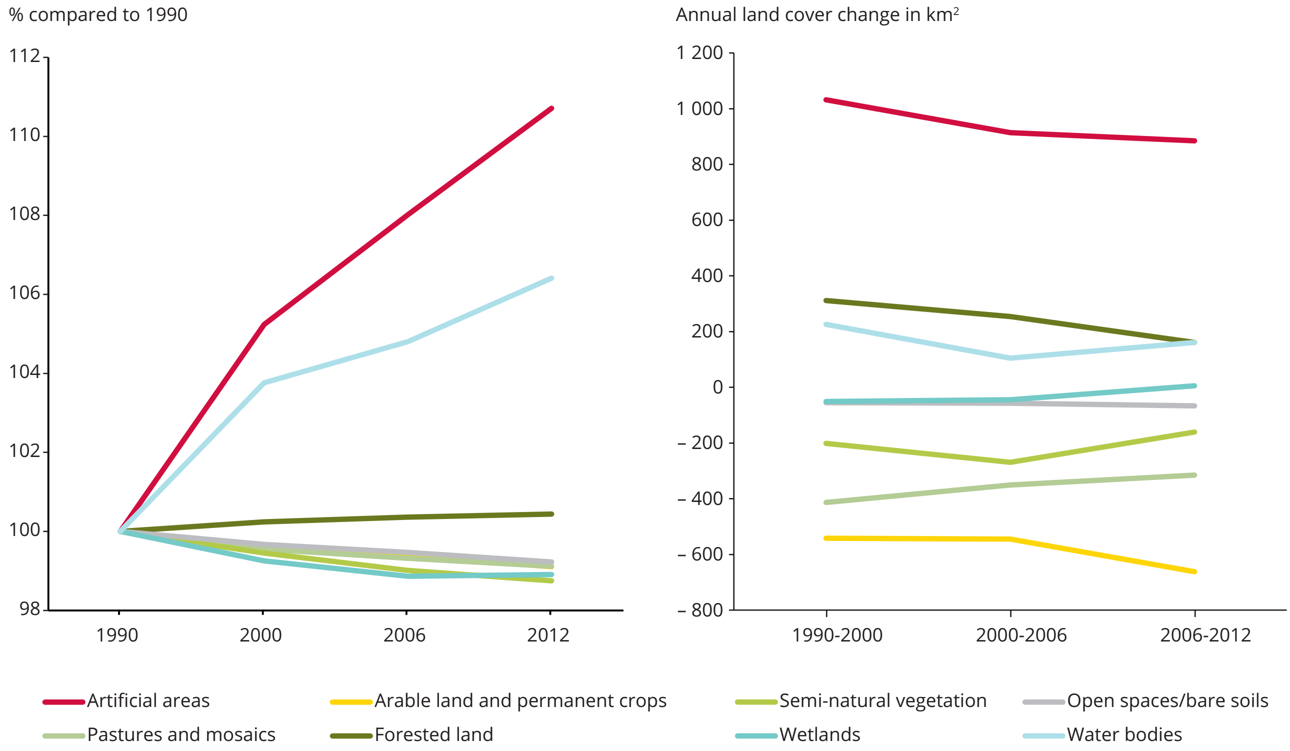
Table 2.5 Trends in land cover surface area in 27 selected European countries, 1990-2012 (km^2)

	1990	2000	2006	2012
Artificial areas	197 176	207 498	212 984	218 295
Arable land and permanent crops	1 414 434	1 409 012	1 405 743	1 401 769
Pastures and mosaics	919 646	915 515	913 410	911 518
Forested land	1 281 983	1 285 100	1 286 625	1 287 592
Semi-natural vegetation	368 052	366 037	364 422	363 458
Open spaces/bare soils	167 361	166 808	166 467	166 065
Wetlands	68 498	67 988	67 720	67 750
Water bodies	60 035	62 295	62 920	63 885

Note: Countries included are Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, the Netherlands, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain and Turkey.

Source: ETC/ULS, 2016.

Figure 2.4 Main trends in selected land cover categories over 22 years (based on 27 countries): (a) % compared with 1990; (b) annual land cover change in km^2



Note: List of included countries in Table 2.4.

Source: ETC/ULS, 2016.

can be observed in many of the mountainous regions of Europe, and in Hungary, Italy, Portugal and Slovakia, as well as in some parts of Germany, where arable land has been transformed to forest through the process of natural regeneration. In addition, the MacSharry set-aside measures ([4]) have led to the transformation of arable land into grassland. The marked transfer of agricultural land to forest and semi-natural cover observed in Denmark and the Netherlands probably reflects national policies regarding nature protection, recreation (Netherlands), reforestation and groundwater protection (Denmark).

– Secondly, the 2006-2012 period. There was a slightly faster decline of agricultural land (average loss 1 000 km^2 per year), compared with previous periods. This loss is the result of a combination of agricultural land being consumed by artificial areas, land abandonment (increase in semi-natural vegetation) and conversion to pastures and rural mosaics.

- Since 1990, forest land in the 27 countries presented in Table 2.5 has been increasing but this increase has slowed. New forest area is the result of afforestation (planting and seeding of trees on land that was not previously forested) and natural expansion of forests, for example on abandoned land.

Almost all trends in land cover change were consistent throughout the 1990-2012 period (Figure 2.4). Artificial areas increased most among all categories, in terms of both net area and percentage change. This is a constant trend observed since 1990, although the increase in the period 2006-2012 was less than in the 2000-2006 period. In addition, a slight attenuation of the increase in forest area can be observed, and the decrease in wetland area stopped during the last period (2006-2012).

([4]) Set-aside measures are policy incentives to temporarily or permanently convert cropland into grassland or unused land. In the EU they were part of the 1992 MacSharry reforms of the Common Agricultural Policy (see e.g. Cunha and Swinbank 2011).

3 How are land changes measured?

3.1 Land monitoring

The current environmental challenges require the consideration of ecological, economic and social factors at local to global scales. There is therefore a fundamental need to monitor these factors and their impact on land, which manifests in the form of biophysical characteristics (i.e. the land cover), socio-economic function (i.e. the land use) and other characteristics of the land (Feranec et al., 2016; Manakos and Braun, 2014). Land-monitoring activities aim to observe the spatial distribution and changes over time of these factors. In Europe, land-monitoring data are required by users (decision-makers and communities at the subnational, national and European levels) for the following major general purposes:

- to provide information on the status of the terrestrial environment (maps, statistics);
- to provide information on changes in the status of the environment over time (statistics, objects, parameters);
- to provide input parameters for modelling changes related to land.

Copernicus is the European system for monitoring the Earth ([5]). It consists of a complex set of systems that collect data from multiple sources: Earth observation satellites and in situ sensors such as ground stations and airborne and sea-borne sensors. It processes these data and provides users with reliable and up-to-date information through a set of services related to environmental and security issues. The Copernicus land-monitoring service includes the Corine Land Cover programme, as well as an increasing number of sophisticated land-monitoring products.

3.2 Corine Land Cover: main characteristics

Information on land cover (LC) and land use (LU) is crucial for any kind of land-monitoring activity in a wide range of thematic fields of work (environmental monitoring — nature protection; spatial planning — soil sealing control; agriculture — crop yield estimations; emergency management — natural hazard zones, etc.). Besides mapping and observing directly the Earth's surface (bio)physical condition, status and change, land cover and land use data are also important for other monitoring systems that use them as a vital input factor for their data models (climate change — biomass and carbon cycle; renewable energy — location of windmills, etc.).

Increasing political commitment to preserve natural resources has led over the last decades to a variety of national and European initiatives aiming to monitor changes in the landscape (land cover and land use). The cross-border nature of environmental issues requires cross-border solutions, which need to be built on coordinated and comparable environmental information across the European continent.

The European Commission therefore implemented the Corine programme (Co-ordination of Information on the Environment) from 1985 to 1990. During this period, an information system on the state of the European environment was created and nomenclatures and methodologies were developed and agreed at the EU level. As part of this, the Corine Land Cover (CLC) project was implemented, providing information on the physical characteristics and use of the Earth's surface. Images acquired by Earth observation satellites are used as the main source data to derive land cover information, in the form of a wall-to-wall map of Europe. Classes of CLC nomenclature are not pure land cover classes, but a mixture of land cover and land use information relevant to actual features of Europe's landscape.

The history of European land monitoring is a story of permanent evolution of approaches and concepts, resulting in different solutions for individual needs and specifications. In this context, the CLC specifications provided the first set of European-wide accepted de facto standards, i.e. a nomenclature of land cover classes, a geometric specification, an approach for land cover change (LCC) mapping and a conceptual

([5]) http://www.copernicus.eu.

data model (Heymann et al., 1994). In this sense, CLC represents a unique Europe-wide, if not global, consensus on land monitoring, supported by 39 countries.

CLC specifications, including nomenclature, were formulated in the 1980s with regard to initial user needs, input data availability and methodology. The spatial resolution is a compromise between information needs and the cost of production (mainly influenced by the cost of human input). The nomenclature was designed to focus on the initial geographical scope (Mediterranean countries), the visual interpretability of the classes and the general purpose of mapping. The nomenclature includes 44 classes, organised in a three-level hierarchical system, with five main categories: artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands, and water bodies. Harmonised production of the data set is aided by very detailed, illustrated nomenclature guidelines as well as well-established technical coordination (guidelines, training, quality control) provided by the EEA's CLC Technical Team. Although the list of classes has remained unchanged since the beginning, class descriptions have undergone significant refinement, in response to methodological developments.

For further description of the CLC programme, its advantages and shortcomings, see Annex 2 and Feranec et al. (2016).

3.3 New generation of land-monitoring products

The EEA implements parts of the Copernicus land-monitoring service: the pan-European and local components. The pan-European and local component data sets, produced for the 2012 reference year, are summarised in Table 3.1 and given in more detail in Annex 3. All of the products listed below are available free of charge through the Copernicus land portal land.copernicus.eu (see more details on the HRLs in Annex 4). The complementarity and different thematic focus of these various data sets enables a very rich analysis of the status and dynamics of European land use and land cover.

3.3.1 Relevance of Copernicus instruments for land assessments

A large number of policies have implications on land use and land cover. A recent assessment (EEA, 2016b) specifically looked into the direct and indirect impacts of EU policies on land. Issues such as urban land expansion are serious challenges for 'living well, within the limits of our planet', the aim of the EU's Seventh Environment Action Programme to 2020 (7th EAP). All assessments with a land component rely to some extent on reliable, up-to-date and relevant information on the status and dynamics of land use and land cover.

Table 3.1 Short summary overview on the 2012 reference year Copernicus land-monitoring service products, managed by the EEA. Significant changes and improvements are being implemented for the 2015 reference year

	Product	Product details	Reference year
Pan-European	HR and VHR image mosaics	Image mosaics of European Space Agency data-warehouse imagery in high resolution (HR — 20/25 m) and very high resolution (VHR — 1.5-2.5 m)	2012
	EU-DEM	Digital Elevation Model with 30 m spatial resolution	n.a.
	EU-Hydro	River network and drainage model	n.a.
	CLC	Flagship land cover and land use product with long time series	1990, 2000, 2006, 2012
	HRLs	Five thematic HRLs: (1) imperviousness; (2) forests; (3) natural grasslands; (4) wetlands; (5) water bodies	2012; (1) also 2006 and 2009
Local component	Urban Atlas (UA)	High-resolution mapping of urban land use and land cover (27 classes) for functional urban areas (FUAs)	2012 (and 2006)
	Riparian zones (RZs)	Set of complementary products mapping (1) land cover and land use, (2) delineating riparian zones, and (3) mapping green linear elements within the RZs	2012
	Natura 2000 (selection of grassland-rich sites)	Detailed LC/LU mapping for 524 selected Natura 2000 sites (including a 2 km buffer), rich in endangered grassland species	2006 and 2012

Source: EEA.

The EEA is publishing two indicators based on Copernicus land-monitoring products: (1) the 'land take' indicator (EEA, 2017a), which is based on the land cover flow information in the CLC change products, and (2) the indicator on imperviousness and soil sealing (EEA, 2016i), which was published for the first time in 2016 based on respective HRL data (see Figure 4.7). The initial publication of the indicator is based on the 2006-2009 data, and it will be thereafter supplemented by data for the 2009-2012 period. Once (in the frame of the upcoming production for the 2015 reference year HRLs) a fully reprocessed timeline for imperviousness (2006-2009-2012-2015) exists, the indicator will be updated, based on the full time period.

The added value of the imperviousness indicator, in combination with the 'land take' indicator, lies in the fact that it is more directly based on changes in sealing. While the CLC-based land take reflects and documents complex changes in land use, it cannot be easily used as a proxy for soil sealing, given that CLC classes reflect ranges in soil sealing rather than distinct soil sealing profiles for each land cover parcel. Also, once classified into one of the urban classes, further filling-in of green spaces or brownfield development is not captured if the land cover change covers less than 5 ha (the minimum mapping unit of CLC change). By using its 'degree of imperviousness (%)' variable, the imperviousness indicator captures all soil sealing changes at 0.04 ha level.

There is experience with regard to using Copernicus land-monitoring products in assessments, particularly with CLC, which is routinely used directly in the form of CLC-derived data sets in many EEA publications and other European assessments.

For example, the use of both CLC and the imperviousness HRL was instrumental in a recent report on urban sprawl in Europe (EEA, 2016f). These data sets, in combination with Urban Atlas, were also used for a report on urban sustainability issues (EEA, 2015e), and some of the forest data were used in an assessment of European forest ecosystems (EEA, 2016c). For an overview of the most recent EEA reports and their land-related conclusions, and use of Copernicus products, see Annex 7.

More demanding requirements, in particular in terms of the timeliness and update frequency of environmental information, are being met by increasing the production speed, publication frequency and spatial resolution of many of the products. This is in part enabled by improvements in the availability, quality, and spectral and spatial resolution of remote sensing imagery delivered by the new Sentinel series of European Space Agency satellites, in particular Sentinel 1 (radar) and Sentinel 2 (optical) data. Copernicus services will further improve for 2015 reference year. This will include extension of local component products and new change products for forest (Annex 5). Annex 6 presents more details on the Copernicus land services evolution under the EEA's responsibility.

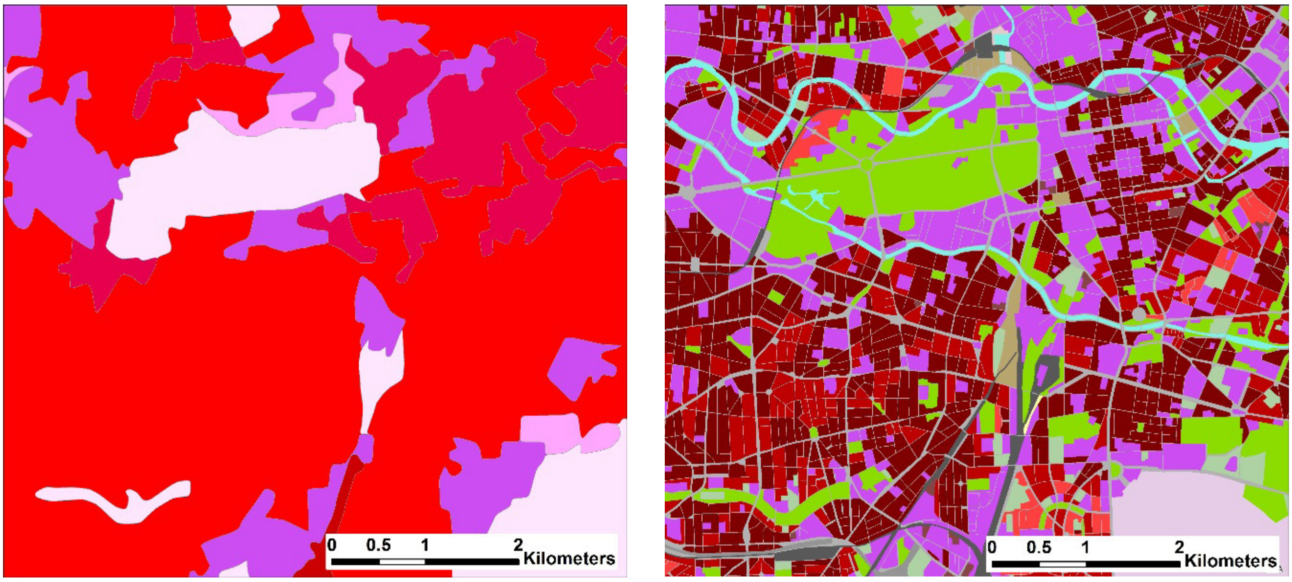
3.3.2 Combined use

CLC, and almost 25 years of change information contained in the CLC change products, can be combined and enhanced in a number of ways with the complementary higher resolution products of Urban Atlas (Map 3.1), riparian zones, Natura 2000 and the various HRLs (for more detailed information, see the Copernicus website) ([6]). For example, polygons from CLC can be used in any number of ways as reference units in combination with other data sets, e.g. the imperviousness HRL. Combining imperviousness data and CLC, the average sealing density for urban CLC polygons can be derived and compared on the basis of very distinctive imperviousness profiles for different CLC artificial area classes (residential areas, industrial sites, airports etc.).

The analysis of soil sealing dynamics within artificial area CLC classes can also be done as a regional analysis, or for specific sensitive zones (e.g. coastal or protected areas). In this way, regional differences in the sealing impact of land take can be quantified and understood.

([6]) http://land.copernicus.eu.

Map 3.1 **Visual comparison of the level of detail as captured for the same small area in central Berlin with (left) Corine Land Cover, 2012 and (right) Urban Atlas, 2012**



Note: Urban Atlas captures more urban/developed classes and distinguishes 5 densities of urban fabric. In addition the MMU of Urban Atlas is only 0.25 ha as compared to 25 ha for CLC. The legends are not included given that the aim is only to show the different levels of detail.

Source: Copernicus land monitoring service.

3.3.3 LUCAS as in situ component of land monitoring

LUCAS (Land Use/Cover Area Frame Survey) is a field survey run by Eurostat every 3 years (2009, 2012, 2015, planned for 2018), based on an area-frame sampling scheme ([7]). Data on land cover and land use are collected at each observation point and landscape photographs are taken. Statistical tables with aggregated results by land cover and land use at geographical level are obtained from survey results. These estimates are based on weighted point data.

Moreover, the transect, a 250 m walk along which linear elements and land cover changes are recorded, offers comparable indicators on the fragmentation, richness and dominance of the landscape as those are detected in sampling locations. The LUCAS survey is complemented by a topsoil sampling scheme that provides a new collection of European soil data.

The extent of the area covered by LUCAS has been gradually expanding and 2015 survey contains the 28 EU Member States (EU-28), a subset of the 39 EEA member countries and cooperating countries (EEA-39).

Given the large number of survey points (> 270 000), the unique standardised sampling scheme and the frequent updates of LUCAS, it has been used in production and verification and validation work for part of the Copernicus land services products, and it is used for the 2015 update of the HRLs. A recent report confirmed the overall good conformity of the different Copernicus nomenclatures with the current LUCAS data model, and it concluded with a set of recommendations and actions to improve the uptake of LUCAS in Copernicus (Buck et al., 2015).

3.4 Data comparability and analysis

A land cover data set is defined as a collection of (bio)physical cover units on the Earth's surface — represented in geographic information system (GIS) data layers as delineated (vector) polygons or raster cells (pixels). Land cover units are attributed either with a land cover code (e.g. CLC code 311 for broadleaved forest) or with a covered percentage of a land cover component in a cell (e.g. Tree Cover Density).

([7]) http://ec.europa.eu/eurostat/web/lucas/overview.

Land cover is different from land use, which is dedicated to the description of the socio-economic function of the Earth's surface. Land cover and land use are, however, related to each other and often combined in practical applications. For example, CLC data includes land cover and land use aspects, as well as other land-related characteristics.

Earth observation (satellite remote sensing) is mostly mapping pure land cover components like most of the Copernicus HRLs. The field observations like LUCAS makes a clear distinction between land cover and land use by using independent attributes and nomenclatures for the same point sample. Land cover mapping (e.g. by interpreting satellite imagery) and statistical surveying of land cover can be described, classified and mapped in many different ways, justified by a multitude of applications and user requirements. These include definitions (e.g. scale), survey instructions (e.g. interpretation rules) and a nomenclature (e.g. CLC classes).

The direct comparability of land cover mapping data sets and statistics derived from area frame field sampling is limited due to (ETC/ULS, 2016):

- *Semantic content (Box 3.1)*. The same class name may cover different thematic content, depending on definitions. For example, most land cover data sets contain the class 'forest', but forest is understood in some cases as a land use category and in others as land cover. Definitions are often based on characteristics such as height of trees, a minimum crown cover density or a minimum area defining the 'forest class'. In contrast, the same thematic content may be labelled with different class names.

- *Scale and generalisation*. The minimum mapping unit (MMU) and minimum mapping width (MMW) of linear features are two typical parameters of generalisation determining the content of a land cover mapping data set. It is difficult to estimate how area statistics are influenced by generalisation, as it depends on the survey rules, the thematic content and the landscape character.

- *Land cover sampling units*. Vector polygons, raster cells (with different spatial resolutions) or point observations at a precise location may be overlaid, but in most cases a one-to-one relationship between the covered areas will not be found.

- *Accuracy*. Most observation points are checked in the field; consequently, for a given location, the thematic accuracy of the land cover/land use interpretation is considered very high. Land cover/land use mapping products (e.g. from satellite data) are mostly the result of visual photo-interpretation or image classification and may represent variable accuracy, often expressed by a confidence value (e.g. 85 %). However, in these confidence limits, the outcome is a representation of land cover in its full territorial extent and spatial detail.

Box 3.1 Comparability of semantic content: The EAGLE approach

One way to assess the semantic distance between similar classes of different nomenclatures is to decompose class definitions into elementary semantic information and then compare their content. The EAGLE ([8]) model provides a conceptual framework for such semantic decomposition, by describing the semantic content of a class with the pure land cover components (LCCs) that potentially make up the class, land use attributes (LUAs) that represent its typical socio-economic function(s) and other characteristics (CHs) such as spatial and temporal pattern, cultivation practices, biophysical characteristics (e.g. phenology, wetness, height) and status (e.g. damage type). The distance between classes of one nomenclature or different nomenclatures can be assessed (and potentially also quantified) by comparing the results of this uniform descriptive decomposition. The methodology of EAGLE decomposition is described in detail at http://land.copernicus.eu/eagle.

([8]) The concept and data model have been developed as a result of voluntary work by the Eionet Action Group on Land Monitoring in Europe (EAGLE). The methodology has been refined and documented with support from the Copernicus land-monitoring programme.

