EEA Report | No 17/2021

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European Environment Agency

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Layout: Formato Verde

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Luxembourg: Publications Office of the European Union, 2022

ISBN 978-92-9480-465-5
ISSN 1977-8449
doi:10.2800/714139

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Key messages

Land take and the associated soil sealing cause ecosystems to become less resilient through landscape fragmentation and habitat destruction, decreased carbon sequestration and impaired flood protection. These processes are one of the major drivers of land degradation. Restoring **wetlands, peatlands, coastal ecosystems, forests, grasslands and agricultural soils** is essential for preventing biodiversity decline and for climate change adaptation.

Major drivers of land take include population growth, the need for transport infrastructure, cultural preferences and economic welfare.

The majority of these processes occur in functional urban areas (FUAs), which represent 23 % of the territory of the EU-27 and the UK, but host 75 % of the population.

Between 2012 and 2018, land take in FUAs of the EU-27 and the UK increased by 3 581 km^2 and soil sealing increased by 1 467 km^2, mostly at the expense of croplands and pastures. Almost 80 % of land take took place in commuting zones, which, in contrast to city centres, provide more wildlife habitats, support carbon sequestration, allow flood protection, and supply food and fibres. Land use efficiency improved slightly overall, but citizens in commuting zones use far more artificial areas than those in cities, meaning that in these areas land use is less efficient.

Impacts are manyfold:

- 46 % of the FUAs in the EU are strongly fragmented, with the continuity of forest habitats being most affected, followed by cropland and grassland habitats. The average continuous habitat size within FUAs is 0.25 km^2, while outside FUAs habitats are 1.4 km^2 on average. Floodplain fragmentation is high, with 1 km^2 of this type of land hosting four habitats on average.
- While fragmentation affects 33 % of protected areas in FUAs, the average habitat size in a protected area is approximately 2.5 km^2, meaning that land take in protected areas is 10 times lower than in unprotected areas, indicating the effectiveness of policy measures.
- Of the area of soil that became sealed between 2012 and 2018, one fifth was of high productivity potential and almost two thirds were of medium productivity potential.
- This new soil sealing caused a loss of carbon sequestration potential estimated at 4 million tonnes of carbon of the FUAs.
- New sealing also caused an estimated potential loss of water-holding capacity of 668 million m^3.

Europe cannot continue its recent land take trends, as the continuous loss of ecosystem functions renders it increasingly vulnerable to natural disasters, while it continues to lose biodiversity.

Land use efficiency needs to improve. However, while we need to act now, there is no legally binding policy target in relation to land take and soil sealing at the EU level. The new EU soil strategy for 2030 calls on Member States to only set land take targets for 2030, with the aim of reaching land take neutrality by 2050. As proposed in the soil strategy, Member States are requested to implement measures that follow the land take hierarchy: to achieve no net land take, (1) land take needs to be avoided, (2) more land needs to be reused, (3) land take needs to be minimised and, finally, (4) land take needs to be compensated for.

Executive summary

This report addresses land take as one of the key drivers of land degradation. Other forms of land degradation like soil erosion or compaction as well as the impacts of climate extremes are not covered in this assessment and will be addressed in follow-up reports.

Land take entails the conversion of non-urban areas into urban areas, which usually happens at the expense of natural areas. The most intense form of land take is soil sealing, which is an essentially irreversible process that leads to the destruction or covering of soils by buildings and other construction, and layers of completely or partly impermeable artificial material (asphalt, concrete, etc.). Soil sealing accompanies land take, but areas subject to land take are usually not entirely sealed.

The report addresses land take in Europe's functional urban areas (FUAs), i.e. cities and their commuting zones. FUAs represent 23 % of the EU territory, but host 75 % of its population. They are therefore the most dynamic regions for land take, with most land take and soil sealing taking place in these areas.

With the availability of new data from the Urban Atlas of the Copernicus Land Monitoring Service, it is now possible to assess the land use changes and socio-economic trends of the 662 FUAs of the EU-27 and the UK. The Urban Atlas has a 10-fold higher resolution than the Corine Land Cover (CLC) data set, which has been used for previous land take analyses ([1]). The Urban Atlas allows an assessment of cities in the context of their surrounding areas (i.e. commuting zones, together referred to as FUAs) and enables a comparison of urban areas across Europe. The report investigates in detail land take dynamics in core cities and their commuting zones between 2012 and 2018. Once high-resolution data become available for the entire area of the 38 EEA member countries, the assessment will be extended to the entire area.