4 The impacts of current land use practices

4.1 Urban land take and landscape fragmentation

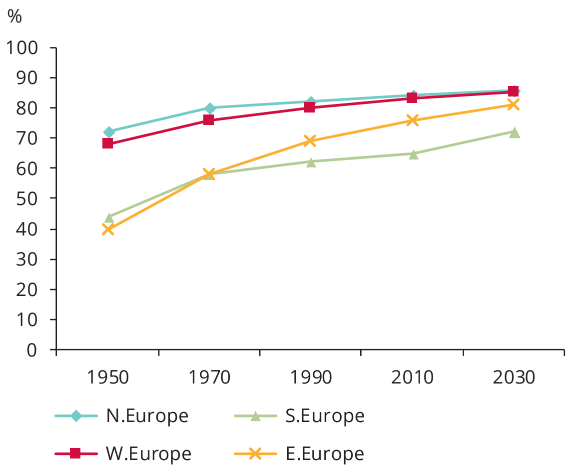
4.1.1 Urbanisation

The process of widespread urbanisation in Europe is a relatively recent phenomenon, stimulated by the industrial revolution and many accompanying societal changes. It is estimated that the proportion of people living in urban areas worldwide was only 1.6 % around year 1600 and 2.2 % at the beginning of the 19th century, and it fluctuated between 4 % and 7 % in the mid-19th century (Antrop, 2004) ([9]). Today, the proportion of population in urban areas (cities, towns and suburbs, based on the degree of urbanisation) is 72 % (EC-UN/HABITAT, 2016) and is projected to rise to just over 80 % by 2050 (Eurostat, 2016a).

The increase in the proportion of the urban population has been slowing, having grown considerably faster before 1991 (Figure 4.1). Since the middle of the last century, most of Europe has been characterised by spreading cities and an increased proportion of the population in suburban and peri-urban areas. Moving out from inner cities had the result that, even in the 1990s, many cities were declining. This trend has been partly reversed since 2000, though not as much in the eastern Member States (EC-UN/HABITAT, 2016).

The current tendencies towards total population decline, especially in northern and eastern European regions, but also in several Mediterranean regions, and population growth in western parts of Europe (Map 4.1) are also an indication of associated changes to be reflected in the land use. Hidden behind these figures, however, are the local changes in population density between the rural and urban areas, as depicted for the Netherlands in the years to come in Map 4.2. There are large variations across Europe (see Box 4.1), however, in most EU Member States, the capital city tends to outperform other cities and regions (Eurostat, 2016a).

Figure 4.1 Evolution of the proportion of people living in urban places in the main European regions between 1950 and 2030



Source: Antrop, 2004.

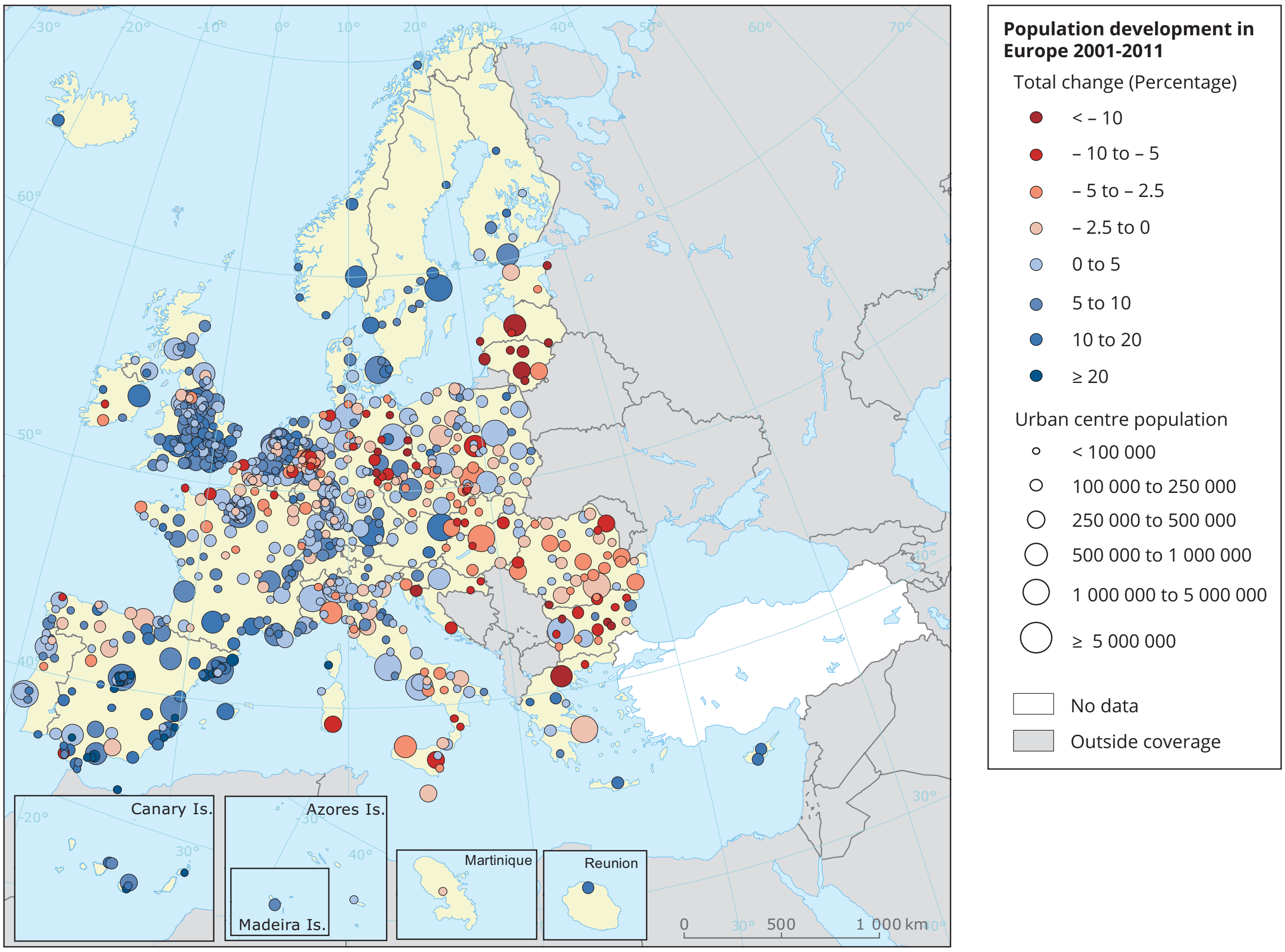
Box 4.1 Rural population growth in England, United Kingdom

England is distinctive in now having 60 years of rural population growth. This can be considered the consequence of a lifelong trajectory in the demography of the rural population: taking young people to cities for further and higher education, keeping them there into the start of childbearing age; and then moving them to the outer suburbs for quality secondary education; and finally to market towns and the countryside or coastal locations.

Source: Lowe and Ward, 2007.

([9]) Citing the United Nations Centre for Human Settlements (1996, 2001).

Map 4.1 Population development in Europe 2001-2011



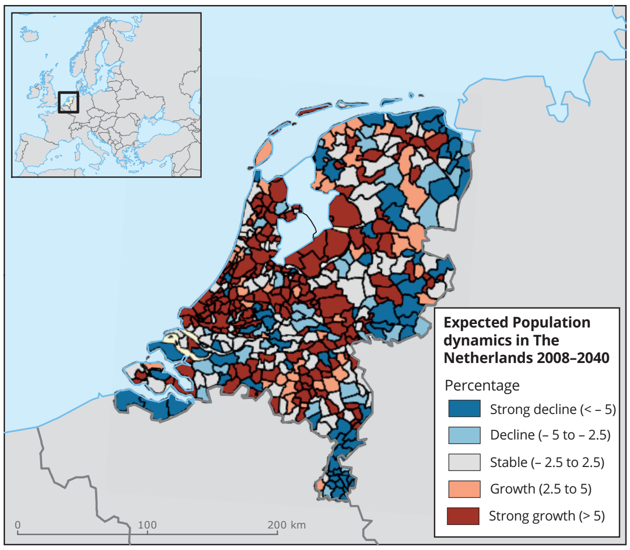
Source: EC-UN/HABITAT, 2016.

4.1.2 Land take by built-up areas

A continuous increase in built-up areas can be observed in Europe during the 1990-2012 period (Figure 2.4). This general trend is associated with drivers of the development of artificial areas during that period (Fina, 2017). While the annual rate of land take has been decreasing (Figure 4.2), there have been important changes in the proportion of its components. Land take by housing, services and recreation has decreased from 600 km^2/year during the 1990s to 300 km^2/year in the latest available period (2006-2012). At the same time, the proportion of land take by industrial and commercial areas has been increasing.

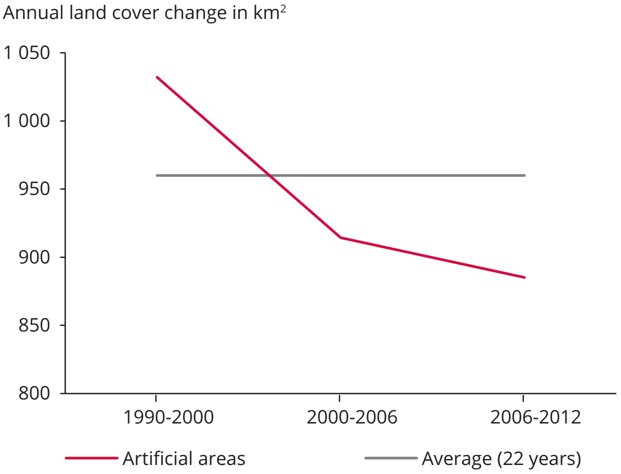
A useful insight is provided by land take associated with new construction sites. An increased number of new construction sites in the 2000-2006 period evolved into increased land take by industrial and commercial sites in the next period (2006-2012), when the number of new construction sites returned to its previous value. This reflects the fact that the 2000-2006 period saw intense development of new

Map 4.2 Expected population dynamics in the Netherlands 2008-2040



Source: Kooiman et al., 2016

Figure 4.2 **Trend in artificial areas in 27 selected European countries, 1990-2012**



Note: The red line is the annual average land cover change in km²; the grey line is the annual average for 1990-2012. List of 27 selected European countries in Table 2.4.

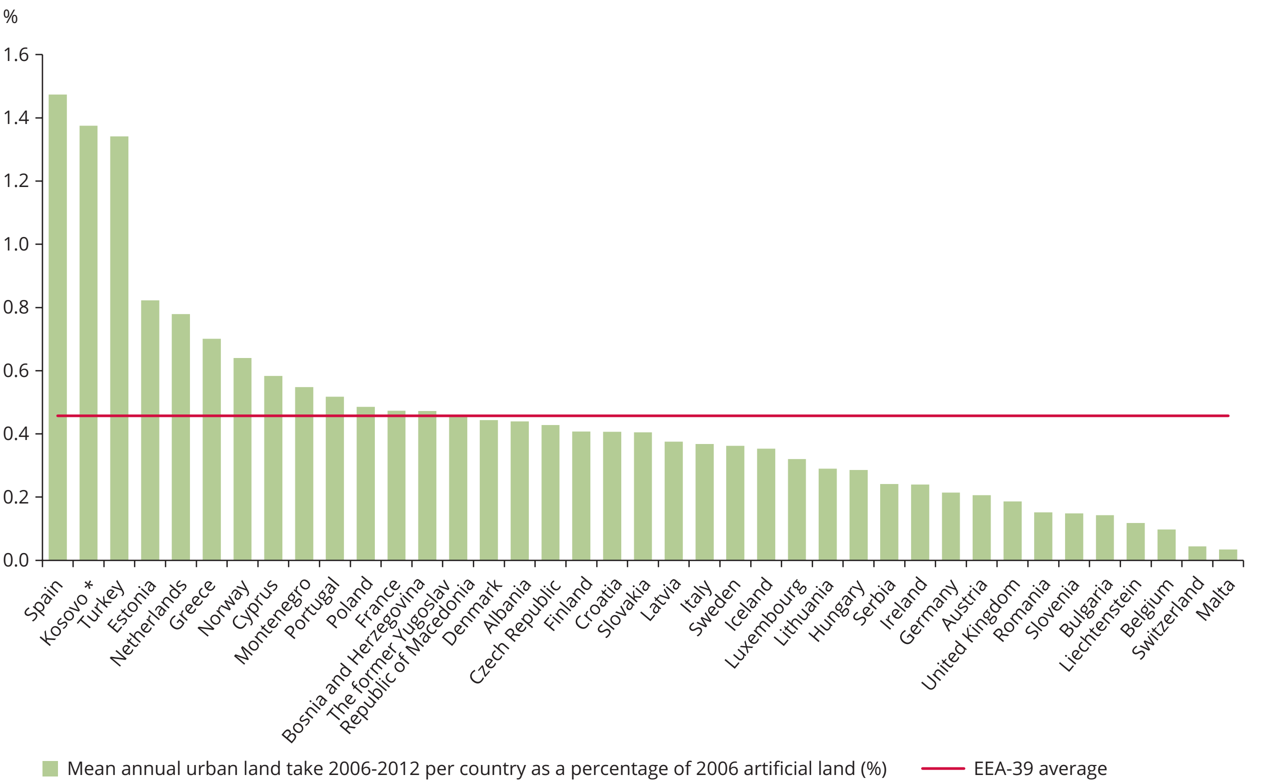
Source: ETC ULS, 2016.

industrial and commercial areas (still identified as new construction sites), which was confirmed by the analysis of 2012 data. Against a background of decreasing overall land take, the land take by industrial and commercial areas remained almost the same in the latest period (2006-2012) compared with 2000-2006.

Figure 4.3 gives the mean annual land take in the 2006-2012 period as a percentage of the 2006 artificial land. In particular, Spain, Kosovo (under United Nations Security Council Resolution 1244/99) and Turkey show high rates of land take in relation to the amount of artificial land already identified. Figure 4.4 shows that Spain, Turkey and France together account for almost half of the land take in the EEA-39 countries in the 2006-2012 period.

Measuring land take supports the quantitative analysis of the urban sprawl process — the migration of urban inhabitants to low-density residential developments in suburban and peri-urban areas that were formerly rural. Urban sprawl (in this case, understood in its wide

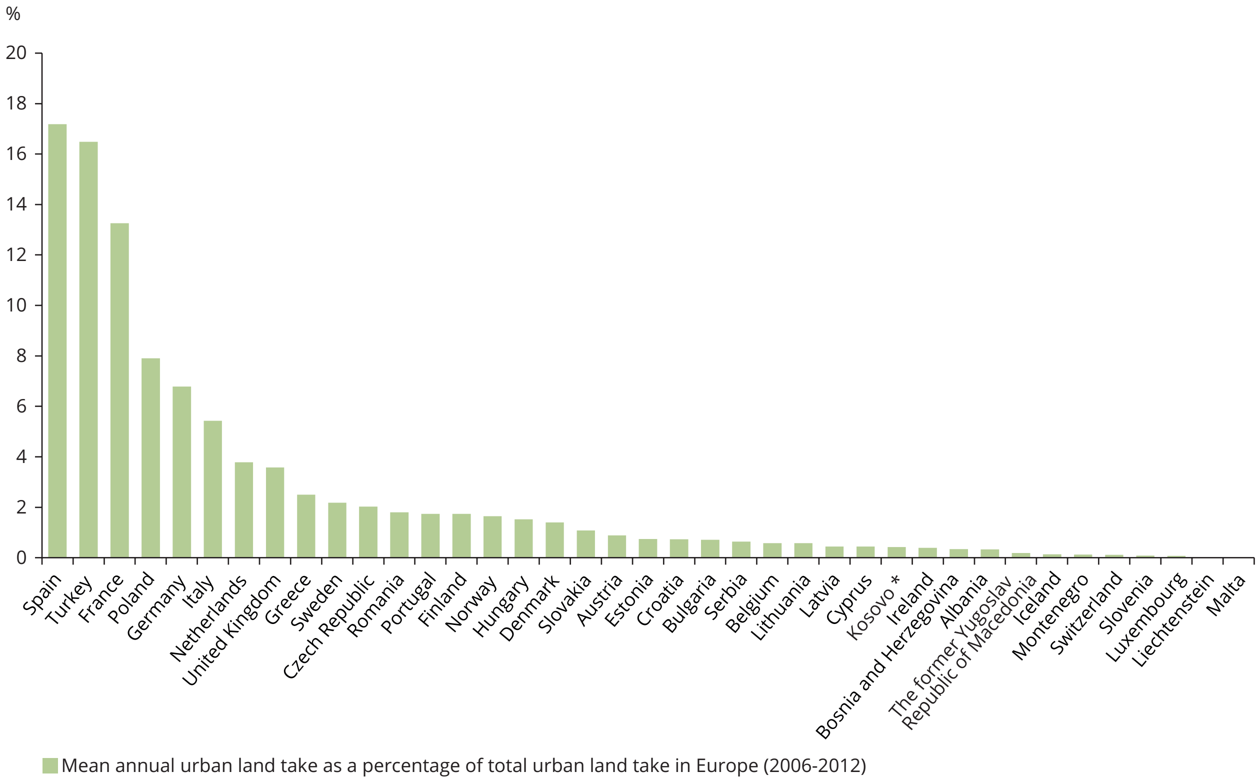
Figure 4.3 **Mean annual land take by built up areas, 2006-2012, for the EEA-39 countries as a percentage of 2006 artificial land (%)**



Note: * Under UNSCR 1244/99.

Source: Copernicus data processed by EEA.

Figure 4.4 Mean annual land take by built up areas per country as a percentage of the total land take in Europe (100 %) for the 2006-2012 period



Note: * Under UNSCR 1244/99.

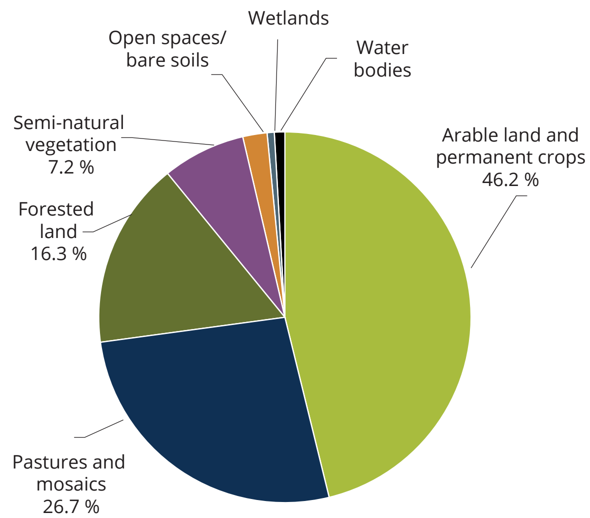
Source: Copernicus data processed by EEA.

sense as the increase in built-up and artificial areas) is a spatial development process associated with a number of ecological, economic and social effects, basically resulting in the inefficient use of land and other resources (EEA, 2016f). Some of these relate to people's desires, for example, to live in single-family homes with gardens.

Large and compact cities can potentially deliver sizeable savings in terms of resource efficiency. It is increasingly recognised that compact cities offer resource-efficient ways for people to live and for businesses to exist, as being in close proximity and pooling resources provides potential efficiency gains. Cities tend to use land more efficiently due to their higher population densities and generally have a lower amount of artificial area per capita than rural areas (Dijkstra et al., 2013).

In contrast, urban sprawl has detrimental and long-lasting effects. For example, urban sprawl contributes significantly to the loss of fertile farmland (Figure 4.5), to soil sealing and to the loss of ecological

Figure 4.5 Relative contribution of land cover categories to uptake by urban and other artificial land development (2006-2012)



Source: EEA, 2017a

Box 4.2 Preventing urban sprawl in Łódź

A recent case study addresses land use governance in Łódź, the third largest city in Poland. After a period of economic decline following the collapse of the traditional manufacturing industry in Łódź in the late 1990s, at present several major projects are under way that have the potential to significantly reinvigorate the economy. However, uncontrolled sprawl and a declining population in the city pose a challenge for Łódź's fiscal and environmental sustainability. The city seeks a more compact and sustainable urban form, with a vibrant city centre, but the various tools available are not effective to address uncontrolled sprawl. It appears that certain elements of the Polish planning system are inconsistent, such as national legislation on infrastructure overriding local planning law and an absence of local spatial development plans in many areas, while in special economic zones other rules apply. Moreover, in Łódź, collaboration among urban, peri-urban and rural locales is only just beginning.

The study recommends strongly enhancing incentives and governance structures for municipalities to undertake planning based on the functional urban areas. To compensate for the imperfections in the Polish planning system, in October 2015, a Revitalisation Act was approved to strengthen balanced city centre renewal, including brownfield redevelopment, and to mobilise the public in participatory approaches. The Metropolitan Unions Act, also approved in October 2016, aims to stimulate the cooperation of municipalities in metropolitan areas and more efficient use of land.

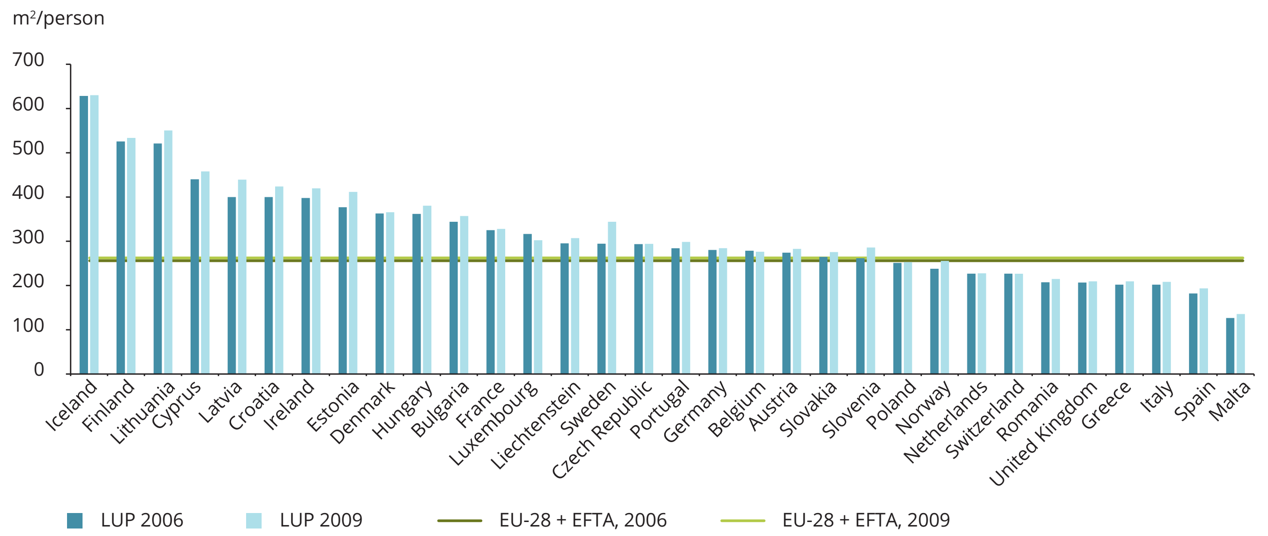
Source: OECD, 2016.

soil functions (EEA, 2016e; Gardi et al., 2015). The increase in built-up areas reduces the size of wildlife habitats and increases landscape fragmentation and allows the spread of invasive species. Urban sprawl leads to higher greenhouse gas emissions, higher infrastructure costs for transport, water and electrical power, the loss of open landscapes, and the degradation of various ecosystem services.

Despite various attempts to address this problem, urban sprawl has increased rapidly in Europe in recent decades (Prokop et al., 2011). Since the mid-1950s, the total surface area of European cities has expanded on average by 78 % while the population has grown by just 33 % (EEA, 2006). Thus far this trend has not changed (EEA, 2016f). An illustration of the urban sprawl issue is provided in Box 4.2.

An analysis of sprawl at the 1-km^2 grid level (EEA, 2016f) shows that sprawl is most pronounced in wide circles around city centres, along large transport corridors and along many coastlines (particularly in the Mediterranean countries) [10]. The level of sprawl, as measured by WUP (weighted urban proliferation),

Figure 4.6 Land uptake per person (LUP) in 2006-2009



Source: EEA, 2016f.

([10]) The actual values for these indications depend on the distance used for determining dispersion and the weight given to dispersion relative to land use per capita.

increased in all European countries between 2006 and 2009 (EEA 2016f). This is also reflected in the land uptake per person (Figure 4.6).

The overall WUP value for Europe (32 EEA member countries combined) increased from 1.56 urban permeation units (UPU)/m^2 in 2006 to 1.64 UPU/m^2 in 2009 — that is by 5 % in 3 years or by 1.7 % per year. In most countries, the increase was higher than 1 % per year, and in many countries WUP increased by more than 2 % per year.

4.1.3 Soil sealing

New Earth observation data from the Copernicus programme (Chapter 3) have allowed the development of another indicator for monitoring the extension of artificial man-made areas — the occurrence of sealed soils (degree of imperviousness).

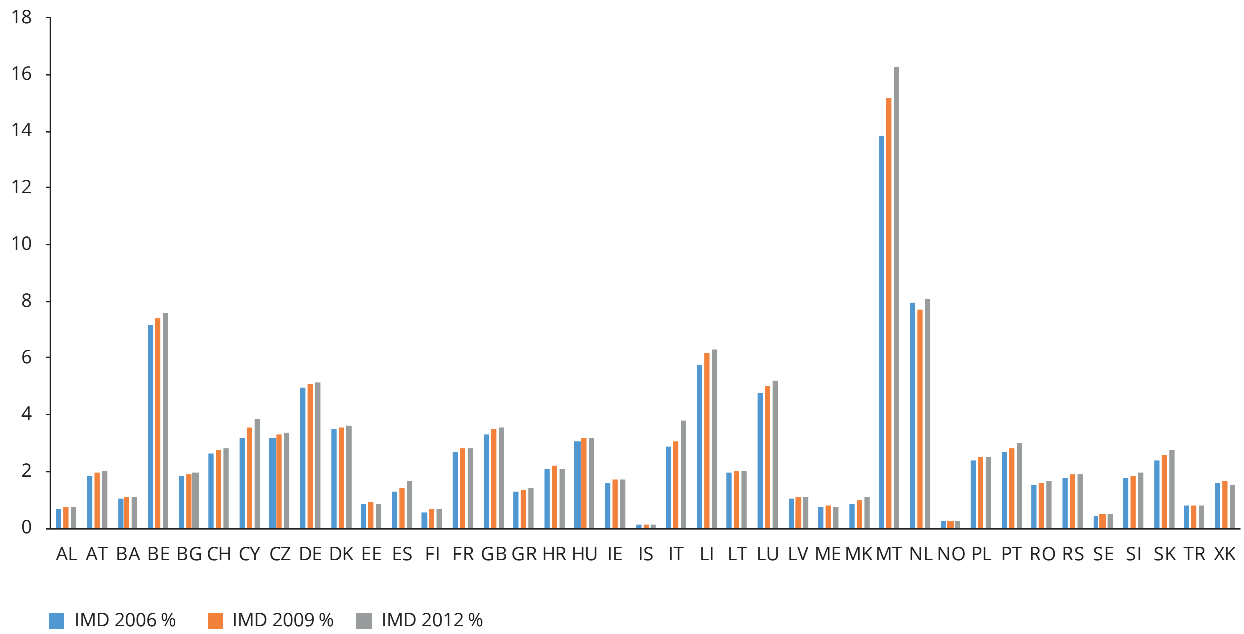
Impervious areas lead to more frequent rapid surface run-off and increased flood risk and isolate the soil from functional ecosystem components. In particular, the densely populated small countries —Malta, the Netherlands and Belgium — have very high and still increasing percentages of sealed soils, but the measure of soil sealing is also increasing in the larger and less densely populated countries (Figure 4.7).

4.1.4 Landscape fragmentation

Expanding built-up areas and the transport infrastructure can lead to landscape fragmentation, which has a number of ecological effects (EEA, 2011). It contributes significantly to the decline in and loss of wildlife populations and to the increasing endangerment of species in Europe, for example, through the dissection of habitats and isolation of populations, and it affects the water regime and the recreational quality of landscapes. Urban expansion is still increasing in Europe (i.e. Figures 4.3 and 4.7), and many more new transport infrastructure projects are planned, in particular in eastern Europe, which will further increase the level of landscape fragmentation.

Landscape fragmentation by transport infrastructure and urbanisation was analysed for 2009 (EEA, 2011) and again for 2012, following the same methodology (using the index S_{eff}, effective mesh density, for the fragmenting network FGA2 ([11])). The preliminary results of a recent EEA study ([12]) suggest that in 30.1 % of the continent there is no indication of an increase in

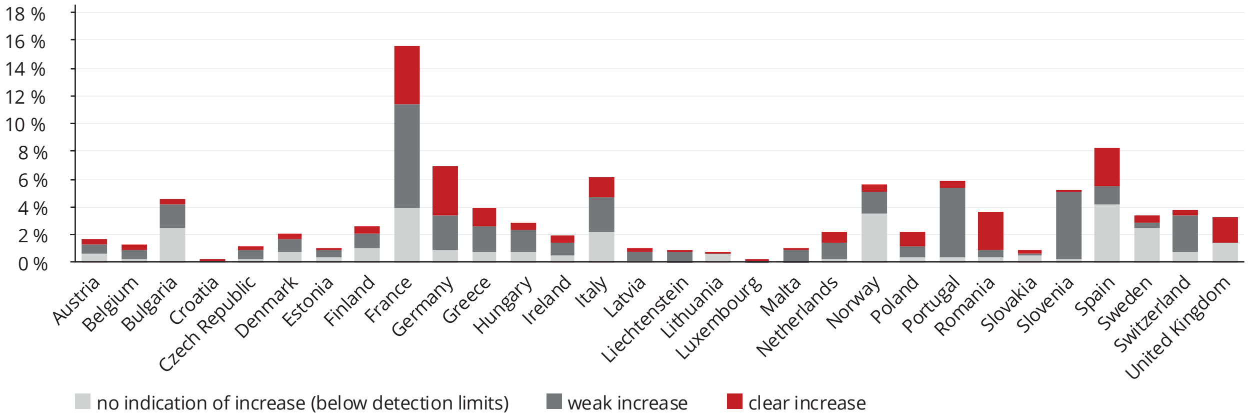
Figure 4.7 Imperviousness degree (IMD) of soils (%) per country for 2006, 2009 and 2012



Source: EEA, 2017.

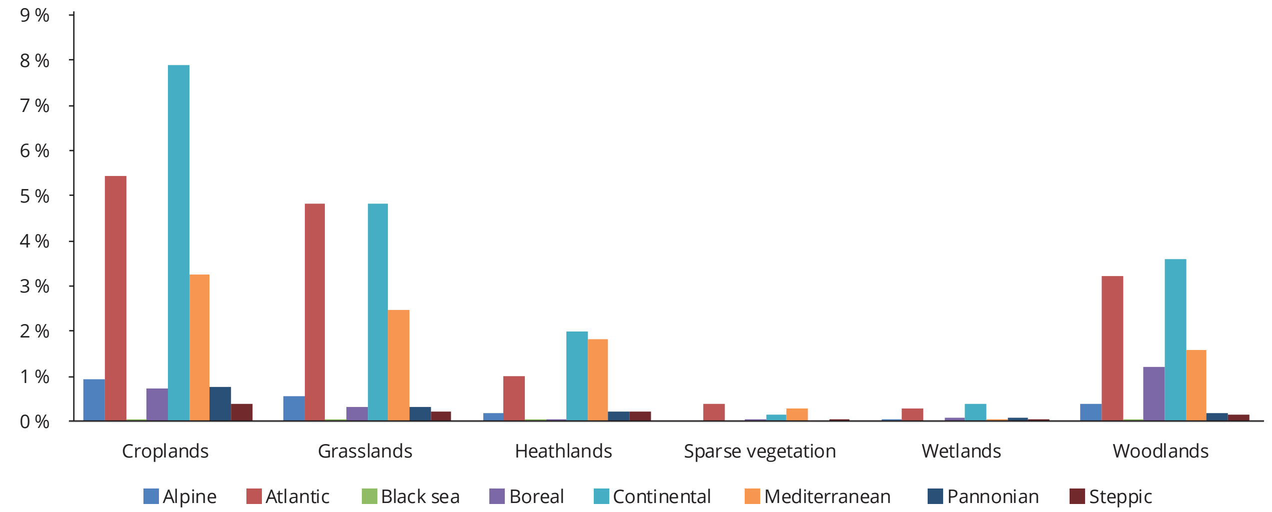
([11]) The FGA2 fragmenting network takes into account as fragmenting elements developed areas, railway lines, European and national roads and regional and local roads (EEA, 2011).
([12]) Following a planned reanalysis using higher resolution Copernicus data, the absolute values for landscape fragmentation might change in future reports.

Figure 4.8 **Area distribution (% of Europe) in which the S_{eff} index indicates no fragmentation change (below detection limit), a weak increase and a clear increase in fragmentation between 2009 and 2012**



Source: Preliminary results of EEA study, 2016.

Figure 4.9 **Area distribution (% of Europe) of clear indications of an increase in fragmentation within the analysed ecosystems and biogeographic regions ('MAES' categories, after Science for Environment Policy, 2015)**



Source: Preliminary results of EEA study, 2016.

fragmentation (below the detection limit), in 43.3 % of the investigated territory there are indications of a weak increase in fragmentation, and over 26.6 % of the area a clear increase in fragmentation can be determined from the S_{eff} index. Clear indications of an increase in fragmentation can be observed in France, Germany and Spain (Figure 4.8). At the same time, Spain and France represent the largest area with no change in fragmentation.

In terms of ecosystems (Science for Environment Policy, 2015), for croplands, grasslands and woodlands, the highest increase of fragmentation happened in Continental, Atlantic and Mediterranean regions (Figure 4.9). The same applies to heathlands, but heathland fragmentation in the Mediterranean region is relatively higher than that in other biogeographic regions.

4.2 Land use intensity

4.2.1 Spatial patterns of change in land use intensity

Land use is usually encompassed by land cover, but the opposite is not necessarily the case (Plieninger et al., 2016; Temme and Verburg, 2011; Verburg et al., 2009). From land cover, major categories of land use can be deduced, but the functioning of the land use — e.g. the use intensity — may be very dissimilar under different circumstances. This is because land cover may remain relatively unchanged, while large changes in land management may appear in the land cover only following a considerable time lag (Gingrich et al., 2015; Levers et al., 2016; van der Sluis et al., 2015; van Vliet et al., 2015).

The intensification of agriculture by the cultivation of high-yielding crop varieties, consolidation of land parcels and the application of fertilisers, irrigation and pesticides has been a major contributor to the very large increases in food production over the past 50 years globally.

Kuemmerle et al. (2016) identified hotspots of change in land use intensity and explored the spatial concordance of area versus intensity changes. They compiled and analysed high-resolution, spatially explicit land use change indicators capturing changes in both the extent and the management intensity of cropland, grazing land, forests and urban areas for all of Europe for the 1990-2006 period. Spatial patterns of changes in the intensity within broad land use classes in Europe between 1990 and 2006 were analysed for 5 key variables:

- fertiliser use on cropland (scaled between – 120 and + 150 kg/ha);
- crop yields (± 1 kg C/m^2);
- livestock density (– 90; + 25 livestock units);
- biomass removal from grazing land (± 1 C/m^2);
- roundwood production (– 14.2; + 7.6 m^3/ha per year).

A clear east–west divide was found with regard to agriculture, with stronger declines in cropland and lower management intensity in the east than in the west. However, these patterns were not uniform, and diverging patterns emerged: intensification in areas highly suitable for farming, and extensification and cropland withdrawal in more marginal areas.

Despite the moderate overall rates of change, many regions in Europe experienced a substantial spatial reorganisation of land use during the 1990-2006 period and opposite trends that took place simultaneously at different locations: shrinking agricultural area and land use intensification in some places, and area enlargement with more extensive land use in other sites (for details see Kuemmerle et al., 2016).

Although some trends have changed since the reviewed period, this analysis highlights the diverse spatial patterns and the heterogeneity of land use changes in Europe. It is important to consider at the same time the changes in land use spatial patterns and the management intensity of land use, as well feedbacks from the land use sectors.

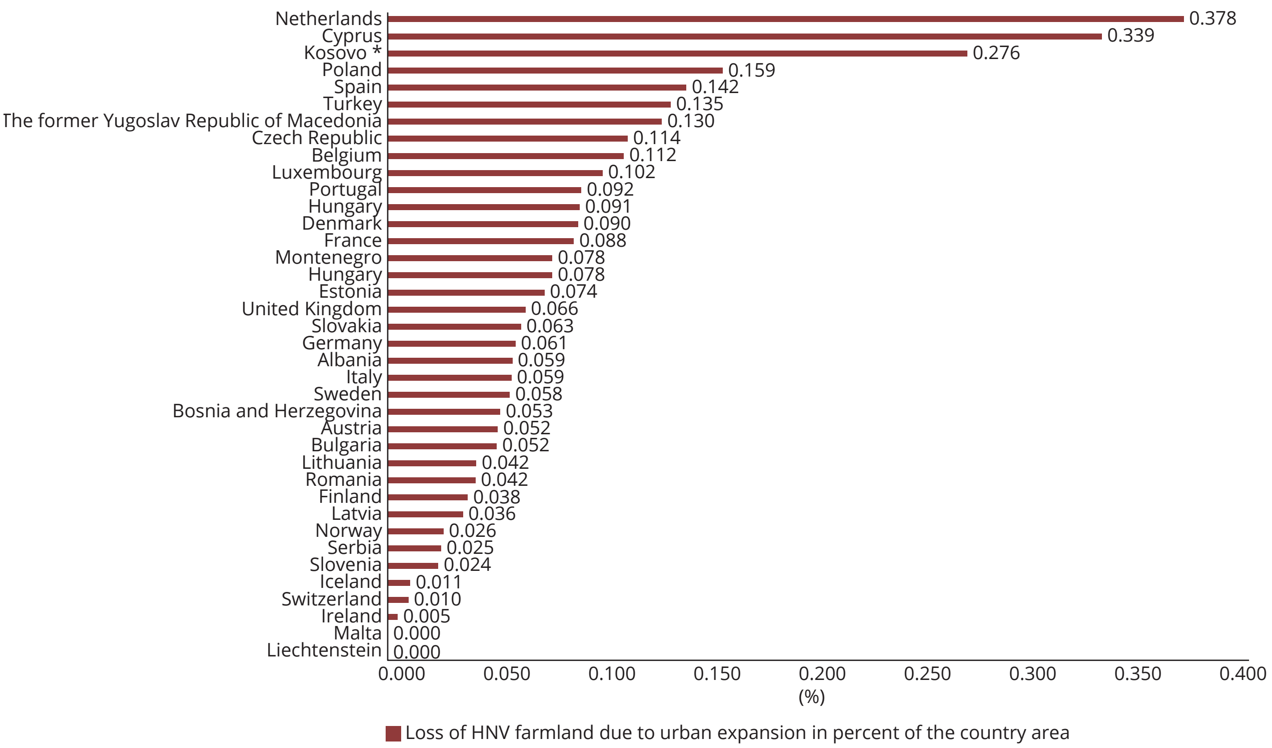
4.2.2 High nature value farmland and land use intensity

The high nature value farmland (HNV) concept emerged in the early 1990s as a result of growing recognition of the role of agricultural land and associated traditional extensive farming systems in conserving biodiversity in Europe. HNV farmland comprises areas with high species and habitat diversity and/or the presence of species of European conservation concern. The EU 2020 Biodiversity Strategy acknowledges that the preservation of biodiversity associated with agricultural land will be essential to meet the 2020 targets to halt biodiversity loss. An initial assessment of HNV farmland (Paracchini et al., 2008) was followed up by EEA updates in 2012 and 2016. Based on land cover flows analysis, these studies showed that HNV farmland continues to be lost.

The main drivers of this decline are urban expansion (Figure 4.10), which was, for example, responsible for up to about 0.4 % of HNV farmland loss from 2006 to 2012 in the Netherlands, and agricultural intensification, responsible for up to 0.5 % of HNV farmland lost in central and eastern European countries (Map 4.3). In addition, HNV farmland is lost due to expansion in uniform agricultural areas at the expense of agricultural mosaics and natural and semi-natural areas. HNV farmland can also be affected by the de-intensification or reduction of agricultural practices, leading to a loss of biodiversity determined by low and medium-intensity land use practices in cultural landscape settings.

Agricultural intensification represents the highest proportion of the decline in HNV farmland during the 2006-2012 period in some remarkable hotspots across Europe, such as the Baltic countries (in particular Estonia and Latvia), the Czech Republic, Hungary (and some nearby regions in Serbia and Romania), huge

Figure 4.10 Loss of HNV farmland (%) due to urban expansion 2006-2012, by country



Note: The following land cover flows are classified as urban expansion: urban residential development and development of economic sites and infrastructures.

* Under UNSCR 1244/99.

Source: ETC/ULS, 2016.

parts of northern and eastern Germany and smaller spots in the south and west of the country, and the southern half of the Iberian Peninsula.

4.3 Land use and healthy soils

Soil underpins 90 % of all food, feed and fibre production, and it provides raw material for activities from horticulture to the construction sector. Soil is also essential for ecosystem health: it purifies and regulates water, and it is the engine for nutrient cycles and a reservoir for genes and species, supporting biodiversity. It is a global carbon sink, playing an important role in the potential slowing of climate change and its impacts. Moreover, by conserving traces of our past, it is an important element of our cultural heritage. However, the loss of soil by erosion and the degradation of soil quality represent serious threats to these functions of the soil.

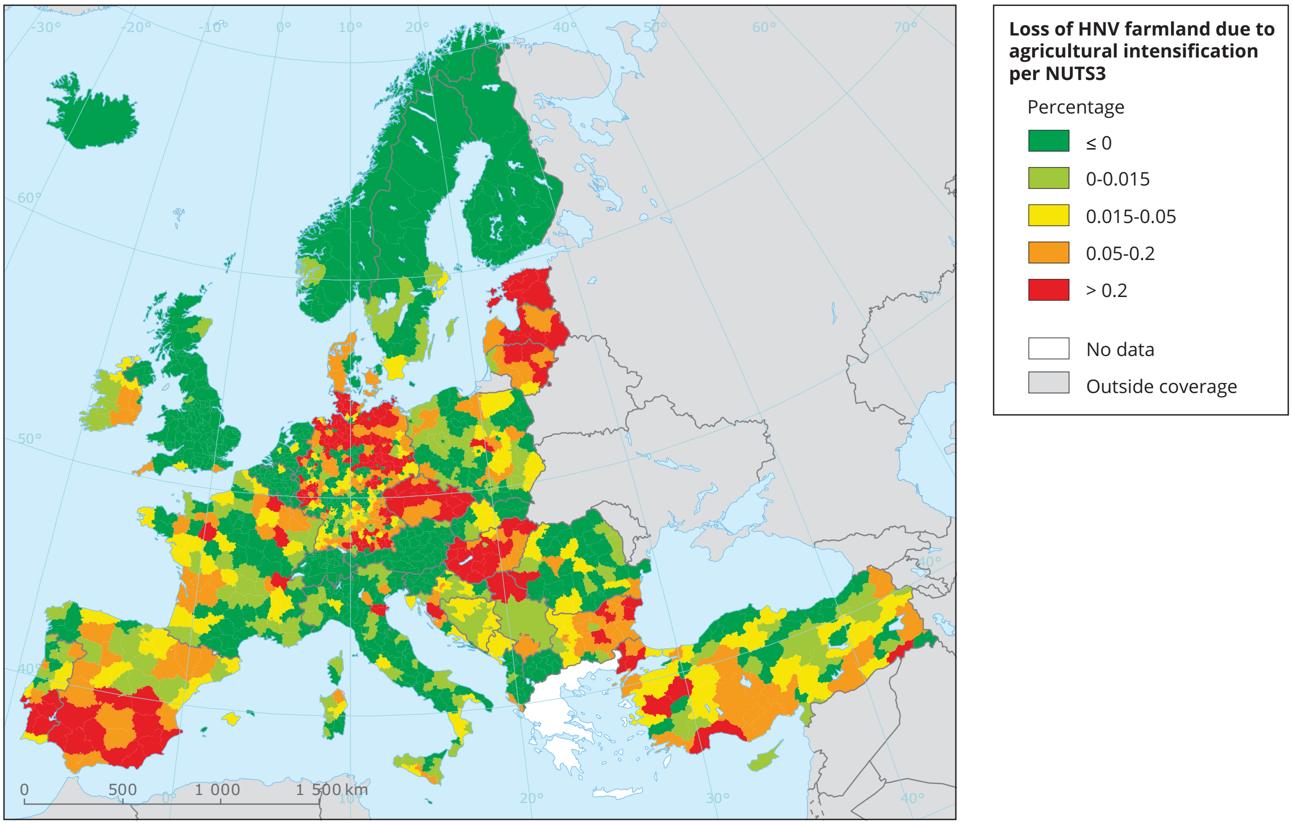
4.3.1 Soil organic carbon

Land cover change, and also changes in land use intensity, have a direct effect on soils, especially on soil organic matter (EC, 2012), and on carbon emissions and sequestration (EC, 2013a; Edenhofer et al., 2011). Sustainable Development Goals ([13]) explicitly refer to these aspects. Estimates derived from the European Soil Database indicate that around 45 % of the mineral soils in Europe have a topsoil organic carbon content that is very low to low (0-2 %) and 45 % have a medium organic carbon content (2-6 %) (EEA, 2017b).