Land take and the spread of buildings and construction sites in Europe continue to increase. Land take during 2012-2018 increased by 3 581 km^2 in FUAs in the EU-27 and the UK region (5 330 km^2 in the EEA-38 and the UK region). Of new land take, 78 % happened in commuting areas in the EU-27 and the UK region (with a similar proportion in the EEA-38 and the UK region), converting land to urban areas and hence areas of lower ecosystem support value. The vast majority of land take affected the most productive areas of FUAs, such as arable lands (a loss of 1 694 km^2, accounting for 47 % of all land take) and pastures (a loss of 1 276 km ^{2}, accounting for 36 % of all land take). The area of forests lost (338 km^2) was only about one fourth of the area of arable lands lost, and only 79 km^2 of permanent croplands were lost to urban areas.

The major land use pressure causing these changes is the expansion of industrial and commercial units, the sprawl of residential areas and the expansion of construction sites. While the expansion of industry dominates both cities and their commuting zones, urban residential sprawl is a significant driver in commuting zones.

High land use efficiency means that small parts of artificial areas are used by many inhabitants. A drawback of high land use efficiency is that sealing rates are high and hence land functions (cooling, flood protection, carbon sequestration, habitats for wildlife) are low. Land use efficiency has slightly increased in FUAs, with the area of artificial surface being used per inhabitant decreasing by 5.5 m^2 between 2012 and 2018. In core cities, however, far less artificial area is needed per citizen than in commuting areas. Hence, land use efficiency is in general much higher in core cities than in commuting zones, as inhabitants in cities use 60 % less artificial area than those in commuting areas.

Using Earth observation and modelled data, the environmental impacts of land take and soil sealing can be estimated. One of the impacts of land take and soil sealing is landscape fragmentation, i.e. the creation of traffic and other infrastructure that blocks the movement of wildlife. Of FUAs, 46 % are strongly fragmented, affecting mostly croplands and grasslands, with an average FUA habitat size of 0.25 km^2. This contrasts with rural areas, where the average size of a landscape object is 1.4 km^2. However, policy measures seem to be effective, as the average habitat size in protected areas of FUAs is around 2.5 km^2. On the other hand, the effectiveness of protection measures varies widely; for example, in Malta the size of protected habitats is only 0.2 km^2, whereas in the Baltic countries, Finland, Ireland, Hungary and Sweden the average size of a protected habitat is around 20 km^2.

([1]) https://www.eea.europa.eu/data-and-maps/indicators/land-take-3/assessment

Impermeable surfaces in urban floodplains increase the intensity and related impacts of floods because excess water cannot infiltrate the underlying soil. The estimated average increase in sealing during 2012-2018 in FUA floodplains was 2.4 %, amounting to around 146 000 ha (1 460 km^2), mostly on account of new industrial, commercial and public areas, as well as the expansion of residential areas and construction sites. These activities sealed 880 ha (almost 9 km^2) of pastures and herbaceous vegetation associations and 348 ha (3.5 km^2) of arable lands. Land take is one of the major causes of habitat destruction in floodplains and therefore potentially impacts on biodiversity. Floodplain fragmentation is high, with 1 km^2 of land hosting four habitats on average, and as much as 18 habitats being squeezed into 1 km^2 in Belgium and nine habitats in 1 km^2 of land in Luxembourg and the Netherlands.

The principle of sustainability implies that mostly low-productivity lands that are less relevant for biodiversity and carbon sequestration should be subject to land consumption. However, soil sealing happens mainly on prime lands and on lands of medium productivity and therefore this principle is disregarded in many areas in Europe. In 2018, 50 % of FUAs occupied medium-productivity lands and 25 % extended over high-productivity surfaces. Sealing in FUAs occurred at an alarming rate on croplands, with 35 % of all sealing happening on this land type. The increase in the area of wetlands sealed was very low in absolute values; however, with a 10 % increase in sealing compared with 2012, the sealing rate was the highest in the EU-27 and the UK region. As wetlands store a large amount of carbon and provide important habitats, this pattern is worrying.