A recent assessment (using the LUCAS database, along with soil organic carbon (SOC) predictors) shows that predicted SOC contents are lowest in Mediterranean countries and in croplands across Europe, whereas the largest predicted SOC contents are in wetlands, woodlands and mountainous areas

([13]) Sustainable Development Goals, target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

Map 4.3 **Loss of HNV farmland (%) due to agricultural intensification 2006-2012, given at NUTS-3 level**



Note: The following land cover flows are classified agricultural intensification: conversions of arable land to permanently irrigated areas; conversions of permanent crops (vineyards, orchards, olive groves) to irrigated and non-irrigated arable land; and conversions of pasture to arable land and permanent crops.

Source: ETC/ULS, 2016.

(de Brogniez et al., 2015). This is in line with the notion that croplands generally act as a carbon source, while forest soils generally provide a sink (Schils et al., 2008). Nevertheless, some cropping practices can lead to sequestration in arable soils if given time, while CH_4 emissions from livestock and N_2O emissions from arable agriculture may be fully compensated by the CO_2 sink provided by forests and grasslands (Schulze et al., 2009).

In particular, erosion of the upper part of the soil (topsoil) leads to declining SOC and nutrient stocks, which influences fertility and has further knock-on effects (see also Section 5.5). According to the revised water erosion model developed by the European Commission's Joint Research Centre (JRC) in 2015, around 11.4 % of the EU-28 territory is estimated to be affected by a moderate to high soil erosion rate (> 5 tonnes/ha per year) (EEA, 2017b). About 0.4 % of EU land suffers from extreme erosion (> 50 tonnes/ha per year). A further 6 % is affected by wind erosion (JRC IES, 2012). Soil organic matter loss leads to a breakdown of the soil structure and reduced soil water storage, which can lead to an enhanced risk of flooding and landslides in adjacent areas. Soil organic matter can be a strong indicator of soil biodiversity, which plays a crucial role in carbon and nutrient cycling. In addition, both soil organic matter and soil organism diversity and activity are affected by temperature and moisture changes. The interlinkages between the climate and soil system, along with the interaction between people and these natural systems, define the degree to which soil can deliver services to society. Land use and land management can thus respond effectively to the challenges of climate change and its impacts if these interactions are well governed.

The capacity of soils to act as a carbon pool is essential for the global carbon cycle as SOC is considered to be the second largest carbon pool after the oceans (Lugato et al., 2014). Hence, one of the goals of the EU Thematic Strategy for Soil Protection (EC, 2006) is to maintain and enhance SOC levels in

Table 4.1 The impacts of land cover flows (LCFs) 2000-2006 on the good carbon pool potential of soils and percentage share of individual land cover flows/impacts, per country

Country	Total area of good carbon pool potential soils (ha)	Share of good carbon pool potential soils affected by LCFs (%)	Share (%) of LCFs (land use changes) in total area of affected good carbon pool potential soils (total 100 %)					
			Land take	Agriculture intensification	Agriculture extensification	Agriculture expansion	Forest creation	Forest felling
AL	2 055 728	1.32	15.13	0.74	1.11	1.11	24.35	**57.56**
AT	6 348 353	0.40	16.41	0.00	0.00	0.00	5.47	**78.13**
BA	3 399 340	0.88	3.67	7.33	0.67	1.00	28.33	**59.00**
BE	1 338 247	0.97	11.54	0.00	0.00	0.77	27.69	**60.00**
BG	4 792 712	0.95	1.77	0.22	0.00	0.44	29.36	**68.21**
CY	408 949	4.01	21.34	0.00	0.00	15.85	**62.80**	0.00
CZ	3 002 506	2.38	3.49	1.40	15.50	0.00	**53.35**	26.26
DE	16 112 359	0.59	16.95	11.79 *	2.74	2.32	**35.89**	30.32
DK	565 272	1.65	2.15	0.00	1.08	0.00	**54.84**	41.94
EE	2 733 555	3.29	3.33	4.00	0.56	0.11	22.56	**69.44**
ES	24 676 056	1.56	8.87	0.42	1.56	19.99 *	**38.01**	31.15
FI	25 323 980	2.61	1.12	0.00	0.00	4.04	42.40	**52.43**
FR	26 283 156	0.94	8.63	1.25	0.04	0.61	17.67	**71.80**
HR	3 518 013	1.15	11.66	6.95	3.97	6.70	16.13	**54.59**
HU	2 262 887	5.59	1.19	0.79	0.95	0.40	41.53	**55.14**
IE	5 424 651	2.16	11.95	1.02	0.43	0.00	**54.27**	32.34
IT	12 863 741	0.60	3.73	0.39	0.77	2.96	33.08	**59.07**
LT	2 118 482	3.74	0.88	1.64	0.25	0.13	32.58	**64.52**
LU	172 163	1.28	13.64	0.00	0.00	0.00	**81.82**	4.55
LV	3 554 844	3.78	0.45	0.45	0.15	0.00	2.31	**96.65**
ME	1 211 010	0.24	6.90	0.00	0.00	3.45	**44.83**	**44.83**
MK	1 555 010	1.72	3.37	0.00	0.37	0.75	24.34	**71.16**
NL	2 149 009	1.46	**75.08**	4.47	13.10	0.00	5.11	2.24
NO	26 853 695	0.71	4.11	0.00	0.00	0.05	10.38	**85.46**
PL	10 391 452	1.07	3.06	0.36	0.72	0.09	32.61	**63.15**
PT	4 363 549	13.54	2.50	0.05	0.03	3.16	24.25	**70.00**
RO	9 276 446	0.63	1.70	0.17	0.00	0.00	3.40	**94.74**
RS	3 012 934	0.72	4.17	4.17	0.00	7.87	34.26	**49.54**
SE	33 676 541	3.83	0.70	0.01	0.02	0.00	17.50	**81.78**
SI	1 638 862	0.15	25.00	0.00	0.00	0.00	4.17	**70.83**
SK	2 317 327	2.52	0.17	0.69	0.34	0.00	17.67	**81.13**
UK	16 614 904	1.26	6.26	0.00	0.33	0.57	37.41	**55.42**
XK	628 891	0.84	1.89	0.00	0.00	0.00	**77.36**	20.75

Note: The methodology is described in Box 4.3, and the highest proportion of a most dominant land cover flow is highlighted in bold.

* In some cases land cover flows may be unrealistic due to a change in CLC methodology, as for example, may be the case with agricultural mosaic classes in Germany.

AL, Albania; AT, Austria; BA, Bosnia and Herzegovina; BE, Belgium; BG, Bulgaria; CY, Cyprus; CZ, Czech Republic; DE, Germany; DK, Denmark; EE, Estonia; ES, Spain; FI, Finland; FR, France; HR, Croatia; HU, Hungary; IE, Ireland; IT, Italy; LT, Lithuania; LU, Luxembourg; LV, Latvia; ME, Montenegro; MK, the former Yugoslav Republic of Macedonia; NL, the Netherlands; NO, Norway; PL, Poland; PT, Portugal; RO, Romania; RS, Serbia; SE, Sweden; SI, Slovenia; SK, Slovakia; UK, United Kingdom; XK, Kosovo under UNSCR 1244/99.

Source: ETC/ULS, 2016.

Box 4.3 The impacts of land cover flows (LCFs) on the potential of soils to be good carbon pools

The 'capacity of soils to serve as a carbon pool' geospatial data layer was prepared by the JRC in 2016. The values show the ratio between the actual SOC stock (t C/ha in the 0-30 cm horizon) and a potential stock that could be reached under grassland (assuming that, under this land use, the upland (mineral) soils are close to saturation capacity). The values range from 0 to 1, with values close to 1 indicating that the soil is close to its maximum SOC storage capacity. It is important to note that the work was oriented towards agricultural areas; thus, a value of 1 is attributed to all forests.

The soil function data are classified into three production potential (or soil capacity) classes — 'poor', 'average' and 'good'. This classification is based on the value distributions and their statistical parameters (mean and standard deviation). This means that the lower third of all values are classified as 'poor', the upper third as 'good', and the values in between these two classes as 'average'. After reclassifying the soil functions, the selected land cover flows are used as a spatial mask to identify the areas with soil of a certain (e.g. good) potential impacted by a specific land cover flow. The statistics presented in Table 4.1 are expressed as percentages of soil with a good soil function potential (carbon pool) affected by each defined land cover flow.

Source: ETC/ULS, 2016.

the EU, given that the decline in SOC is recognised as one of the eight threats to soil identified in the Soil Thematic Strategy. Against this background, the impact of various land cover flows on this soil function is crucial for the identification of areas of potential SOC decline (e.g. soils affected by urban land take or peatland conversion) or increase (grassland or forest expansion) (Smith et al., 2016).

The concept of the 'good carbon pool potential' of soils allows the most valuable soils in terms of organic carbon content to be identified (Box 4.3). More than half of the soils belonging to this category for each of the countries are affected by several different land cover flows (land use changes). However, the most dominant land cover flows and impacts are due to forest felling or forest creation, except in the Netherlands (Table 4.1).

4.3.2 Emissions to the atmosphere

Exchange of greenhouse gases between soil and the atmosphere is a component of soil natural respiration. Current practices in land use change, land use intensity and agricultural and forestry production operations significantly affect the biogeochemical fluxes of these gaseous substances.

Increasing the production of forest biomass can potentially help to reduce greenhouse gas emissions. At the same time intensive forestry (including for bioenergy) may result in deterioration of soil and water quality (Laudon et al., 2011, p. 253). Some of these potential negative impacts can be reduced by prudent forest management. However, the synergistic effects of climate change and land management on forest soils have been insufficiently studied and documented. At any rate, large-scale bioenergy from additional harvesting of forest biomass through intensive forestry is neither sustainable nor greenhouse gas neutral (Schulze et al., 2012).

Around 94 % of ammonia (NH_3) emissions to the air in Europe stem from agriculture, mainly from activities such as manure storage, slurry spreading and the use of inorganic fertilisers containing nitrogen (EEA, 2016a). Ammonia contributes to deposition of nitrogen leading to terrestrial (and adding to aquatic) eutrophication and acidification of ecosystems. It also forms particulate matter in the atmosphere, which harms human health. Box 4.4 gives an example of a potential strategy to reduce agricultural emissions in Denmark.

The annual EU emission inventory report under the Convention on Long-range Transboundary Air Pollution (LRTAP) shows that NH_3 emissions fell by 23 % between 1990 and 2015 but increased in the EU-28 between 2014-2015 by 1.8 %. The principal key categories for

Box 4.4 Example of reducing agricultural emissions from Denmark

With regard to agriculture, an analysis of potential measures to reduce greenhouse gas emissions in Denmark indicated that a 50-70 % reduction in agricultural emissions by 2050, relative to 1990, would be achievable. The measures included mitigation measures in relation to the handling of manure and fertilisers, optimisation of animal feeding and cropping practices, and land use change, with more organic farming, afforestation and energy crops (Dalgaard et al., 2011). In addition, these authors indicate that bioenergy production may be increased significantly without reducing food production, whereby Danish agriculture could achieve a positive energy balance.

NH_3 emissions are application of inorganic N fertilisers and animal manure applied to soils (EEA, 2017c). Ammonia emissions from agricultural operations are an important part of the overall gaseous nitrogen balance of European landscapes.

Monitoring of air emissions related to land management will be complemented by an accounting framework for emissions and removals of greenhouse gases from land use, land use change and forestry (LULUCF) proposed for the 2021-2030 period (EC, 2016c) .

4.4 Recreational and cultural aspects of land use

The demand for tourism and recreation opportunities has grown steadily over the last 50 years, with a particular emphasis on historical urban centres, coastal zones and islands, as well as picturesque rural areas and mountains. Tourism can also be seen as a land-dependent economic sector, and in this regard land has multiple values for tourism. Two main categories may be identified (Table 4.2).

Land can be seen as a supplier of cultural ecosystem services that sustain the development of tourism and recreational activities. Therefore, land is contributing to quality of life and improving health. However, in most cases, consumption of these cultural services is combined with other ecosystem services, such as 'provisioning' (i.e. game hunting, berry and mushroom picking, honey harvesting) and 'regulation and maintenance' (i.e. micro and regional climate regulation, storm protection, natural or planted vegetation that serves as shelter belts), and will require focused land management to support these cultural ecosystem services.

It is important that tourism-related functional and operational services are not developed at the expense of the attractive natural and cultural features of landscape. Maintaining the right balance is essential for securing tourism as a healthy and resilient socio-economic sector (Photo 4.1).

Table 4.2 Land values for tourism development

Main categories	Subcategories
Land as a space for tourism-related infrastructure and related services	**Transport** network, such as road and rail, and infrastructure such as stations, airports and ports and their respective annexed facilities
	Sports and leisure facilities, such as golf courses, pools, marinas, beach resorts
	Accommodation establishments, e.g. hotels, camping grounds etc.
Land as attractive natural and cultural landscape, i.e. providing cultural ecosystem services for tourism development	**Cultural/aesthetic landscape tourism**: land use bearing cultural values and expressing various aesthetic values, such as those that can be found in certain agricultural land use patterns (groves, vineyards at both low and high altitude, etc.) and spatial organisation (e.g. Alpine farmsteads or, in German, *geschlossener Hof*), in connection with the functional recovery of historical buildings and as a result of the co-evolution of nature and low-intensity livestock grazing.
	Farm/rural/food tourism: this is strictly linked to the previous category and the productive function of land, and it is a rapidly growing market, allowing urbanites to reconnect with nature. Usually, attractive farms are those whose produce and products are environmentally-friendly, sustainable and very closely linked with nature.
	Eco-tourism (including mountain and forest tourism): this is still a market niche but still an important aspect to take into consideration when planning forest and mountain trail management. The revenues from tourism can often provide an incentive for sustainable forest and natural park management too.
	Waterfront/coastal tourism: this is the major segment of summer holidays, which also covers lakes and river banks, where the essence of this amenity is to be by the water, but it may also include wildlife observation (e.g. bird watching).
	Forms of urban tourism in which tourists experience different patterns of **urban landscape** (spatial organisation patterns of cities, open spaces, gardens and parks, including those that have benefited from land recycling to create new land use in urban areas).

The sustainable management of land will require the involvement of different stakeholders and local communities. This can be a result of participatory processes that are a key element of sustainability for the tourism sector. In this regard, raising awareness of and education about ecosystem services is a crucial element to achieve consensus regarding measures for the protection and conservation of habitats in sensitive tourism areas.

Another key element for the sustainable development of the sector is monitoring and measuring the impacts of tourism on land resources. Here, different options are available at the level of sectoral (transport/ mobility) or integrated governance approaches (i.e. adaptive spatial planning, environmental impact assessment, integrated coastal management).

Photo 4.1 Traditional agricultural landscape with high tourism value, such as for accommodation and water sports facilities : Nieuwkoop in the Green Heart of Holland, 30 km south of Amsterdam.

5 Progress in reducing the negative aspects of land use

5.1 The need to secure and sustainably use Europe's land resources

An impetus for an integrated environmental policy is clearly needed (Falkenberg, 2016; SRU, 2016). It can be shown that options are available to defuse conflicts between ecological, economic and social objectives, which at the same time give greater priority to ecological concerns. What is mainly needed are precise and nuanced analyses of relevant problems, a long-term vision and integrated approaches developed jointly in environmental and other policy fields (SRU, 2016).

In the autumn of 2015, the United Nations adopted a plan of action, as the 2030 Agenda for Sustainable Development (UN, 2015). The 17 Sustainable Development Goals (SDGs) set forth in the document constitute an integrated approach. They show that social and economic development, as well as securing peace, can be achieved only if we preserve our natural resources and use them sustainably. Failure to do this, the action plan states, will put 'the survival of many societies' at risk. The EU's Global Strategy, adopted in 2016, integrates the SDGs into coherent EU policies aiming to achieve sustainable development (EC, 2016b).

Land-related objectives, in the European Commission's view, are essential for protecting the environment and safeguarding quality of life, and substantial further efforts will be required, especially to achieve the EU targets of halting biodiversity loss by 2020 and restoring at least 15 % of degraded ecosystems (EC, 2016b). As part of the implementation of the 7th EAP, land- and soil-related objectives are contributing to preserving natural capital and the transition to a low-carbon, climate-resilient, resource-efficient and circular economy. Furthermore, in view of the role of agriculture in determining the condition of the soil and biodiversity, the European Commission seeks to maximise agriculture's contribution to the SDGs.

In response to such policy objectives, a place-based approach is often put forward as a precondition for sustainable development (Barca et al., 2012). The trend towards the focus on ecosystem goods and services, strongly anchored in neo-classical economic principles, has gained momentum in recent years. However, by focusing on single services and benefits, it has led to even greater detachment from the place-based landscape perspective, and it still does not solve the value plurality that underlies the different positions of the various societal groups (Bredin et al., 2015; Martín-López et al., 2014).

To overcome the sustainability quest, Potschin and Haines-Young (2013) defend the need for a place-based approach in the analysis of ecosystem services. The identification of the ecosystem elements that provide the ecosystem service does not explain how these services change. Therefore the land manager, or other users of the landscape, can get consistent information on ecosystem services only by including the context-dependent variations in the landscape perspective.

As the preferences and needs of people are diverse and change over time, it is important, from a regional development point of view, that the European territory offers a choice of different places (Ulied, 2014). The choice of place of location in respect of the specific development conditions of each place ranges from some seeing more rural settings as giving the highest satisfaction to others firmly preferring an urban environment.

In this sense, for the 2014-2020 period, a number of relevant reforms have already been implemented under the EU's cohesion policy, promoting endogenous development and empowering regional institutions, and favouring a more place-based approach, such as the community-led development and integrated territorial investment strategies authorizing local and regional governance.

5.2 Policy response

5.2.1 Policy actions at EU level

A number of intentions and initiatives that have an impact on land use (see Section 1.1) are addressed in EU policies (see, for example, EC, 2016b; EEA, 2016b) identifying specific land-related objectives that will:

- avoid additional land take (e.g. for urban sprawl) and avoid urban sprawl on fertile soils;
- remediate contaminated sites;
- optimise land use to reconcile it with other uses and reverse soil loss;
- halt the degradation of ecosystem services in the EU and restore ecosystems as far as possible by 2020;
- halt the loss of biodiversity;
- invest in green infrastructure;
- reduce the amount of land used for biofuels.

There is growing awareness in the EU that land is a finite resource. Although land management per se is not specifically targeted by EU environmental policies, the EU is taking action to set targets that will lead to more sustainable management of land as a resource. The first step towards this aim was reported in the 2011 Communication from the Commission on a Roadmap to a Resource Efficient Europe (EC, 2011c). The Roadmap's vision is that, by 2020, EU policies will take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take will be on track to achieve the aim of no net land take by 2050.

In 2013, the 7th EAP, which is a crucial policy document for land related policy issues for the period up to 2020, was adopted by the European Parliament and the Council (EU, 2013). The priority areas in which more action is needed in relation to land-related issues are natural capital and resource efficiency. Natural capital explicitly includes land, with the 7th EAP requiring action at EU and national levels to enhance soil protection and sustainable use of land, including forest land. Resource efficiency objectives follow up on the Roadmap. Further EU policy responses to land use changes are addressed by the reform of the CAP (2014-2020), especially by rural development measures and greening the CAP (see Section 5.3).

Land issues are addressed in the Territorial Agenda of the European Union 2020: Towards a more competitive and sustainable Europe of diverse regions (EC, 2011d), an informal strategic policy paper agreed by the ministers responsible for spatial planning and territorial development. This agenda indicates strategic priorities for territorial development in Europe. It identifies the overexploitation of natural resources as a major challenge for the EU: urbanisation, intensification of agriculture and fisheries, transport and other types of infrastructure development, particularly where they take place in a territorially uncoordinated manner, can cause severe environmental problems. It calls for the protection of high-quality soils, ecological systems and landscapes.

Other EU policy documents also highlight the importance of measures that address land take and land degradation. The EU Forest Strategy (EC, 2013d) highlights the importance of maintaining the multifunctional potential of European forests and stresses the provision of vital ecosystem services by forests, managing them in a sustainable and balanced way. It also calls for the protection and maintenance of forests to safeguard them from the increasing pressures on forest ecosystems.

Land management largely determines the diversity and specific character of Europe's landscapes. Fertile land is a critical resource for food and biomass production, and land use strongly influences soil erosion rates and soil functions such as carbon storage. However, there is no specific overall EU legislation on the management of soil resources, despite the large range of activities that ultimately depend on soil. It is the 2006 EU Soil Thematic Strategy (EC, 2006) that is the basis of action in this context. To date, and unlike water and air, soil protection is mainly addressed indirectly or within sectoral policies: agriculture and forestry, energy, water, climate change, nature protection, waste and chemicals. The lack of a coherent soil protection policy at the EU level is also reflected in the scarcity of harmonised soil data (Ecologic Institute, 2016).

With regard to urban areas, in 2006, the European Commission adopted a Thematic Strategy on the Urban Environment (EC, 2006c), which identifies urban sprawl as one of the main challenges faced by European urban areas, and encourages local and regional authorities to adopt an integrated approach to urban management. In 2016, an Urban Agenda for the EU was agreed (EU Ministers responsible for Urban Matters, 2016). The Commission will have a central role in the implementation of the Urban Agenda for the EU, keeping in mind the diversity of cities and their responsibilities and interactions with the wider territory, providing expertise, implementing measures and facilitating the multilevel governance process (EC, 2016b, p. 17).

5.2.2 How national policies can drive change

There is a need to increase awareness of the common value of land- and soil-related ecosystem services and of the long-term economic impacts of losing them. EU- and national-level policy and target-setting can provide strategic direction for effective communication. Six EU Member States or regions have already set quantitative objectives, albeit in very different ways.

For example, Austria, Germany and Luxembourg have defined the level of land take that should not be exceeded. France has stipulated that the rate of agricultural land take should be halved by 2020. And the United Kingdom and Flanders (Belgium) have set a target for 60 % of new housing or urban developments to be on brownfield land (Decoville and Schneider, 2015).