Soils store more carbon than the atmosphere and terrestrial vegetation combined (FAO and ITPS, 2015), and play a significant role in the global carbon cycle and thus in climate regulation. Soil carbon is also key to storing nutrients, enhancing underground biodiversity, and filtering and buffering pollution. The estimated increase in sealing between 2012 and 2018 (approximately 1 467 km^2) created a loss soil of carbon sequestration potential of approximately 4.2 Mt.

About half of the volume of soils is pore space, which can hold and transfer water, with multiple benefits, from supporting plant growth to controlling local climate. Sealed surfaces prevent water infiltration to the subsoil, thereby increasing the detrimental effects of floods. The estimated potential loss of topsoil's water-holding capacity due to soil sealing in FUAs of the EU-27 and the UK between 2012 and 2018 amounted to around 668 million m^3, around 67 million m^3 of which was lost from floodplains. Hence, today's extent of sealed areas in FUAs of the EU covers topsoil pore spaces that could potentially hold a comparable amount of water to that of Markermeer and Lake Balaton, the largest lakes in western Europe and central Europe combined.

The EU has recognised the severity with which land take impacts on the environment and, with the new soil strategy ([2]), published in November 2021, it has now called on Member States to set land take targets by 2030 with the aim of reaching no net land take by 2050. The recently published biodiversity strategy for 2030 ([3]) also aims to mitigate the detrimental effects of urbanisation. A key aim of the biodiversity strategy for 2030 is to restore destroyed ecosystems and establish nature-based solutions. At the global level, an assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has identified five root causes of biodiversity loss that policymakers must address, with land use change, notably deforestation overseas and urban sprawl, being identified as one of the main causes (IPBES, 2018).

Hence, the momentum to reduce the impacts of land take and the resulting land degradation is growing. This report aims to support EU policymakers to set targets and monitor their effectiveness. All sections and figures in the report are accompanied by interactive dashboards, which provide access to reported statistics.

([2]) https://ec.europa.eu/environment/publications/eu-soil-strategy-2030_en

([3]) https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en

1 Why is land take in urban areas important?

Key messages

- **Key impacts of land take in urban areas are soil sealing, where all soil functions are lost, and landscape fragmentation.**
- **Major drivers of land take are, above all, population growth, topography (slope gradients), the need for transport infrastructure, cultural preferences and economic welfare.**
- **At the policy level, the EU is committed to achieving no net land take by 2050. This will be achieved only if land use efficiency is improved. Land recycling is considered a key solution in this context.**

1.1 How does land take impact on ecosystems?

Land is a resource with many functions: it supports biodiversity, mitigates and enables adaptation to climate change, contributes to carbon sequestration, produces food and is a key resource for the circular economy. Land take and soil sealing result in quantitative losses of land functions. Land that is affected by land take and sealing is deprived of most of its ecosystem functions, many of which cannot be restored, and hence land take is one of the major drivers of land degradation.