However, strong regional development policies are needed to complement a national strategy. Building on agricultural land is often the most economically competitive option due to its relatively low market value and the fact that — unlike some brownfield sites — no risky decontamination is needed. Regional policy can therefore be crucial for setting precise ceilings for the consumption of previously undeveloped land. This could be most effective if there were greater cooperation between regions — to reduce unnecessary competition for investment and, in some cases, to offset expansion in one area with compensation in another.

In Bulgaria, the Czech Republic, Poland, Slovakia and the Lombardy Region of Italy, the conversion of agricultural land to urban development requires a fee depending on the quality of the soil, the category of settlement and the potential for irrigation. Polish law gives local authorities the option to demand that, when agricultural land is converted, valuable topsoil is removed and used to increase the fertility of other soils or contribute to the reclamation of degraded land somewhere else (EC, 2011c).

In all German regions, two Austrian provinces, Tuscany (Italy) and the autonomous Italian province of Bolzano (Bozen), land-planning guidelines already take soil quality into account and help steer new developments towards less valuable soils. The protection of soil functions in spatial planning is relatively new and depends on growing awareness of the consequences of soil degradation (EC, 2011c).

National targets can be useful in creating broad awareness of the urgency of the situation. However, as recommended in the European Commission's Soil Sealing Guidelines (EC, 2012), goals to reduce soil sealing and land use should be defined on a regional level. Local strategies should define how to reach the goals: therefore federal states (provinces) and municipalities are responsible for implementing appropriate measures in practice (Table 5.1).

Table 5.1 Examples from countries and innovative land management practices

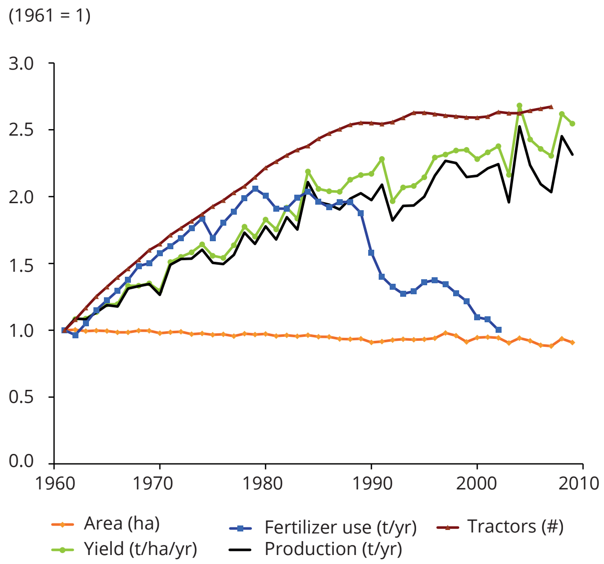
Case	Description
Trends in living space per inhabitant (Germany)	In Germany, the average living space per inhabitant increased from 34.9 m^2 in 1991 to 46.5 m^2 in 2015 (data from DESTATIS, the German Federal Statistical Office, 2015). A similar trend has been reported Europe-wide, but to a variable extent (UN, 2008). Such an increase is not possible within the confines of mature European city centres and it mostly occurs on their periphery. Villages and towns surrounding a city centre compete with each other for the revenue rewards of attracting new inhabitants and new businesses. The changes in associated land cover depend on whether this living space is created horizontally or vertically: decision to build higher may increase energy use but not the requirement for land.
Regulatory interventions to limit urban sprawl (Denmark and Switzerland)	National governments can also introduce novel regulatory interventions to limit urban sprawl and land take. For example, Denmark's 'station proximity principle', adopted in 1989, requires new offices of over 1 500 m^2 to be located within 600 m of a rail station. This has contributed to Copenhagen's efficient, compact urban form (Caspersen and Olafsson, 2010). The urban growth boundaries set by the Swiss Land Use Plan in 1970 have been successful in promoting increased building density and restricting most development to building zones (Gennaio et al., 2009).
Transferable development rights (United States)	Some countries have experimented with ways to increase the economic value to landowners of preserving agricultural land. For example, in a transferable development rights (TDR) market, landowners can sell their right to build. This can result in lower land consumption in areas where there is low demand and increased density of housing where there is high demand. Menghini (2013) highlights the most successful programme in the United States so far, whereby, in Maryland, nearly 7 000 ha of cultivated and uncultivated land was saved from development, and farmers were able to sell TDR as compensation for discontinuing some potential development. Source: Science for Environment Policy, 2016
Agricultural parks and alternative food networks (Spain)	In 1998, EU funding helped an agricultural park to be established near Barcelona, covering 621 mostly family-run farms. Researchers found that, as well as such planning procedures, successful farmland protection requires a strategy to sustain the status of productive farmland. Studying this and other cases, Paül and McKenzie (2013) found that, as long as it is close to a large agglomeration, peri-urban agriculture can be innovatively managed through alternative food networks (AFNs). Instead of focusing on industrial-scale production for export, farms on the urban–rural fringe can help feed their nearest cities and reduce land use impacts of farming. This was found to work particularly well when farmers are actively involved, for example in selling direct to consumers.

5.3 Land use, farming and the reform of the EU's Common Agricultural Policy

Grass and cropland together form a large part (39 %) of Europe's land cover (see Section 2.2). The agricultural sector plays an important role in shaping land use and landscapes across Europe (Photo 5.1). More than 50 % of the arable land in the EU-28 is used for cereal production (Eurostat, 2017a). Although cereal cultivation decreased in terms of area by about 10 % over the 1960-2009 period, the average production of cereals more than doubled (Figure 5.1).

Annually, production results per hectare may vary, due to extreme weather conditions for example. However, increasing yields per area, and thus an increase in land-use efficiency, is a phenomenon to be observed for several crops. Efficiency gains have also been observed for other inputs into the farming process such as in the use of fertiliser (Figure 5.1; EEA, 2016j; Eurostat, 2017b). Such trends are less obvious in other inputs such as mechanisation (represented by the number of tractors in Figure 5.1) which closely follows the trend in production outputs. While comprehensive understanding of the mechanisms underlying these dynamics is still limited (Rounsevell et al., 2012), it is clear that innovation in production methods is a key determinant for the relation between inputs and outputs in agricultural production.

Figure 5.1 Land use change: area change versus cereal production in the EU-27 between 1960 and 2009



Note: Data source: Faostat, online; data indexed to 1961.

Source: Rounsevell et al., 2012.

Farmers are essentially land managers and their decisions about what to cultivate on their fields are influenced by a number of factors, among them markets, policies, biophysical conditions, and socio-cultural aspects. Assessing the influence of policies on landscape requires a solid understanding of the laws of cause and effect (van der Sluis et al., 2015). While there is no doubt that the Common Agricultural Policy (CAP) has had a significant impact on land-use patterns in the EU over recent decades (Kristensen et al., 2016), energy and climate policies, for example, have driven the increase in energy crop production over the last decade as well (OECD and FAO, 2017).

The CAP is a complex policy system that has evolved through a series of reforms (Cunha and Swinbank, 2011). These reforms cannot be comprehensively discussed in this report (see e.g. EP, 2017; Terluin et al., 2017), however a brief overview of development trends and some examples of how CAP instruments have influenced the development of rural landscapes can be presented.

Since its introduction in 1962 the CAP has fulfilled its objective of securing food supplies (European Parliament, 2017). After phases of guaranteed prices and export refunds, which led to over-production, direct aids per hectare were introduced in 1992, and guaranteed prices were reduced. The second pillar of the CAP, and therefore rural development policy with strong structural and socio-economic dimensions, was established in 1999 through the Agenda 2000 process. Environmental cross-compliance (Box 5.1) was also set as a condition for granting aids to farmers. Subsequent reforms in 2003 and 2009 reinforced the trends of decoupling with the introduction of the Single Payment Scheme, the structural orientation in Pillar 2, and a focus on environmental standards.

Box 5.1 Summary of environmental cross-compliance measures

Cross-compliance rules consist of statutory management requirements (SMR) under EU law and standards for good agricultural and environmental conditions for land (GAEC) established at the national level. They relate to environment, climate change, and good agricultural condition of land; public, animal and plant health; and animal welfare (ECA, 2016). For the current CAP funding period (2014-2020) key features of cross-compliance are listed in Annex II of Regulation (EU) No 1306/2013.

Next to coupled support, specific measures, which have been introduced over time, had effects to production patterns. Particularly relevant from a land use perspective are payments for Less Favoured Areas in 1975, forestry measures in 1985, extensification of production (1987-1997), aid for set-aside of arable land in 1988-1992 and agri-environmental measures in 1992. There are many examples how CAP measures have led to landscape changes like land abandonment across Europe, such as cases taken from the Mediterranean region (Serra et al., 2008) and mountainous areas (MacDonald et al., 2000). Furthermore, in the late 1990s, CAP measures stimulated the afforestation of agricultural land. This meant that large areas of former crop and grazing land in the most marginal areas were once again afforested (Barbati et al., 2011).

Conceptually the CAP design for the current 2014-2020 period followed the trends of the previous reforms, yet focused on counterbalancing some of the negative environmental impacts with which the originally production-oriented CAP had been associated with (EEA, 2016b). Moreover, the joint provision of public and private goods was placed at the core of the policy (EC, 2013d). The principal objectives of the current CAP focus on viable food production; sustainable management of natural resources and climate action; and balanced territorial development.

As in the previous funding period, the CAP rests on two pillars: Pillar 1 covers direct payments and market measures, and Pillar 2 covers the full spectrum of rural development, not just farming (Box 5.2).

Box 5.2 Structure of the CAP budget

A total of 37.8 % of the EU multiannual financial framework for 2014-2020 is assigned to measures under the CAP, corresponding to EUR 408 billion. Pillar 1 has a budget of around EUR 313 billion, and Pillar 2 EUR 96 billion (in 2013 prices, and without considering Member States' shifts between both pillars (EC, 2013d)). Under Pillar 2, there is a portfolio of measures, from which Member States or regions can select suitable ones for their Rural Development Programmes, such as investment support to farmers, agri-tourism, village renewal (e.g. support for the renovation of streets or community buildings) or support to the management of Natura 2000 sites. Most of these measures have to be co-financed by national, regional or private funds.

However, in the current 2014-2020 period the architecture of 'green payments' changed, with the introduction of 'greening measures' under Pillar 1, to which 30 % of the budget for direct payments is allocated, available to eligible farmers when following the greening obligations (see Box 5.3). Overall, payments related to sustaining the environment in the current CAP follow a stepwise approach to achieve cumulative environmental benefits: a) the regulatory requirements of Cross-Compliance form the baseline for receiving payments under most CAP measures; b) the obligations, which are mandatory with the greening measures; and c) Agri-environment-climate measures, in which farmers can participate voluntarily and are paid for costs and income foregone related to demands which go beyond cross-compliance and greening obligations, e.g. for not using pesticides or establishing parts of their fields where flowers are sown, so called 'flowering strips'.

Further measures in the current CAP, which are likely to have influence on production decisions and subsequently on land-use patterns, are coupled payments, which Member States may offer under Pillar 1, e.g. for protein crops and sugar beet, and under Pillar 2, e.g. payments for areas with natural constraints and organic farming. In addition, under the Rural Development Programmes, — among others — advisory schemes and research and development (R&D) are supported, for example under the European Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI). This aims to stimulate the sector's competitiveness, further sustainable farming practices and innovation, and to increase efficiency, whereby the latter is directly related to land-use efficiency (see Figure 5.1).

The results of the greening measures on land use patterns have already become visible, e.g. the

Photo 5.1 Agricultural landscape in Central Europe.

Source: Pixabay.com

Box 5.3 Overview of the 'Greening measures' in the CAP direct payments scheme for 2014 - 2020

30 % of EU Member States' direct payment budgets are allocated to the so called 'Greening measures'. They can be regarded as decoupled 'green payments' per hectare under CAP Pillar 1. For receiving those payments, most eligible farmers do not only have to comply with cross-compliance, but also with additional obligations, which include:

- improving crop rotations and increasing the number of crops on farms to move away from monoculture while maintaining permanent grassland;
- maintaining ecological focus areas (EFAs), of at least 5 % of the arable area of a holding such as landscape elements, nitrogen-fixing crops, field margins, buffer strips, green cover;
- maintaining permanent grassland, with a ploughing ban in designated area, and national/regional ratios with 5 % flexibility.

These measures aim at supporting the conservation of the environment and contribute to addressing greenhouse gas emissions by:

- making soil and ecosystems more resilient by growing a greater variety of crops;
- conserving soil carbon and grassland habitats associated with permanent grassland;
- protecting water and habitats by establishing ecological focus areas.

Source: Based on EC (2017c).

production of nitrogen-fixing crops, which can pull nitrogen from the atmosphere and make it accessible to plants, as Ecological Focus Areas (Box 5.3) (EC, 2017b). However, the further impacts of these greening measures on the environment can only be assessed many years from now. More information will be needed to assess adequately the effectiveness of these measures (ECA, 2016).

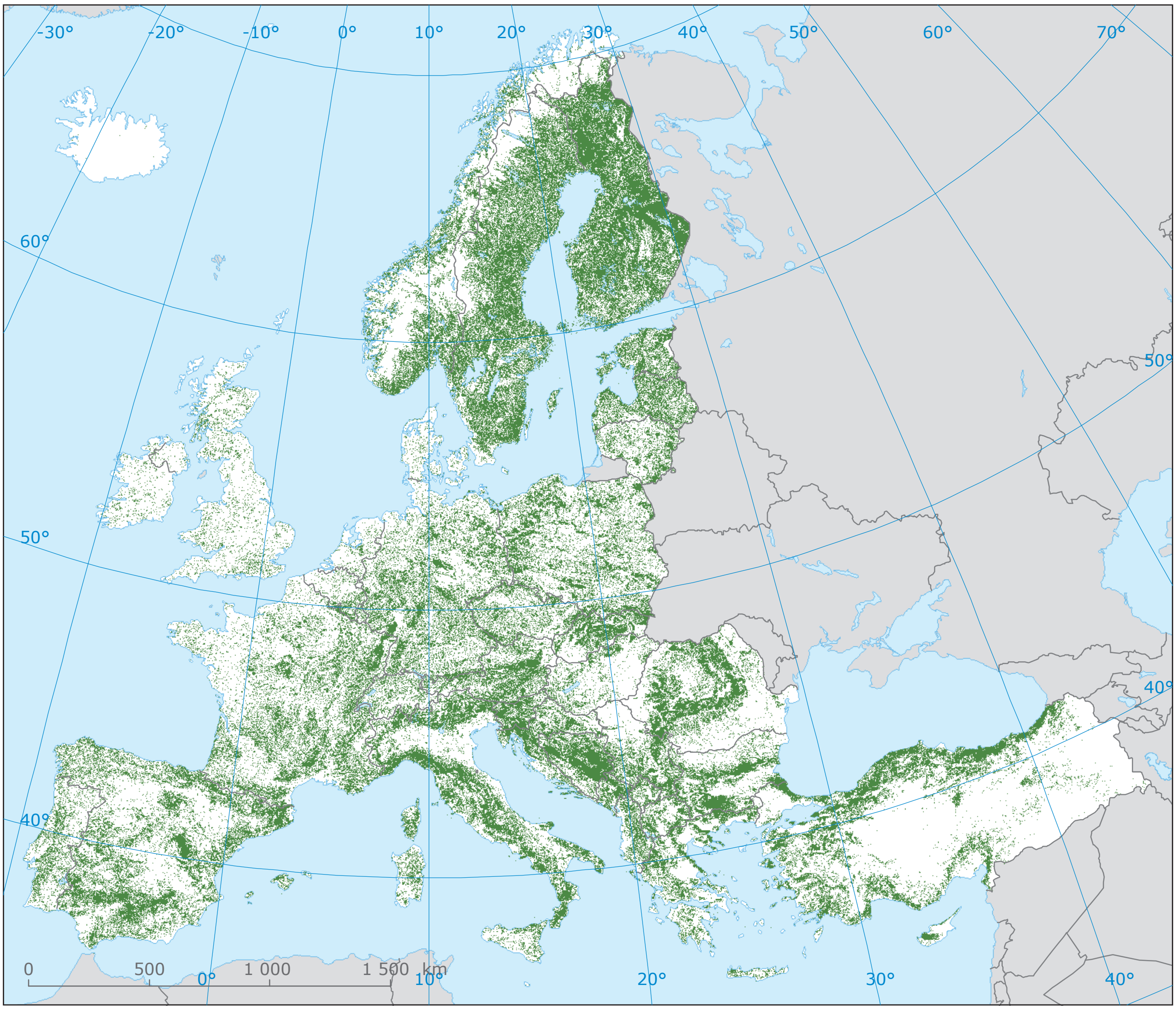
Discussions on the CAP post-2020 have already started and several stakeholders point to the crucial role of the delivery of public goods and results-based agri-environment schemes which are only offered in some Member States (ENRD, 2016). Contributing to the UN Sustainable Development Goals (SDGs) (Fig 5.4) will also be important. It remains to be seen how the focus on public goods and SDGs will manifest itself in policy design and subsequently in land-use patterns, as other influencing factors, including climate change and market trends will also be important. Yet, under the premise of current policy framing conditions, for agricultural land use in the EU, the outlook report up to 2026, jointly published by the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO), predicts a decrease in the overall agricultural area (to smaller rates than in the last decade), and a decrease of cropland due to urbanisation, afforestation and re-conversion of cropland into permanent grassland (OECD and FAO, 2017).

5.4 Forest management and habitat protection

In many European landscapes, forest is the dominant land use, or it is at least as important as farming, which determines the character of the land use alone or in a mosaic with farming (Map 5.1). Forest landscapes have a history and character of their own (Stanners and Bordeaux, 1995), which is strongly connected to the range of natural vegetation of the European continent (Bohn et al., 2003). Typically, forestry and farming were combined in what are today called agro-silvopastoral systems (see Photo 1.9), or silvopastoral systems, which often led to open farming areas.

The lowest proportion of forest in relation to total land cover was reached during the early 20th century, although there were considerable differences between regions. Compared with 1960, the area of European forests in 1990 had increased by about 4 million hectares (almost the size of Switzerland),

Map 5.1 Forest distribution in Europe, 2012



Forest distribution in Europe, 2012

Forest

Non-forest

Outside coverage

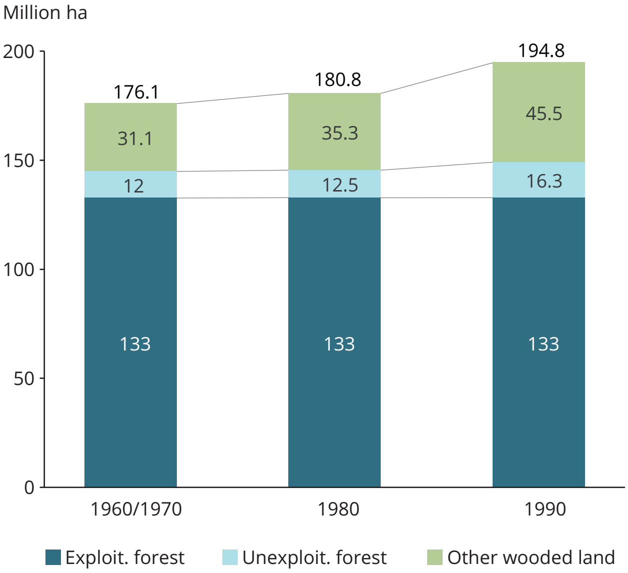
Source: EEA, 2016c.

due to afforestation of treeless land, shrublands, fields and pastures, which more than compensated for the conversion of forest into other land uses (Kuusela, 1994). When considering *other wooded land*, which does not meet the UN Food and Agriculture Organization's definition of forest, the increase in forest land in Europe was considerably larger (see Figure 5.2). Other forest parameters in Europe have changed even more (Figure 5.3). While the forest area has increased, the growing stock has increased much faster, despite the fact that harvesting, e.g. for timber, has also increased.

Since 1990, forested land in the EU-28 continued to increase as a result of afforestation programmes, natural succession of vegetation and abandonment of farming (Photo 5.2). More than half of these new forests are planted. Today forests and other wooded land in the EU-28 amount to about 180 million hectares, making Europe one of the most forest-rich regions in the world, with more than 42 % of its land covered by forests (Eurostat, 2016b).

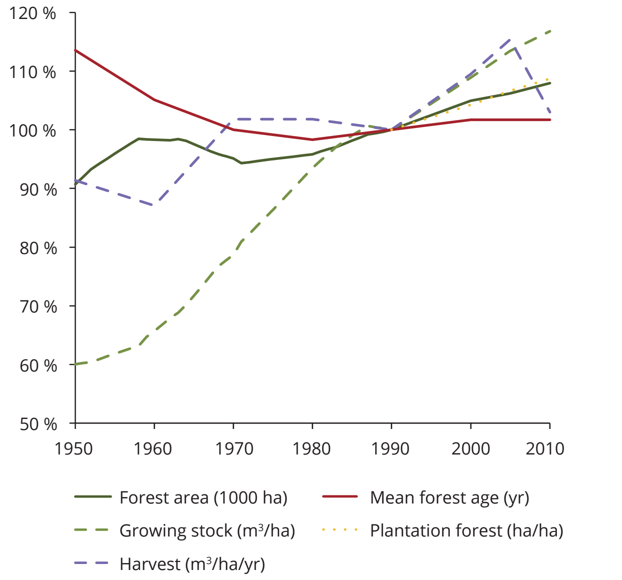
The area of protected forests in Europe increased by around half a million hectares annually between 2000

Figure 5.2 Estimates of exploitable and unexploitable forest and other wooded land in Europe in the 1960-1990 period



Source: Reproduced from Kuusela, 1994.

Figure 5.3 Area changes and management intensity changes in Europe's forests compared with 1990



Source: Kuemmerle et al., 2013.

Photo 5.2 Forest encroachment and photovoltaic panels installed on abandoned agricultural terraces (Lesvos, Greece)

and 2010 and is about 12 % of the total forest area. Half of the protected forests are managed for conservation of biodiversity. Forests represent more than 45 % of the Natura 2000 protected areas (31.3 % of the national designated protected areas).

Despite efforts to halt loss of biodiversity, 70 % of forest habitats in Annex I of the Habitats Directive still have an unfavourable conservation status, i.e. about 28 % of all forests in the EU-28 (EEA, 2015c).

The overall increase in forest cover has been followed by a drastic change in the composition and use of some of Europe's forest areas (see also Map 2.3). At present, there are still some forests in Europe, which may be considered primary forests, where the forest dynamics follow natural processes (see Photo 1.7). The area of forests undisturbed by man ([14]) in the EEA-39 (except Kosovo under UNSCR 1244/99) has been assessed to be approximately 6 million hectares (< 3 % of all forests and other wooded land) (EEA, 2016c).