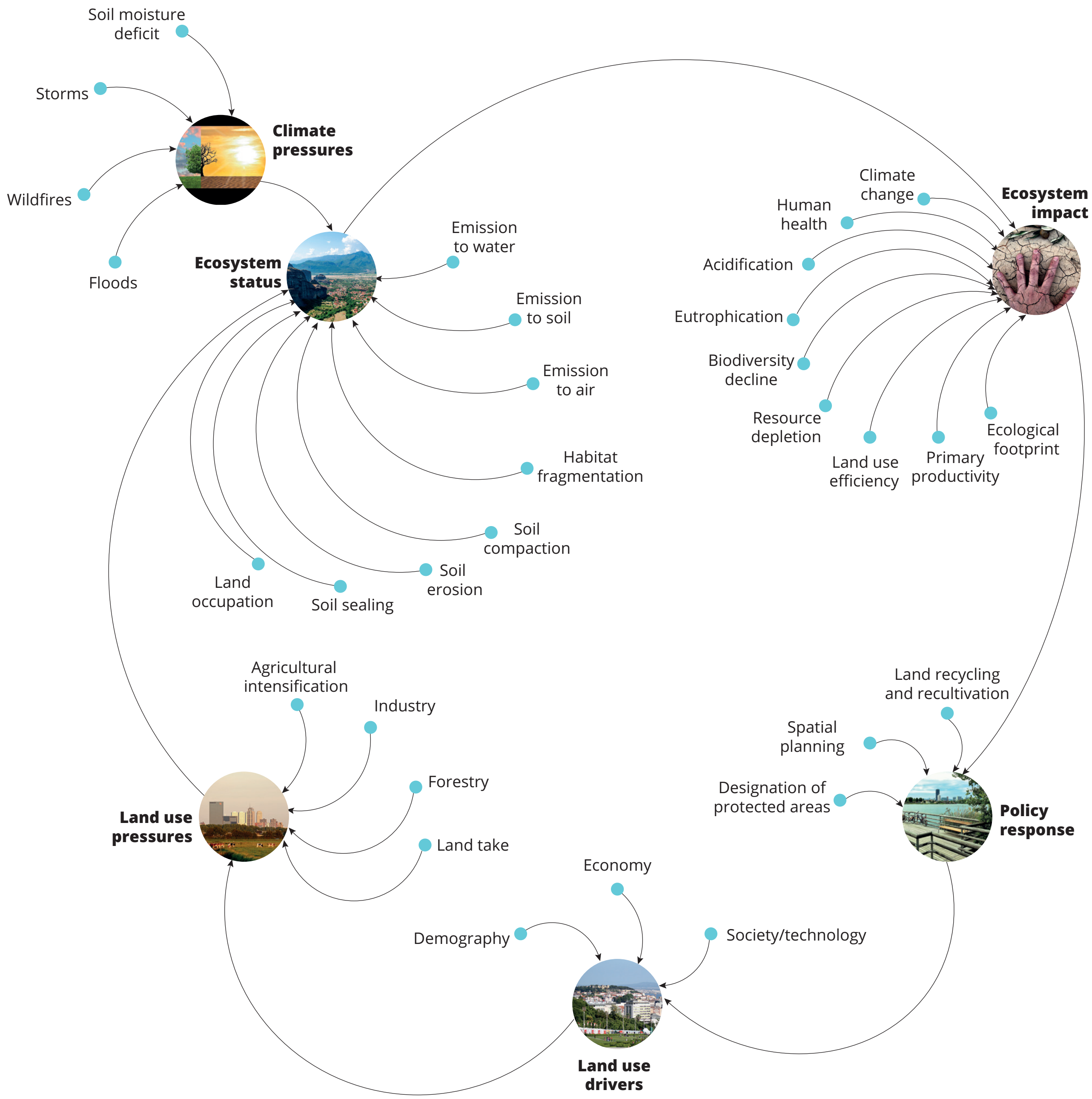
Land take mainly happens in and around urban areas, as these areas usually change in a dynamic way, where land is mostly needed for housing, commuting infrastructure or economic development. Urban areas are part of the land system, which is depicted in Figure 1.1 according to the driver-pressure-state-impact-response (DPSIR) framework (EEA, 1999). Urbanisation and related land take cause ecosystems to become less resilient to climate change and extreme weather events and have major impacts on biodiversity through pressure on land resources.

Most urban areas experience growth in population and jobs and this results in land take at the fringes of core cities at the expense of croplands and grasslands. This increases landscape fragmentation, threatens biodiversity and destroys carbon-rich habitats by reducing the area of grasslands and wetlands, but also agricultural areas.

Land take due to urbanisation affects all ecosystems and regions: it impacts on coastal zones and floodplains, increases landscape fragmentation, threatens biodiversity, destroys carbon-rich habitats and reduces grassland, agricultural and wetland areas. Key pressures relating to urbanisation include sports, tourism and leisure activities, which particularly affect marine/coastal habitats and floodplains.

In floodplains, erosion and sedimentation occur as a result of constructing new roads and buildings. Land take increases the risk of landslides if riparian vegetation is removed on steep slopes. Floods cause economic loss and in the case of flash floods may directly contribute to the loss of human life. The sealing of floodplains increases the risk of floods because of an increase in excess water run-off, which is another detrimental impact of land take.