However, the majority are semi-natural forests, e.g. man-modified forest communities shaped by silviculture or agro-forestry, so that the forest structure and composition of species have been changed from the original natural situation and potential vegetation.

The plantation represents a particular type of forest, as it is established by planting or seeding in the process of afforestation or reforestation. Intensively managed boreal forests (particularly coniferous stands) are subject to intensive felling and replanting, and although these forests are generally recognised as natural forest area and are sometimes the result of natural reforestation, such forests in fact can be considered plantations as well. Land cover conversions that are related to forest management are a predominant factor in overall land cover change in Europe (Table 2.3 and Map 2.3).

Europe is becoming greener. In many areas, the past 100 years have seen periods of widespread abandonment of marginal agricultural land and a gradual, but substantial, increase in forest land (Fuchs et al., 2015).

On the one hand, the abandonment of farmland can be considered as an opportunity to rewild ecosystems, particularly in highly fragmented landscapes where it could provide significant large-scale restoration of specific habitats. Many often iconic species (Photo 5.3) will benefit from rewilding and natural habitat regeneration. Positive effects are also associated with ecosystem services such as carbon sequestration and opportunities for recreation and tourism development (Tomaz et al., 2013). Rewilding also provides space for ecological processes at the ecosystem scale.

On the other hand, rewilding will decrease the area of semi-natural habitats that has traditionally been managed by low-intensity agricultural use (such as grazing) and its associated species of nature conservation importance, many of which are concentrated in Natura 2000 sites and HNV farmland.

Photo 5.3 Lynx, an iconic species for rewilding areas

5.5 Resource efficiency for land and soil

The vision of the 7th EAP is turning the EU into a resource-efficient, green and competitive low-carbon economy. This applies also for land and soil that are regarded as a resource that should not be degraded. Furthermore, 'a land-degradation neutral world' as promoted at the Rio 2012 conference under SDG, target 15.3 (Griggs et al., 2013), explicitly addresses land use as a fundamental issue of concern (see also Figure 5.4).

Land take and land use intensification can have a considerable impact on soils (Smith et al., 2016) and

([14]) According to the Forest Europe definition: forests in which the natural structure, composition and function have been shaped by natural forest dynamics with no or little human interventions over a long time period, allowing for re-establishment of the natural species composition and processes.

Figure 5.4 Land's part in the Sustainable Development Goals

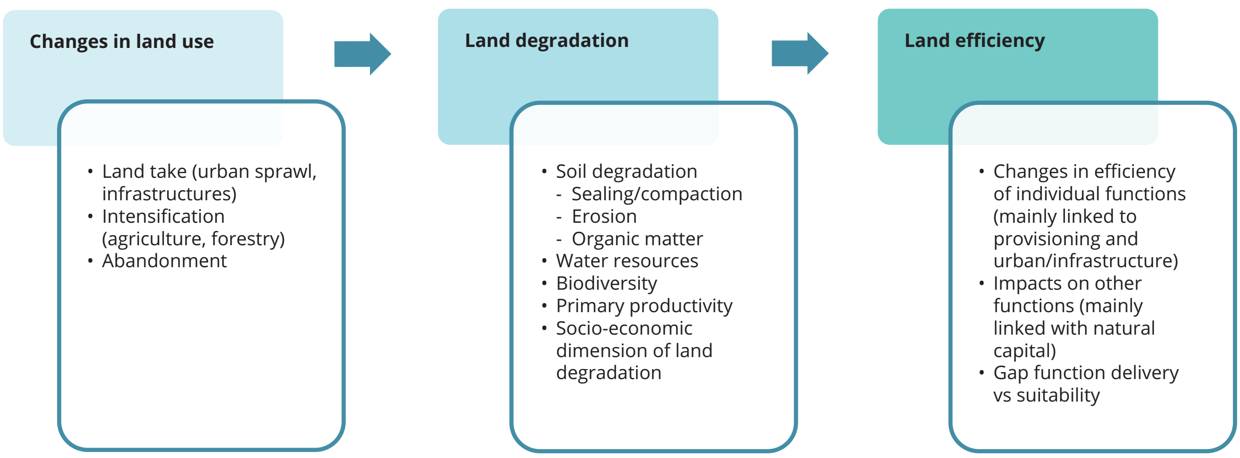
Source: UN Sustainable Development Goals and European Commission.

eventually undermine soil functions and lead to an overall decline in land resource efficiency (Figure 5.5). Land degradation (e.g. by erosion, compaction, sealing and salinisation) affects a significant proportion of Europe's land area (Section 4.3).

Competition for land — when several agents demand the same good or service produced from a limited area — implies that, when one agent acquires scarce resources from land, fewer resources are available for competitors (Haberl, 2015). However, the resource competed for is often not land but rather its function, e.g. for biomass production, which may be supplanted by other inputs that raise yields. Increased competition for land (or a function) may promote efficient use of land, but negative environmental effects are likely without sufficient regulation.

Competition between stakeholders is likely to result in adverse social and developmental outcomes if not mitigated through effective policies. The demand-supply

Figure 5.5 Links between land take, land degradation and land efficiency



Source: EEA, 2016b.

aspects of the land system (see also Figure 1.1) are central to the policy response cycle to increase the resource efficiency of land use and provide balanced solutions in land allocation trade-offs (Figure 5.6).

Existing legislation, such as the Strategic Environmental Assessment Directive (EC, 2001), applies to a wide range of public plans and programmes (e.g. on land use, transport, energy, waste, agriculture) and provides useful means of assessment, but strategic environmental assessment needs to be implemented more systematically, including for efficient management of land (EC, 2013c). Territorial analysis and especially spatial planning is essential for sustainable management of land resources across scales — national, regional and local, and including urban (EEA, 2015d).

5.6 Maximising land use benefits across all land functions

Since the 1970-1990 period, land use has become increasingly specialised (Pedroli et al., 2016), and with this a territorial polarisation in Europe's landscape is taking place. On the one hand, this results in highly productive intensive farming and forestry areas (van Vliet et al., 2015) and, on the other, increasingly marginalised small-scale farm mosaics and extensive land use systems, or even abandoned land (Estel et al., 2015; Kapfer et al., 2015; Pinto-Correia and Breman, 2009).

Where there are advantageous biophysical and structural conditions for agriculture, farm production is often a main driver of land use changes (Primdahl and Swaffield, 2010). The farming landscape often has a modernised structure, with large fields and neat boundaries between different parcels.

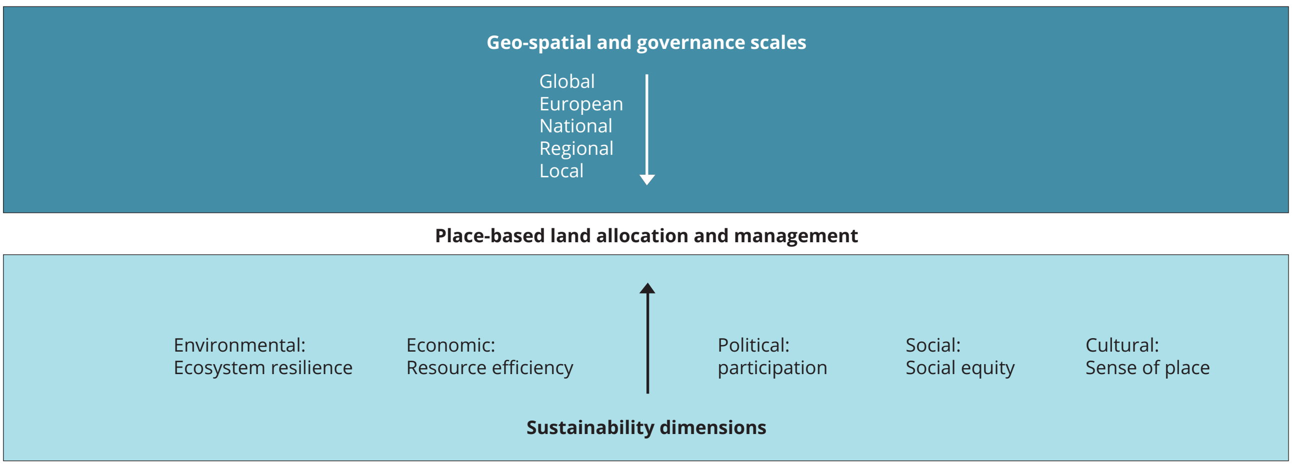
Although society's demand for land functions related to environment regulation, recreation and quality of life has been increasing (Stobbelaar and Pedroli, 2011), the farming sector needs to produce and be competitive in a global market. This requires agricultural production to improve its efficiency and remain socially acceptable and environmentally sustainable, while also creating attractive landscapes for both rural and urban citizens (Photo 5.4).

Competition for space between market-oriented intensive agriculture and other land uses, such as urbanisation or preservation (maintenance) of attractive and diverse rural landscapes, is especially pronounced in peri-urban areas.

Areas with marginal agricultural production (Photo 5.5) are often highly appreciated by society for their natural and cultural heritage values, but also

Photo 5.4 High-intensity cereal production can offer a feeding ground for barnacle geese (Skåne, Sweden)

Figure 5.6 **Dynamics in the land system that guide land allocation and management**



Source: http://www.eea.europa.eu/soer-2015/europe/land.

as the basis for recreational and cultural activities. However, these values are not well integrated into the modern farming discourse and ideals (Pinto-Correia and Kristensen, 2013). Such additional societal expectations — especially in peri-urban areas — could be the basis for innovative forms of rural management, eventually leading to the emergence of new societal roles for farming (Barbieri and Valdivia, 2010; van der Ploeg, 2009).

At the same time, in many remote regions, extensive agriculture represents HNV farming systems. While these are highly appreciated by society, their maintenance remains a challenge (Oppermann et al., 2012), due to the low productivity, and modest investments and entrepreneurship associated with this farming sector, which lead to limited capacity for innovation (Pinto-Correia et al., 2014).

The medium-intensity land use that is typical of Europe is characterised by family farming (Davidova and Thomson, 2014) (Photo 5.6). The future of the small and medium-sized (family) farm, which has given the European landscape its appearance, is far from secure, and it is not certain whether or not such farms would safeguard the diversity of the European landscape (and its associated biodiversity) in the future (Bartoli and De Rosa, 2013).

Photo 5.5 Low-intensity Mediterranean land use (Feuilla, near Perpignan, southern France)

Photo 5.6 Medium-intensity land use (Low Carpathians, Slovakia)

Farm management has attempted to diversify, and the greening of agricultural production policies, supported by rural development programmes, reflects a quest to combine production with environmental protection. However, the demand for multifunctionality has also overwhelmed agriculture: many of the functions that society expects today from rural areas cannot be provided by a single farm or managed by individual farmers (Domon, 2011; Pinto-Correia and Godinho, 2013; Selman, 2009). Therefore, some territorial specialisation, preferably driven by the functional suitability of land, i.e. in terms of natural production conditions and logistical location, seem to be appropriate.

To conclude, it seems that European society is at the crossroads between the demand for food, feed and fibre production and socio-cultural demands for multifunctional land use that serves a multitude of societal functions.

6 Looking forward

6.1 Towards sustainable land use

Societal demands for land development have been reviewed in recent years (Maes et al., 2015; Paracchini et al., 2011; Pérez-Soba et al., 2015; Zasada, 2011). Many land use modelling exercises have studied options for future land management in Europe (Kuemmerle et al., 2016; Lavalle et al., 2011; Lavalle et al., 2013; Verkerk et al., 2016). Some common conclusions can be deduced from this evidence.

The generally adopted scenarios for global economic and societal development show a strong polarisation of land functions in Europe in the near future (EC, 2011a; Rounsevell et al., 2012), in particular pertaining to 'land sharing' (aiming to integrate goals for food production and biodiversity protection on the same land) and 'land sparing' (aiming to separate intensive farming from protected ecosystems at the larger scale) (Phalan et al., 2011). Continuing current trends, land sparing seems a much more likely prospect than land sharing over large parts of Europe, with the possible exception of peri-urban landscapes.

Nevertheless, the majority of the visions expressed in stakeholder consultations aim for a considerable degree of multifunctionality or polycentricism (Pérez-Soba et al., 2015; Ulied, 2014; van Vliet et al., 2015). However, policy alternatives do not always achieve that target even if they set out to do so (Box 6.1).

This planning paradox requires due societal consideration and debate, especially because it seems that neglecting the long-term consequences of current trends could lead to almost irreversible land transitions, including uncontrolled land abandonment (Estel et al., 2015), soil degradation (Panagos et al., 2015), decrease in biodiversity (Zisenis et al., 2013), loss of ecosystem services (Stürck et al., 2015) and decline in the liveability of rural areas (Pedroli et al., 2016).

The SEI-Milieu Consortium (2010) identified a number of key global megatrends that are likely to be particularly important for Europe's environment. In terms of impacts on the land system, the relative importance of the global megatrends is different, related to substantial transition processes such as land take, land abandonment, land recultivation, land use intensification, land grabbing, land degradation and soil pollution, and their subsequent effects on ecosystems and landscape quality. Table 6.1 gives a general indication of some of the major relationships of the global megatrends and the land system.

Some of these impacts are evident — such as the effects of growing pressure on ecosystems on the provision of ecosystem services (Wolff and Kaphengst, 2015). Other impacts are more complex, and imply intricate cross-relationships between various global megatrends. The summary of the impacts of global megatrends on land for some last decades is presented under five main themes (Box 6.2), as elaborated in the FP7 project Volante ([15]) (Pedroli et al., 2015a).

Table 6.1 Relationship of global megatrends (GMT) and the land system in Europe

Theme		Global megatrend	Impact on land	Volante fact sheet
Social development	GMT1	Diverging global population trends	Land abandonment, recultivation	P3 Agricultural abandonment, recultivation and intensification V6 Agricultural abandonment
	GMT2	Towards a more urban world	Land take, urban sprawl, more transport infrastructure	P5 Drivers of change A12 Zoning for compact cities
	GMT3	Diseases and pandemics	(Redistribution of animal farming)	

([15]) Visions of Land Use Transitions in Europe: http://volante-project.eu/.

Table 6.1 Relationship of global megatrends (GMT) and the land system in Europe (continued)

Theme		Global megatrend	Impact on land	Volante fact sheet
Technology	GMT4	Accelerating technological change	Precision farming and irrigation	A7 Agricultural productivity increase A8 Bio-based economy and bioenergy
Economy	GMT5	Continued economic growth?	Land pressure, land grabbing, land degradation, soil pollution	A13 Climate change impacts with respect to flood protection
	GMT6	Increasingly multipolar world	Various	A15 Increased trade barriers for higher EU self-sufficiency
	GMT7	Intensified global competition for resources	Land grabbing, bioenergy cropping on marginal lands	P1 Displacement effects P5 Drivers of change
Environment	GMT8	Growing pressures on ecosystems	Loss of land-related ecosystem services and landscapes	A24 Ecosystem services
	GMT9	Increasingly severe effects of climate change	Erosion, flooding, desertification	A13 Climate change impacts with respect to flood protection A14 Climate change mitigation and agricultural emission taxes
	GMT10	Increasing environmental pollution	Soil pollution, land degradation	A6 Nitrogen and water quality
Governance	GMT11	Diversifying approaches to governance	Irrational land use transitions	P5 Drivers of change

Sources: Qualitative assessment based on EEA, 2015b, Volante fact sheets (see www.volante-project.eu) and literature cited therein.

6.2 Urban development — smart and sustainable

Globally, a majority of the world's population is already living in urban centres and this century will see this trend continuing. This increasing urban growth will influence the associated land use, creating challenges for urban and rural life. This has led to the adoption by the General Assembly of the United Nations in 2016 of a New Urban Agenda — 'an action-oriented document which sets global standards of achievement in sustainable urban development and rethinking the way we build, manage, and live in cities' (UN, 2016).

The agenda is to be seen as key development opportunity for promoting a new model of urban development that is able to integrate all facets of sustainable development and turning the urbanisation challenge into an opportunity to promote human wellbeing and quality of life while protecting the environment. As such, it is a strong support for SDG 11 of making cities inclusive, safe, resilient and sustainable (UN, 2015).

Also in Europe, environmental quality and social issues have long dominated how cities are seen — more as a problem than a potential. Despite progress, these issues have not disappeared. Cities today, however, are increasingly recognised for their economic, social and environmental potential and may have substantial consequences for land use management in the entire land area of Europe, because the economic power of cities is also growing. Between 2000 and 2013, the growth in gross domestic product in cities was 50 % higher than in the rest of the EU, and employment in cities grew by 7 % while it declined slightly in the remainder of the EU.

Population growth in cities is a major land use driver and is fuelled by higher natural change and higher net migration. People of working age in particular tend to move to cities looking for education and job opportunities, while those over 65 tend to move to less expensive locations (towns, suburbs or rural areas). Due to these movements, city dwellers tend to be younger, and projections indicate that demographic ageing among city populations is slower (see also Box 4.1). In particular, the capital cities tend to have the highest population growth, as well as the highest proportions of working-age and foreign-born populations, within their country.

Many European cities provide excellent examples of how innovation can foster urban development, and some of these cities are quite moderate in size, such as Eindhoven (NL) or Cambridge (UK). Due to the dense and well-connected network of cities in Europe, some benefit from 'borrowed size' (EC/UN-HABITAT, 2016, p. 64). This means that cities in close proximity to others can become more productive than their size alone would predict, which also benefits rural development and overall balanced territorial development, as promoted by the Territorial Agenda of the European Union 2020 (EC, 2011d).

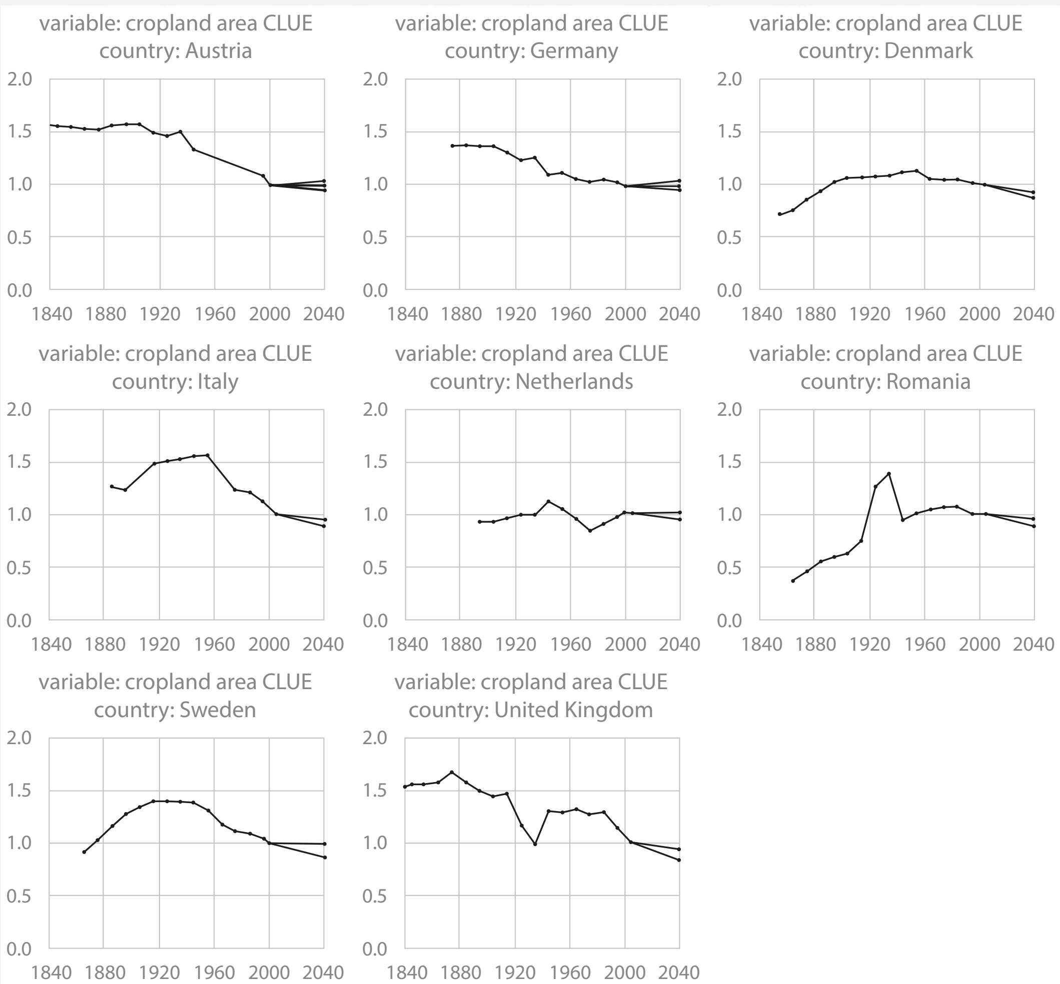
Box 6.1 Visions of future land use in Europe

The Seventh Framework Programme (FP7) project Volante came to the conclusion that it is very difficult to define and model a feasible pathway towards a multifunctionality target, because the dominant societal trends do not support this vision (Pedroli et al., 2015b). Following current trends, a future that is substantially different from 'business as usual' is difficult to set out (Verkerk et al., 2016).

Even when choosing quite radical pathways (increasing nature protection measures beyond those set out for the Natura 2000 network, or payment for recreational services) under a relatively modest economic development scenario such as scenario B2 (a world with emphasis on local solutions to economic, social and environmental sustainability (IPCC, 2000)), regional-scale multifunctional land use (the 'regional connected' vision) can be achieved only to a very limited extent in the various regions of Europe.

The cropland trajectories in the scenarios appear to be within the range of historical changes (Figure 6.1). In most cases, however, the pronounced reduction has not been continued, but rather cropland area is stagnating. There is a particularly pronounced reduction that is somewhat steeper than past decadal trends in the pathways with increased 'Nitrogen and water quality policies' for the Netherlands and for Sweden (Kuemmerle et al., 2014). The range across all pathways is, however, small (– 20 % to + 4 %).

Figure 6.1 Data-derived national cropland area trajectories between 1840 and 2005, contrasted with scenario results from the CLUE model for 2010-2040. Y-axis: indexed to values of 2005 (historical data) and 2000 for scenario results



Source: Kuemmerle et al., 2014.

Box 6.2 Summary of the main impacts of global megatrends on Europe's land use

Social development

Diverging global population trends will not only have a direct influence on the amount of land cultivated in less populated areas (often leading to land abandonment), but will also indirectly influence the pressure on land resources and the incidence of diseases and pandemics, which, in turn, will have an impact on land management. Other evident effects will be caused by urbanisation and greater mobility, leading to urban sprawl, soil sealing and associated increasing greenhouse gas emissions, even though the EU has agreed on a no net land take target by 2050 (EC, 2011c). The trend of peri-urban areas growing much faster than urban areas in Europe (Piorr et al., 2011) will not easily be stopped by urban planning and will lead to land consumption and decreasing agricultural land use. The urban–rural balance will definitely change accordingly (Eppler et al., 2015). Although (human) diseases and pandemics are not likely to directly affect European land use, the threat of animal diseases that might affect human health (bird flu, Creutzfeldt–Jakob disease, Q fever, etc.) may require restructuring of animal husbandry systems through land use planning measures (Butler, 2006).

Technology

Evidently, technological progress will have large impacts on land, primarily by increasing the production efficiency of agriculture through precision farming, advanced plant and animal breeding and sophisticated irrigation and drainage techniques. This may lead to less land demand and land abandonment in areas of less suitable soils.

Economy

Continued economic growth is powering much of the other trends, but it will also lead to pressures on the land to provide new functions (including roads and urban development), to land grabbing in Europe (Franco and Borras, 2013), to land degradation by over-exploitation, and to soil pollution. The increasingly multipolar world is a trend with complex and largely unpredictable impacts on European land use. But it is very likely that the changing balances in major production regions in the world will have substantial impacts on European land use too. In addition, intensified global competition for resources may lead to increasing land pressure on the best soils and production areas (e.g. good-quality wines, cheeses), and open up marginal lands for bioenergy cropping.

Environment

Growing pressures on ecosystems lead to loss of land-related ecosystem services and of the identity of the rural landscape and may affect the quality of life in rural areas, and consequently also that of urban populations enjoying rural life for holidays and recreation. The direct effects of climate change on the land can already be observed in changing patterns of flooding (Arnell and Gosling, 2016; Kaspersen et al., 2015), erosion (Panagos et al., 2015) and desertification (Huang et al., 2015; Salvati et al., 2015). Although increasing environmental pollution does not seem a major issue in Europe, where acid deposition has decreased since the 1980s, increasing yield losses in other continents due to environmental pollution and high ozone concentrations may lead to extra pressure on the land in Europe.

Governance

Diversifying approaches to governance, even within Europe, may lead to shifting balances in the production potential of the land and especially in land prices. In addition, well-developed land management and regional planning may have substantial regulating effects on, for example, urban sprawl (van der Valk and van Dijk, 2009). The current tendency in most European countries is, however, one of decreasing governmental regulation of environmental issues (Collier, 1998; Mol, 2016). What is remarkable is, for example, the decline in staffing in the environmental ministries of selected member countries of the Organisation for Economic Co-operation and Development (OECD), among which Austria, Denmark and the Netherlands stand out (Mol, 2016, p. 54-55).

More households in cities live in more crowded dwellings than in towns, suburbs and rural areas. Access to green space can help to make dense urban living more acceptable. However, good access to green space is not related to the proportion of green space within a city but rather its distribution across the different neighbourhoods. Increasingly, natural wetlands, networks of city parks, green roofs and other nature-based solutions are used to reduce disaster risk and provide opportunities for adaptation to climate change, while improving the quality of life in cities and the rural environment alike. Sound strategies for urban river and lake management should play a fundamental and integrated role in this context (EEA, 2016d).

The Urban Atlas ([16]) (a product of Copernicus land monitoring) provides pan-European comparable land use and land cover data for almost 700 functional urban areas with more than 50 000 inhabitants, as defined by the Urban Audit. The first set of change data, for 2006-2012, has become available, allowing detailed monitoring of green urban areas and land use change.

Smart and sustainable solutions for urban development issues will be needed to foster responsible land management. For example, land recycling and densification can be understood as redevelopment of previously developed land (brownfield) for economic purposes, ecological upgrading of land (e.g. green areas in the urban centres) and re-naturalisation of land (bringing it back to nature) by removing existing structures and/or de-sealing surfaces (EEA, 2016g). Further progress can be made towards sustainable urban and rural development through the wise use of water resources (EEA, 2016d) and better handling of urban waste ([17]).

Many European cities are forerunners in the much-needed transition towards a low-carbon, resource-efficient and competitive economy. The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) ([18]) aims to link and upgrade infrastructures, technologies and services in key urban sectors (transport, buildings, energy, information and communications technology) in a smart way that will improve quality of life and the competitiveness and sustainability of our cities. As an example, one of the measures rolled out in 2016 was for 10 cities and regions with partners to collaborate in developing smart mobility services and to replicate that innovation in up to 50 cities. Such efficiency gains can also promote more sustainable land management in cities.

Considering the above, urban areas play a key role in pursuing the EU's 2020 objectives and in solving many of its most pressing challenges. The success of sustainable urban development is highly important for the economic, social and territorial cohesion of the EU and the quality of life of its citizens both in (peri-)urban areas and in the rural countryside. An inspiring territorial vision for Europe (Ulied, 2014) is necessary to improve the living and working conditions of all citizens.

6.3 Knowledge gaps and the way forward

Although there is sufficiently good understanding of land cover change and the associated drivers and impacts at both European and national scales, there are still crucial gaps in our knowledge to allow us to manage land in Europe in an environmentally and societally sound way. Some of the questions still to be answered are:

- *Monitoring and reporting data*. What data are needed for better land assessments? Do we need more data, or more understanding of processes? The Copernicus programme provides much detailed evidence of land cover change at various scales that needs to be verified with ground truth (in situ). The interpretation of collected monitoring data, e.g. to produce policy-relevant indicators, needs more work. In addition, the lack of a coherent system for reporting and collecting soil data from countries is reflected in the scarcity of harmonised soil data at the European level. EU initiatives such as LUCAS (see Section 3.3.3) can only partly satisfy that need and better access to data on agricultural land use and forest management is needed. The new land use, land use change and forestry (LULUCF) reporting requirements proposed under EU Climate action policy ([19]) will likely create a new data flow to be integrated (EC, 2016c).

- *Land use and management.* How can the information on land cover change be better translated in terms of land use and management? Both modelling approaches and comparison of various land-monitoring and survey sources are needed to better identify the drivers behind the changes in land use patterns (see, for example, the Global Land Programme ([20])). Land use intensity, especially, is an issue that should be understood better in terms of its consequences for sustainable land management and ecosystems condition, particularly in the rural countryside.

- *Impacts and policy responses*. How can the negative impacts of land use change be mitigated by policy measures? Urban sprawl, landscape fragmentation, soil degradation and the declining ecological quality of land are becoming better known and spatially localised. Therefore, increasing attention

([16]) http://land.copernicus.eu/local/urban-atlas/view and www.eea.europa.eu/data-and-maps/data/urban-atlas.
([17]) http://www.eea.europa.eu/highlights/less-household-waste-going-to.
([18]) www.EU-smartcities.eu.
([19]) https://ec.europa.eu/clima/index_en.
([20]) https://glp.earth/glp-themes.

should be given to sound and efficient use of natural (land-related) resources, innovative ways of sustainable rural and urban development and effective spatial planning methods based on shared territorial visions of the future. In this context, special attention is required for indirect land use changes outside Europe, as a consequence of a changing globalised trade in produce from the land.

- *Scaling up*. How can the differences in national implementation be accounted for in developing EU policies for sustainable land management? It remains of the utmost importance to harmonise data collection on land use and land cover change from countries and regions across Europe. This information will allow proper comparison of the condition of land resources and the impacts of policies on the land. Data sharing and exchange of good practice are crucial for developing a common understanding of these impacts and potential solutions to mitigate undesired trends.

These questions need addressing in a coordinated way at national and European level, which will allow co-creation of the environmental knowledge base on land and soil, as part of natural capital and the essential resource base in need of efficient management.

6.4 Land management for Europe, today and tomorrow

European land resources have gradually been brought more and more to the attention of policymakers, scientists, economic stakeholders and civil society, including the wider public. Calls for the sustainable use of land and soil in the 7th EAP (EU, 2013), ongoing CAP reform in the 2014-2020 period, the EU Biodiversity Strategy to 2020 (EC, 2011b) and its mid-term review, the EU Forest Strategy (EC, 2013d), the Territorial Agenda of the European Union 2020 (EC, 2011d) and recent updates to the Urban Agenda for the EU (EU Ministers responsible for Urban Matters, 2016) and Cork Declaration 2.0 for rural areas (EC, 2016a) confirm this.

Some of these policy documents set up targets and aim to measure progress towards sustainability of land and soil. There are some questions that seem to be basic and will need to be answered in the future:

- Responding to a policy vision in the Roadmap to a Resource Efficient Europe (EC, 2011c), 'no-net-land take by 2050': taking into account observed trends in land take so far, are we on track?

- Responding to SDG, target 15.3, 'By 2030 ... strive to achieve a land degradation neutral world': can we stop the (net) loss of cropland in Europe?

- Responding to the EU Biodiversity Strategy to 2020, target 2 'By 2020, maintaining and ... restoring at least 15 % of degraded ecosystems': can we stop the decline of biodiversity-rich HNV areas, such as extensively managed farmland and forests?

There are a number of land use trade-offs that we still need to get right. Society demands a liveable multifunctional rural area that is also within reach of an increasing number of city-dwellers. At the same time, agriculture and forestry will need to provide food and biomass security and maintain a healthy environment in the countryside. The environment as a whole will then safeguard biodiversity while providing the desired ecosystem services.

Achieving a fully balanced territorial organisation may still seem unlikely, given that sector analyses demonstrate how difficult it is to achieve, e.g. the EU's 20 % renewable energy target in 2020, or the no net land take target of 2050, given the economic constraints that determine societal trajectories.

Nevertheless, the opinion is increasingly voiced that citizens could very well take responsibility for self-governance (Ostrom, 2007, 2009). Indeed, in many small-scale initiatives, this seems to work, such as urban farming (ranging from brownfield remediation (Roth et al., 2015) to rooftop farming (Sanyé-Mengual et al., 2015)), the Dutch environmental cooperatives uniting farmers with city-dwellers in safeguarding environmental land quality (Milone et al., 2015), and lifestyle farming in the Mediterranean (Pinto-Correia et al., 2015). However, land recycling and densification in the urban sphere (Photo 6.1) would also greatly enhance the balanced development of cities and rural land.

The quality of the landscape has many angles and can be objectively measured only to a certain degree. Different users of landscape value different landscape characteristics and will remain subjective in their preferences of landscape uses. Natural conditions and resulting landscapes will continue changing in the future and will reflect the transitions in our society (Box 6.3).

Some aspects of organising space are central to human wellbeing. These include the ability to know and shape one's daily living environment, having particular places supporting a life of the expected quality, and having a life that is manageable at the household level and

Box 6.3 Landscapes in transition

The Dutch Council for the Environment and Infrastructure presents that the major transition challenges that are necessary to achieve a sustainable society will guide the policies that will shape our physical habitat. The challenge of climate change consists of preventing climate change through sustainable energy production and adapting to the various effects of global warming. Both will have a significant impact on Europe's landscape (see also EEA, 2017b). Another main challenge with major implications for the landscape is the need to make rural areas (agricultural and forest landscapes) more sustainable. This concerns both the sustainability of agricultural production practices and realising the objectives of nature policy.

A challenge on their own, transitions are unpredictable and their development is often intermittent. Periods of gradual change are interspersed with periods of rapid and profound change. Drastic changes in the landscape can easily evoke tension and resistance, as in the case of large-scale on-shore wind energy development or scaling up and increasing the economic competitiveness of rural areas, which is often at odds with the need for maintaining the accessibility and quality of rural areas for recreation. Therefore, future landscape development should focus on the question of how to properly guide and shape the interventions in the landscape without slowing the pace of the transitions.

Source: RLi, 2016

provides for the necessary public and private services and amenities. It is important that the European territory offers a choice of different places for such basic needs. As people's preferences and needs are diverse and evolve, there has to be room left for flexibility and adaptation to allow change over time (Finka and Kluvánková, 2015).

The overall wellbeing of European citizens will depend on our ability to ensure that, next to economic growth and efficiency priorities, Europe in the long term offers a multitude of multifunctional territories with good social and environmental quality that are capable of meeting the different needs of its citizens.

Photo 6.1 Densification: housing on top of a market square: Market Hall, Rotterdam, designed by MVRDV; artwork by Arno Coenen

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Annex 1 Land cover change in EEA member and collaborating countries, 1990-2012

The table shows the total changes for 1990-2000, 2000-2006 and 2006-2012. Highlights of the main trends for 2006-2012 are included.

Country	Annual land cover change, % of total area			Characteristic land cover changes, 2006-2012		
	1990-2000	2000-2006	2006-2012	Artificial areas	Agricultural areas	Forest and nature
Albania	–	0.18	0.11	Expansion of industrial and transport networks	Loss of pastures	Loss of forest to urbanisation
Austria	0.03	0.08	0.08	Expansion of industrial, commercial, sport and leisure facilities	Loss of agriculture to industrial and commercial sites	Dynamic forest management
Belgium	0.17	0.10	0.09	Low development driven by new construction sites	Land uptake by new construction sites	Internal forest conversions
Bosnia and Herzegovina	–	0.12	0.06	Slow-down of land uptake, mainly by diffuse residential sprawl	Slow-down of agricultural losses by land uptake	Semi-natural land transitions, fires
Bulgaria	0.11	0.09	0.07	Expansion of mines, quarries, industrial and commercial areas	Overall stabilisation, loss of pastures	Internal changes due to forest management
Croatia	0.19	0.17	0.12	Slow-down of land uptake, mainly by industrial areas and transport networks	Uptake of pastures by arable land	Forest management, fires
Cyprus	–	0.49	0.17	Slow-down of land uptake	Slow-down of change dynamics, land uptake by artificial areas	Forest management, fires
Czech Republic	0.81	0.33	0.40	Continued high rate of urban development, driven by commercial and industrial areas, and diffuse residential sprawl	Continued conversion from arable land to pastures	Afforestation and withdrawal of farming
Denmark	0.13	0.13	0.10	Slow-down of land uptake, although continued increase in industrial and commercial areas	Consumption of arable land, conversion of pasture to arable and permanent crops	Forest creation and management
Estonia	0.44	0.38	0.62	Increased land management (recycling) and sprawl of mines and quarrying areas	Highly dynamic. Compensation between internal conversions of arable land and pasture	Loss to quarries compensated by forest creation
Finland	–	0.35	0.31	Increased land take by mines, quarrying areas, and dump and construction sites	Conversion of forest and wetland to arable land	Forest management and increase in wetlands

Country	Annual land cover change, % of total area			Characteristic land cover changes, 2006-2012		
	1990-2000	2000-2006	2006-2012	Artificial areas	Agricultural areas	Forest and nature
France	0.20	0.11	0.20	Continued urban expansion	Consumption of arable land	Slower changes in natural areas, forest management
Former Yugoslav Republic of Macedonia	–	0.14	0.13	Sprawl of mines and quarrying areas	Overall stabilisation	Forest management
Germany	0.24	0.10	0.11	Decrease in diffuse residential sprawl	Conversion of pasture to arable land	Forest management
Greece	0.71	0.12	0.18	High rate of land uptake by new construction sites, mines and quarries	Farmland uptake by sprawl	Forest management, fires
Hungary	0.56	0.48	0.49	Slow-down of land uptake	Withdrawal of arable land, extension of pastures	New forest from arable land
Iceland	–	0.10	0.12	Slow-down of land uptake	Conversion of grassland to pastures	Accelerated decrease in permanent snow and glacier cover, new transitional woodlands
Ireland	0.79	0.38	0.31	Slow-down of land uptake	Extension of pastures	Transitional woodland over open natural and farmland areas
Italy	0.13	0.10	0.10	Growth of industrial and commercial areas	Loss of farmland	Transitions of natural land cover, fires
Kosovo (under UNSCR 1244/99)	–	0.16	0.10	Accelerated sprawl of industrial, commercial, mines and quarries	Conversion from pasture to arable land	Stabilisation
Latvia	0.78	0.38	0.59	Extension of mines and quarrying areas	Conversion from pasture to arable land	Recent forest transitions
Lithuania	0.48	0.25	0.18	Continued fast sprawl, driven by development of construction sites	Withdrawal of farming with woodland creation and conversion of pasture to arable land	Natural land transitions
Luxembourg	0.15	0.23	0.06	Development of construction sites	Stabilisation of farmland	Stabilisation of farmland
Malta	0.07	0.00	0.00	No changes in urban areas	No change in agricultural land cover	No change
Montenegro	0.02	0.04	0.06	Slow-down of land take	Conversion from pasture to arable land	Forest management, fires
Netherlands	0.30	0.27	0.26	Increased urban land management and development of new construction sites	Agricultural land uptake by development of artificial areas	Withdrawal of farming
Norway	–	0.10	0.08	Continued extension of sport and leisure facilities	Low intensity of changes	Forest transitions

Country	Annual land cover change, % of total area			Characteristic land cover changes, 2006-2012		
	1990-2000	2000-2006	2006-2012	Artificial areas	Agricultural areas	Forest and nature
Poland	0.10	0.10	0.16	Sprawl of diffuse residential areas, new construction sites and mines	Loss of agricultural land (mostly arable)	Transitional woodland, changes in forest management
Portugal	0.78	1.43	0.90	Slow-down of land uptake	Conversion from arable land to olive groves	Forest transitions, fires
Romania	0.16	0.05	0.05	Increased sprawl of mines, quarries, industrial and commercial areas	Slow-down of agricultural transitions	Recent felling and land transition
Serbia	0.11	0.07	0.08	Slower residential sprawl, increased extension of mines	Diffuse extension of pasture	Low forest formation
Slovakia	0.51	0.25	0.31	Accelerated sprawl of diffuse residential areas, new construction sites, industrial and commercial areas	Slow-down of changes	Forest creation after withdrawal of farming
Slovenia	0.02	0.03	0.01	Slow-down of land uptake	Limited changes	Limited changes
Spain	0.34	0.29	0.22	Increased urban land management. Decreased residential sprawl and continued land take driven by new construction sites	Loss of arable land to olive groves, fruit trees, construction	Forest transitions, fires
Sweden	–	0.49	1.22	Reduced land take	Loss of arable land	Large increase in forest transitions and management
Switzerland	–	0.03	0.02	Reduced land take	Limited changes	Significant decrease in glacier coverage
Turkey	0.07	0 08	0.12	Increased sprawl of economic sites and infrastructures	Internal changes dominated by conversion from pasture to arable land and permanent crops	Forest creation after withdrawal of farming
United Kingdom	–	0.16	0.14	Continuation of sprawl of economic sites and infrastructures	Limited changes	Forest management

Source: ETC/ULS, 2016.

Annex 2 Corine Land Cover: background

CLC basics — history and nomenclature

The CLC programme has its origins in the European Commission's Corine initiative. Since the establishment of the EEA and Eionet, the responsibility for the Corine databases has fallen to the EEA, which coordinates their implementation by national teams.

Following the first CLC implementation, it became clear that there was a need for regular updates. This has resulted in a 25-year-long time series of CLC data, named after their reference years as CLC1990, CLC2000, CLC2006, CLC2012 and CLC2018 (in preparation). The maps referring to a specific year are referred to as *status layers*. Starting with the CLC2000 survey, a data set of land cover changes between consecutive survey dates has been produced, named after reference years as CLC-Changes$_{1990\text{-}2000}$, CLC-Changes$_{2000\text{-}2006}$ and CLC-Changes$_{2006\text{-}2012}$. These are commonly referred to as *change layers*.

The fundamental characteristics of the data sets have remained unchanged during this time series. These are as follows:

- mapping permanent (more than 1 year old) surface features at a scale of 1:100 000 based on physical characteristics;
- minimum mapping unit: 25 ha for status layers, 5 ha for change layers;
- minimum mapping width: 100 m;
- nomenclature: three hierarchical levels, with 5, 15 and 44 classes of land use and land cover;
- basic data support: satellite imagery;
- ancillary (in situ) data: national orthophotos, topographic maps, thematic maps, Google Earth imagery.

The CLC specifications, including the nomenclature, were formulated in the 1980s with regard to the initial users' needs, the availability of input data and methodology. Spatial resolution is a compromise between information needs and the costs of production (mainly influenced by the cost of human work). The nomenclature has been designed to focus on the initial geographical scope (Mediterranean countries), the visual interpretability of classes and the general purpose of mapping. The nomenclature includes 44 classes, organised in a three-level hierarchical system, with five main categories: artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands and water bodies. Harmonised production of the data set is helped by very detailed, illustrated nomenclature guidelines, as well as the well-established technical coordination (guidelines, training, quality assurance/quality control) provided by the EEA's CLC Technical Team. Although the list of classes has remained unchanged since the outset, the class descriptions have undergone significant refinement, in response to methodological developments (described in the next section).

Methodology

The evolution of techniques and data sources has, however, led to a number of changes in implementation and methodology. CLC1990 was characterised by manual photointerpretation of satellite image print-outs on a plastic overlay, with subsequent digitisation and attribution. From CLC2000 onwards, computer-aided photointerpretation (CAPI) has become the main methodology applied, induced by the wider availability of GIS software, more powerful hardware and an increasing number of digital spatial data. The majority of implementing countries create CLC data directly, by interpreting satellite imagery and delineating polygons on screen, with in situ data used as ancillary information. A growing number of countries have, however, sufficient amounts and quality of in situ data and remote sensing capacity to build their CLC status layers by merging and combining existing data sets and Earth observation data, complemented by human interpretation (bottom-up creation). This production method requires a different, more analytical description of classes, which has been realised by the enhancement of CLC nomenclature guidelines in 2013, based on the decomposition principles of the EAGLE concept.

CLC change data have been produced since the CLC2000 inventory, and since CLC2006 they have become the main output of CLC activities. CLC change data are produced directly, by applying the 'change mapping first' approach, based on visual comparison and evaluation of Earth observation data. Visual comparison of satellite imagery for the two dates (with old status layer vector data overlaid for spatial reference) is followed by direct delineation of change polygons. The interpreter gives two CLC codes to each change polygon: $code_{OLD}$ and $code_{NEW}$, each included as separate attributes. These codes must represent the land cover status of the given polygon on the two dates, respectively. Change code pairs thus show the process that occurred in reality and may be different from the codes occurring in the final CLC (status) databases (due to generalisation applied in producing CLC_{OLD} and CLC_{NEW}).