Figure 1.1. The land use cycle in land systems



The conversion of natural and semi-natural land to housing, settlements or recreational areas mainly puts pressure on grassland habitats and forests (EC, 2020a). These processes directly alter forest ecosystems by removing or fragmenting forest cover. Indirect effects of urbanisation on forest ecosystems occur by modifying hydrology, nutrient cycling, disturbance regimes and atmospheric conditions, and by introducing non-native species (Zipperer, 2003). These changes significantly affect the social and cultural benefits of forests, by reducing carbon storage, nutrient cycling, and water and air purification, and by decreasing the provision of wildlife habitats and timber, fuel and food production.

Grasslands are important for water supply and flow regulation, carbon storage, erosion control, climate mitigation and pollination, and provide cultural/recreational benefits. Urbanisation affects these areas at large, e.g. by altering the composition and spatial arrangement of landscape elements, putting pressure on biodiversity, ecosystem functioning and environmental quality (Wu, 2014).

Sprawling cities tend to consume the best agricultural lands, forcing agriculture to move to less productive areas (Scalenghe and Marsan, 2009). Urban development can reduce the 'critical mass' of farmlands necessary for the economic survival of local agricultural economies, leading to land degradation. Agriculture is also affected by 'indirect land use change' (Gnansonou et al., 2008), as arable land loss in a certain area of Europe is compensated for by converting areas of natural or semi-natural land to agricultural land elsewhere (Gardi et al., 2015).

Wetlands protect and improve water quality through purification, provide fish and wildlife habitats, store floodwaters, maintain surface water flow during dry periods and recharge groundwater aquifers. They contribute to shoreline erosion control and storm protection and are important carbon sinks and habitats for a wide variety of flora and fauna.

1.2 Definitions

1.2.1 Land consumption

Land consumption is an umbrella term indicating human resource consumption, i.e. use of land, where healthy soil and intact habitats are converted for human use, e.g. for agriculture, traffic, urban areas or industry. Hence, land consumption may refer to (1) the expansion of built-up areas; (2) the absolute extent of land that is subject to exploitation by agriculture, forestry or other economic activities; and (3) the over-intensive exploitation of land that is used for agriculture and forestry.

The expansion of built-up areas is a form of land consumption measuring all areas occupied by buildings. These areas are sealed with impermeable human-made materials. Imperviousness on the other hand is when the land surface is impermeable to water and any other material, preventing infiltration into groundwater.

1.2.2 Land take

There are various synonyms for land take, including land consumption and artificialisation. This section provides an overview of available definitions and the general concept of land take. A more detailed analysis on this matter was carried out in the Surface [4] project (Marquard, 2020).

Modern human life is deeply linked to land take, as almost all human activities (disregarding agriculture and forest management) require built infrastructure. Image 1.1 provides an overview of the most common infrastructure types, including housing; road networks; the public sector, with administrative buildings, schools and hospitals; and industry. Recreational activities such as skiing and golfing are linked to land take, as they require parking spaces, new landscaping, lifts, cafes and restaurants, etc. Logistic centres are a relatively new infrastructure type and result from large-scale global trading schemes. This category also includes server farms for data storage, the demand for which is growing rapidly. Other forms of land take include opencast mining and waste disposals. Finally, energy production is also linked to land take, usually through access roads and power lines.

Land take synonyms: land consumption (in the context of spatial planning), artificialisation.

Land take can be defined as the increase in artificial areas over time and represents an increase in settlement areas (or artificial surfaces), usually at the expense of rural areas. This process can result in an increase in scattered settlements in rural regions or in an expansion of urban areas around an urban nucleus (urban sprawl). A clear distinction is usually difficult to make (Prokop and Jobstmann, 2011).

Land recultivation is the inverse of land take. It is measured (when using spatial data sets) as land converted from urban areas into agriculture, forest or other semi-natural areas. Net land take is the mathematical difference between land take and land recultivation. In other words, subtracting the area of recultivated land from the area of land taken gives a value for net land take.