At the end of the process, CLC-$Change_{OLD\_NEW}$ polygons will be combined with polygons from CLC_OLD data to obtain CLC_NEW database:

$$CLC\_NEW = CLC\_OLD\ (+)\ CLC\text{-}Change_{OLD\_NEW}$$

where (+) means the following operation: CLC_{OLD} and CLC-Change are intersected; first CLC-Change polygons' $code_{OLD}$ is replaced by $code_{NEW}$; and finally neighbours with similar codes are unified. The necessary thematic/geometric correction of CLC_OLD data must precede the delineation of change polygons in order to avoid propagating errors from CLC_OLD to CLC_NEW.

Despite the evolution of the methods and input data, the semi-automated derivation of CLC-change data is still uncommon. Even in countries creating CLC status layers by the bottom-up method, the CLC changes are still completely manually interpreted (e.g. Norway) or derived in a semi-automated way then checked and corrected by photointerpreters (e.g. Germany).

Advantages

Although considered 'old-fashioned' by some users, CLC data have advantages that make them in practice a standard in European land monitoring.

- CLC is the first pan-European harmonised land cover data set, whose concept, nomenclature and methodology has influenced other surveys in many ways, be they European or national. For example, the first version of HRLs aimed to represent the five level 1 CLC classes. Many national land use and land cover inventories have also been tailored with reference to the CLC concept (CLC50 of Hungary, SIOSE of Spain, etc.).
- CLC has an impressive time series, spanning from 1990 to today, with nomenclature and main parameters unchanged since the outset, which allows the analysis of European landscape changes over 25 years.
- CLC has full European coverage of 39 countries, giving valuable input information for pan-European comparisons and analyses.
- The CLC change data set, being created directly under human supervision (instead of intersecting two more-or-less independent data sets) gives a realistic and meaningful picture of the change processes.

For the reasons above, CLC fulfils a variety of users' needs, mainly at the European level.

Shortcomings

The CLC concept and nomenclature were designed in the 1980s for a visual photointerpretation method, with central and southern Europe as the main geographical focus. Its extension to become a pan-European database happened without a fundamental revision of the nomenclature (or concept). The reason behind keeping it unchanged was the need to maintain backward comparability (heritage) with previous products. Meanwhile, as the CLC concept has been implemented in an increasing number of countries over a 25-year time span, the need for revision of the concept has become evident, for both participants and stakeholders, to adapt to changing technical circumstances and policy requirements.

The shortcomings of CLC most often cited are as follows (see, for example, Büttner, 2014; Feranec et al., 2016):

- Nomenclature:
  - no equal representation of different biogeographical regions (e.g. Nordic landscapes, peatlands, inland salt marshes and salt planes, transient lakes are difficult to map);
  - mixed representation of land cover and land use in the classes, causing difficulties in bottom-up production and conflicts in change mapping (in cases in which land cover changes, but land use does not, or the other way around);
  - missing thematic content (types of grasslands and wetlands and cultivation practices, among others)

- the temporal aspect (transitional phenomena, status — irrigated, burnt, under construction) is handled only selectively;
- inflexible classification system, missing option to attribute spatial units or handle newly appearing landscape phenomena (e.g. energy plantations, scattered artificial features);

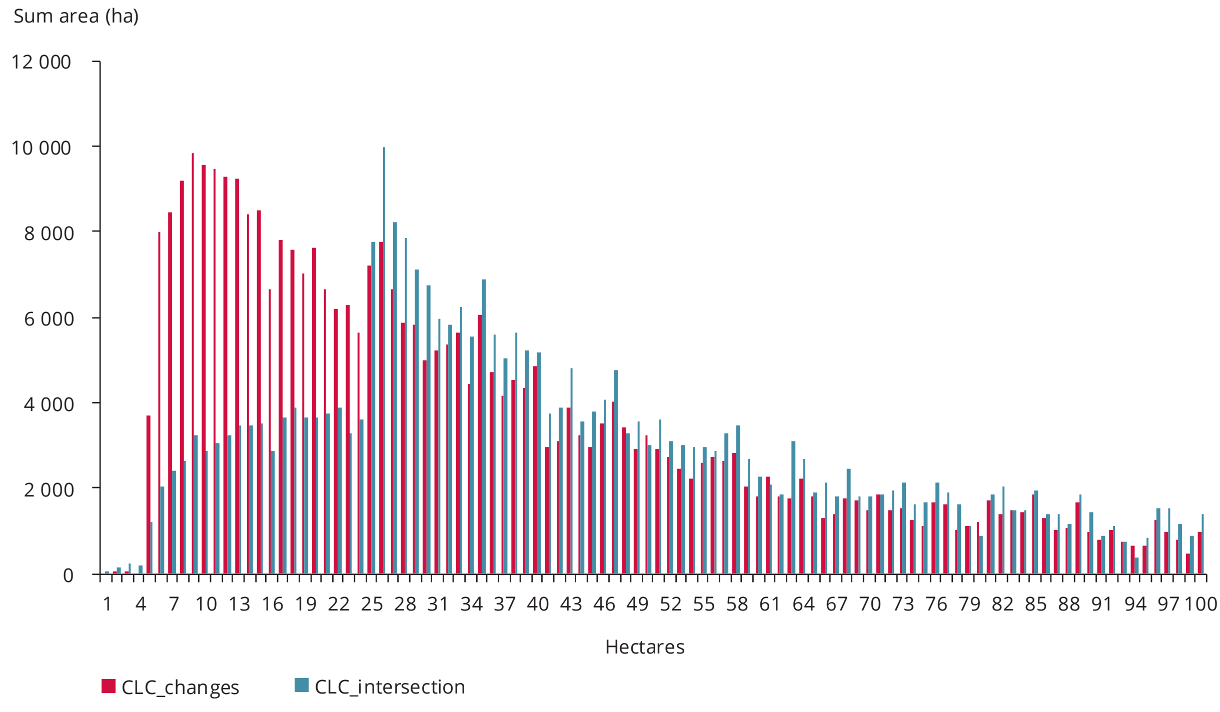
- The scale/spatial resolution is insufficient for national applications and for representation of specific features, e.g. urban land take that is characterised by changes of less than 5 ha and by new linear features.
- The timeliness of the data is often criticised, although implementation time has decreased through successive inventories.
- There is inconsistency with national data sets (duplication of efforts), an issue to which bottom-up production provides an answer in an increasing number of countries.

Trend monitoring with CLC

The different minimum mapping units for the CLC and CLC-Change databases, i.e. 25 ha and 5 ha respectively, determine different levels of generalisation and different resolution, and so ultimately different scales. It is easy to acknowledge that any simple automated operation, e.g. intersecting two lower resolution databases, will not result in a higher resolution database. For this reason, the method of intersecting two status layers in order to produce a change layer, applied by some countries in the CLC2000 project, could not deliver a consistent and full database of real changes larger than 5 ha. This is demonstrated by the chart showing the size distribution of change polygons created with direct change mapping versus intersection (Figure A2.1). CLC-Change method is mapping considerably more change polygons in the range of 5-25 ha.

Since the CLC2006 project, all participating countries have applied the 'change mapping first approach', producing the higher resolution CLC-Change database directly, delineating all real changes beyond the limit of 5 ha.

Figure A2.1 Distribution of CLC-Change polygons produced by intersection method (blue) and 'change mapping first' method (red), 1990-2000 Hungary



Source: CLC2000-HU.

Annex 3 Details of Copernicus pan-European and local land monitoring products

The table below shows a summary of Copernicus land-monitoring service pan-European and local component (page 81) products up to the reference year 2012.

Component	Product	Product details	Reference year	Update frequency	Spatial resolution	Geographical extent	Area mapped (km²)	Source and spatial resolution of input data
Pan-European	High resolution (HR) and very high resolution (VHR) image mosaics	Image mosaics of ESA data warehouse imagery in HR (20/25 m) and VHR (1.5-2.5 m)	2012	3 years	1.5-25 m	EEA-39	EEA-39 (~6 million km²)	Various HR and VHR sensors 1.5 m to 25 m spatial resolution
	EU-DEM	Digital elevation model with 30 m spatial resolution	n.a.	Current update version 1.1, April 2016	25 m	EEA-39	EEA-39 (~6 million km²)	Derived from SRTM data, ASTER GDEM and Russian topographic maps
	EU-Hydro	River network and drainage model	n.a.	Current version: public beta of May 2016	n.a. (vector, line and point data (derived from VHR and HR data)	EEA-39	EEA-39 (~6 million km²)	Derived from 20 m (HR) imagery and VHR data (2.5 m)
	Corine Land Cover (CLC)	Flagship land cover and land use product with long time series	1990, 2000, 2006, 2012, 2018 (in preparation)	Currently: 6 years	Minimum mapping unit (MMU): 5 ha (change layer), 25 ha (status layer)	EEA-39	EEA-39 (~6 million km²)	Derived from a range of input data (HR satellite imagery, orthophotos, topographic maps)
	High resolution layers (HRLs)	Five thematic HRLs: • Imperviousness • Forests • Natural grasslands • Wetlands • Water bodies	2012 (imperviousness also for 2006 and 2009)	Currently: 3 years	20 m (also available as 100 m products)	EEA-39	EEA-39 (~6 million km²)	Derived mainly from HR satellite imagery (20 m). From 2015 also with Sentinel 1 imagery (10 m)

Component	Product	Product details	Reference year	Update frequency	Spatial resolution	Geographical extent	Area mapped (km^2)	Source and spatial resolution of input data
Local component	Urban Atlas (UA)	HR mapping of urban land use and land cover (27 classes) for functional urban areas. Extended from 305 areas (2006) to 695 areas for 2012	2012 (and 2006)	Currently: 6 years	Vector data. MMU 0.25 ha (urban areas), 1 ha (rural areas)	EEA-39 (695 functional urban areas	2012: ~1 million km^2	Derived from VHR (2-2.5 m) imagery
	Riparian zones (RZs)	Set of complementary products mapping (1) land cover and land use (80 classes), (2) delineating RZs and (3) mapping green linear elements within the RZs	2012	Currently: 6 years	Vector data. MMU for LC/LU mapping: 0.5 ha, min. Width: 10 m	EEA-39 (along large and medium-sized rivers (Strahler levels 3-8)	525 000 km^2	Derived from various input data, mainly VHR satellite imagery (1.5-2.5 m)
	Natura 2000 (selection of grassland-rich sites)	Detailed LC/ LU mapping for 524 selected Natura 2000 sites (including a 2 km buffer), rich in endangered grassland species; reference years 2006 and 2012	2006 and 2012	To be decided	Vector data. MMU 0.5 ha	EEA-39 (selected grassland-rich Natura 2000 sites)	160 444 km^2	Derived from various input data, mainly VHR satellite imagery (1.5-2.5 m)

Annex 4 High-resolution layers

The HRLs cover 39 countries in Europe for the reference year 2012 (based mainly on 2011/2012 satellite images). All HRLs are freely available on the Copernicus land portal (http://land.copernicus.eu/), as mosaics covering the whole of the EEA-39 area ([21]) in the European projection and in the original 20x20 m spatial resolution and as validated 100x100 m products ([22]). Products in national projections (20 m spatial resolution only) are also created, but provided directly by the countries, not through the Copernicus land portal. In addition to the products described in this document, two additional products were produced for the JRC for the 2012 reference year: a 'tree cover presence/absence' product, and a 'tree type' (both in 25 m × 25 m spatial resolution). These two products (called internally 'service element 2'), and documentation are available directly through the JRC. Table A4.1 summarises the main products. A full update with some significant changes and improvements is currently in production for the 2015 reference year and will be available before the end of 2017.

Table A4.1 Overview listing all main HRL products

Imperviousness	
Degree of imperviousness 2012 (20 m and 100 m): IMD	Degree of imperviousness, values from 1 % to 100 %
Impervious density change 2009-2012 (100 m): IMC	Mapping degree of change over time from – 100 % to + 100 %
Forest	
Tree cover density (20 m and 100 m): TCD	Tree cover density, values from 1 % to 100 %
Forest type (20 m) consisting of two grids: FTY	Dominant leaf type. Binary product: coniferous and broadleaved. MMU of 0.5 ha and 10 % tree cover density threshold applied (FAO definition)
	Support layer: maps trees under agricultural use and in the urban context derived from CLC2012 ([23]) and imperviousness 2012
Forest type (100 m): FTY	Coniferous, broadleaved and mixed. Trees under agricultural use and urban context from additional support layer removed
Natural and semi-natural grasslands	
Natural and semi-natural grasslands (20 m): NGR	Binary product: mapping 'natural and semi-natural grasslands' and all areas not covered by natural and semi-natural grasslands
Natural and semi-natural grasslands (100 m): NGR	Occurrence of natural and semi-natural grasslands (0-100 %)
Wetlands	
Wetland (based on 2006-2009-2012 data), (20 m): WET	Wetland: binary product — mapping 'wetlands', and 'all non-wetland areas'
Wetland (based on 2006-2009-2012 data), (100 m): WET	Occurrence of wetlands (0-100 %)
Water bodies	
Permanent water bodies (based on 2006-2009-2012 data), (20 m): PWB	Permanent water bodies, including small water bodies: binary product — mapping 'permanent water bodies' and 'all other areas' not covered by permanent water bodies
Permanent water bodies (based on 2006-2009-2012 data), (100 m): PWB	Occurrence of permanent water bodies (0-100 %)

Note: The main products for download through the Copernicus land portal are the European projection mosaics for the whole EEA-39 and a tiled product (1 000 km tiles). 20 m products are also available for each country in the national projection, but only directly from the country.

([21]) In some cases the products are (in addition to the full mosaic), made available as 1 000 km × 1 000 km tiles for easier data handling and processing.

([22]) Validation not fully completed. Preliminary validation results are available in the 'technical library' section of the portal: http://land.copernicus.eu/user-corner/technical-library.

([23]) Where available at the time of production.

Annex 5 Landscape structural metrics based on forest high-resolution layers

In 2015 the EEA organised a small HRL use case study to produce maps and develop measures that can help to evaluate the usefulness of forest spatial pattern metrics for analysing fragmentation and structural connectivity. The approach allows the identification of subtle changes in forest spatial pattern composition and configuration over the EEA-39 territory. The resulting forest spatial patterns provide more detail and may help to improve current or future monitoring of fragmentation and connectivity and can be used for monitoring the biodiversity of forest ecosystems.

In the case study, three simplified forest products were derived from the forest HRLs as a first step. These were:

1. a forest/non-forest mask based on the forest type HRL;
2. a closed/open forest mask based on the tree cover density HRL;
3. a dominant leaf type product based on the forest type HRL.

The actual analysis was then performed in a second step, based on the three products, using Morphological Spatial Pattern Analysis (MSPA). The software used was GuidosToolbox (Vogt, 2016), developed by the JRC.

Biogeographic regions were used for the analysis, but other (perhaps more meaningful and smaller) reporting units could be used. The following metrics (and their ratios) were calculated:

- % core area;
- % edge area;
- perforations;
- connectors;
- branch;
- islet.

In general, in the Anatolian biogeographical region, the forest pattern is the most fragmented (the lowest ratio values and the highest amount of non-core classes), compared with the Steppic region, which has the lowest level of fragmentation (Table A5.1). The overall percentage of forest cover across the biogeographical regions is very different.

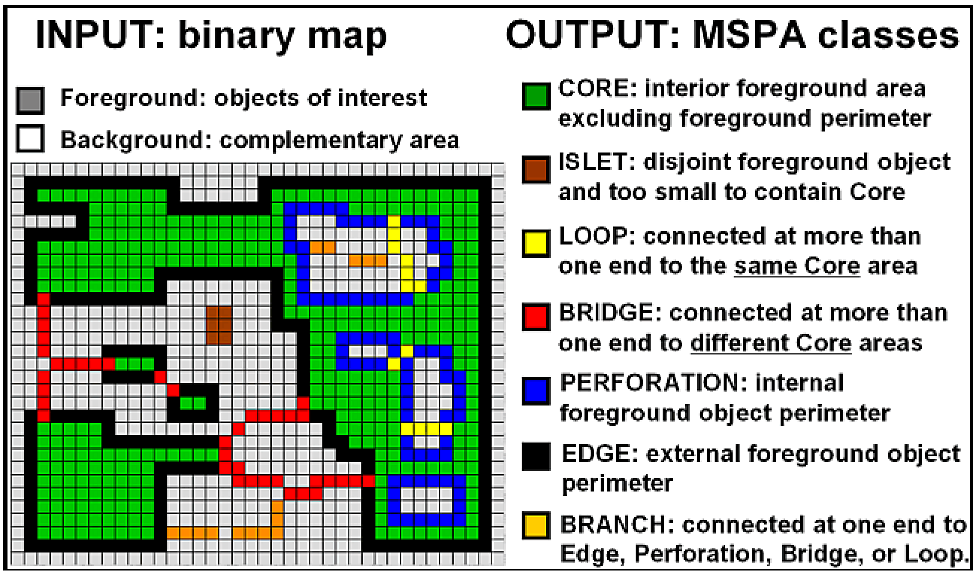


Table A5.1 **Computed forest pattern and MSPA characteristics for the forested parts of different biogeographical regions**

	Proportion of MSP classes in forest						Ratios					
	CORE	EDGE	PERFORAT IONS	CONNECTORS	BRANCH	ISLET	EDGE to CORE	PERFORAT IONS to CORE	CONNECTOR to CORE	BRANCH to CORE	ISLET to CORE	NON_CORE to CORE
EU-39	27.56	9.30	1.96	14.32	16.27	30.59	0.50	0.87	0.32	0.26	– 0.05	– 0.45
Alpine	14.91	8.17	0.65	18.74	19.39	38.13	0.29	0.92	– 0.11	– 0.13	– 0.44	– 0.70
Anatolian	13.75	5.42	0.54	19.81	20.34	40.15	0.43	0.92	– 0.18	– 0.19	– 0.49	– 0.73
Atlantic	16.78	8.09	0.94	18.07	19.02	37.09	0.35	0.89	– 0.04	– 0.06	– 0.38	– 0.66
Black Sea	33.37	4.78	1.97	13.99	15.96	29.94	0.75	0.89	0.41	0.35	0.05	– 0.33
Boreal	25.13	7.52	2.60	14.89	17.49	32.38	0.54	0.81	0.26	0.18	– 0.13	– 0.50
Continental	31.66	11.37	1.86	12.85	14.71	27.55	0.47	0.89	0.42	0.37	0.07	– 0.37
Macronesian	15.52	7.98	0.32	18.89	19.21	38.09	0.32	0.96	– 0.10	– 0.11	– 0.42	– 0.69
Mediterranean	27.07	9.03	1.66	17.73	16.39	31.12	0.50	0.88	0.30	0.25	– 0.07	– 0.46
Pannonian	28.46	13.02	1.63	13.41	15.04	28.44	0.37	0.89	0.36	0.31	0.00	– 0.43
Steppic	38.47	16.62	1.06	10.43	11.49	21.92	0.40	0.95	0.57	0.54	0.27	– 0.23

Annex 6 Evolution of service 2015-2018 and related indicators

The EEA is currently implementing a number of Copernicus land products, some as simple updates of existing time series or 2012 products, some with significant changes and modifications compared with 2012, and some new products. The modifications are mainly the result of lessons learned from the production and use of previous generations of products and feedback from the countries.

	Name of product	Reference year	Changes compared with 2012
Pan-European component	CLC2018	2018 (but input data mainly from 2017)	Very limited, but a more fundamentally improved future CLC is under discussion. The product will use an established approach to ensure delivery in time for SOER 2020 in early 2019
	Imperviousness	2015	Limited changes, but includes full harmonisation of the 2006-2009-2012-2015 time series
	Forest	2015	Limited changes, but first time change product
	Grassy and non-woody vegetation	2015	New baseline replacing the natural grassland produced for 2012. Extending the grassland concept to include intensely used grasslands. Based on longer time series and use of input imagery from multiple sensors
	Wetness and water layer	2015	New and combined wetness and water layer, replacing the separate wetland and water products for 2012. Avoids frequent confusion with ecological concept of wetland and builds baseline on longer time series
	Small woody features	2015	New product, but building on previous case study and experience as part of the riparian zones mapping. Vector mapping of small woody features based on VHR imagery
Local component	Urban Atlas	2012 and 2018	Extension of 2012 product to include Western Balkan countries and Turkey. 2012-2018 change detection and Urban Atlas 2018 update
	Riparian zones	2012 and 2018	Extension of LC/LU product for selected Strahler level 2 rivers (smaller rivers, current product levels 3-8), and change mapping and update for 2018 (of the extended product)
	Natura 2000	2006 and 2012	Selection of additional sites compared with the current status, based on additional grassland habitat types

Annex 7 Recent EEA reports and their land-related conclusions

Title of report	Main land use-/land cover-related issues and conclusions	Copernicus products used
EEA and Federal Office for the Environment (FOEN), *Urban sprawl in Europe* (EEA, 2016f)	Urban sprawl has increased rapidly in Europe in recent decades and presents a major challenge with regards to sustainable land use. Urban sprawl status and dynamics are explored for 2006 and 2009.	Imperviousness HRL was the main input data set for the methodology. CLC was also used.
EEA, *The direct and indirect impacts of EU policies on land* (EEA, 2016b)	Land take listed as the main critical trend. All four policy sectors under consideration (cohesion, transport, energy and CAP) can have major (often negative) impacts on land but there are potential positive impacts.	Focus on policies and potential impacts. Indirect use of CLC and land take indicator.
EEA, *European forest ecosystems — State and trends* (EEA, 2016c)	Forests and other wooded land cover more than 40 % of the EEA-39 area. Forest extent and growing stock are still increasing. The forest sector is influenced by pressures from climate change and growing demands from society on natural resources	HRL forest type in one map. Use of tree cover density and input of forest HRLs into existing or new indictors needs to be explored.
EEA, *Mapping and assessing the condition of Europe's ecosystems: Progress and challenges* (EEA, 2016h), EEA contribution to the implementation of the EU Biodiversity Strategy to 2020	The report summarises the EEA's work on ecosystem mapping and assessment over the last few years. Presents first ecosystem map of Europe and assessment of ecosystem types	CLC and various other sources used. Copernicus data to be explored for future change mapping and refinement.
EEA, *Urban sustainability issues — What is a resource-efficient city?* (EEA, 2015f)	Explores issues of resource efficiency in cities	CLC, imperviousness, Urban Atlas
EEA, *Land recycling in Europe — Approaches to measuring extent and impacts* (EEA, 2016g)	Proposes an approach for analysis of land recycling – redevelopment of previously developed land (brownfields)	Urban Atlas

European Environment Agency

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An account of 25 years of land cover change in Europe

2017 — 84 pp. — 21 x 29.7 cm

ISBN 978-92-9213-882-0
doi:10.2800/81075

TH-AL-17-011-EN-N
doi:10.2800/81075

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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