Data availability at the European level. Land take is measured as the increase in artificial area based on Corine Land Cover (CLC) data from the Copernicus Land Monitoring Service (CLMS) [5]. These data are available for 2000, 2006, 2012 and 2018. The CLC data series measure land cover with a minimum mapping unit (MMU) of 25 ha and are complemented by change layers, which highlight changes in land cover with an MMU of 5 ha. Regarding the extent of urban areas, the Urban Atlas [6] of the CLMS can be used to monitor land take. The Urban Atlas maps 17 urban classes with an MMU of 0.25 ha and 10 rural classes with an MMU of 1 ha.

(4) https://www.ufz.de/surface
(5) https://land.copernicus.eu/pan-european/corine-land-cover
(6) https://land.copernicus.eu/local/urban-atlas

Image 1.1. Most common infrastructure types related to land take

Housing

Mobility

Public buildings

Industry

Recreational infrastructure

Logistic centres

Mining area

Waste disposal

Energy production

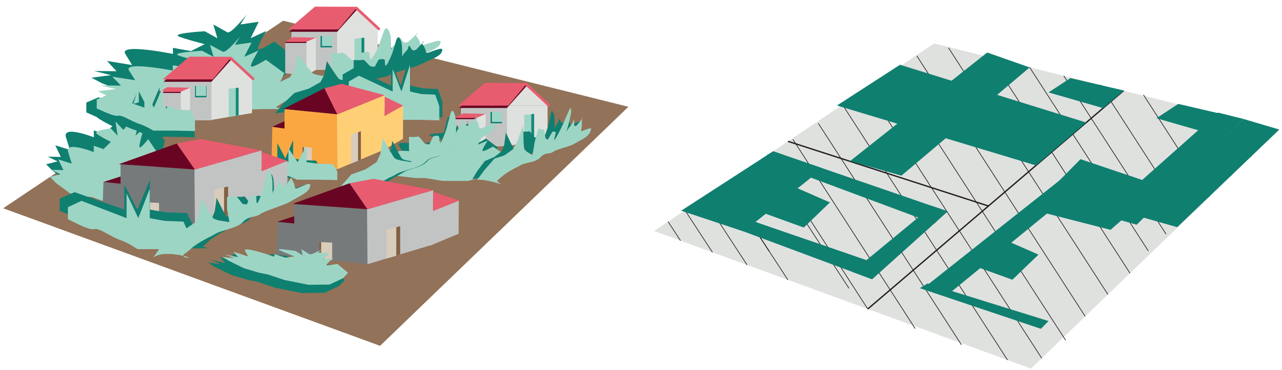
1.2.3 Soil sealing

Soil sealing accompanies land take, but not all areas that are subject to land take are entirely sealed. Sealing rates are usually low in commuting zones (on average 10 %) and very high in cities (on average 36 %) (Naumann et al., 2018). The relationship between land take and soil sealing is illustrated in Figure 1.2.

Soil sealing is a form of land consumption and can be defined as the destruction or covering of soils by buildings, construction and layers of completely or partly impermeable artificial material (asphalt, concrete, etc.). It is the most intense form of land take and is essentially an irreversible process (Prokop and Jobstmann, 2011).

Data availability at the European level. Soil sealing data are available as high-resolution layer imperviousness products (see Box 1.1) from the CLMS ([7]). They are available for the years 2006, 2012 and 2015, with a resolution of 20 m × 20 m, and are complemented by change layers. The latest data set is from 2018 and has a higher resolution, namely 10 m × 10 m. All future data sets will have this spatial resolution. Comparisons of soil sealing in 2018 with previous years is not possible because of the difference in the spatial resolution of the layers.

Figure 1.2. The relationship between land take (left) and soil sealing (right, hatched surfaces)



Source: © Adapted from ETC ULS, G. Prokop.

Box 1.1 The Copernicus imperviousness layer

Copernicus high-resolution layers (HRLs) are Earth observation-derived and raster-based data sets that provide information about different land cover characteristics, such as impervious (sealed) surfaces, forest areas, grasslands, water and wetlands, and small woody features. The longest and most complete time series is available for the HRL imperviousness products, with the first status layer being available for the reference year 2006 and for the years 2009, 2012, 2015 and 2018. Change information is available for all change periods (both density change and change classified). Primary 20-m resolution (and aggregated 100-m resolution) products were harmonised for the period 2006-2015 such that imperviousness status and change layers build a consistent time series, with imperviousness density changes being equal to the difference of subsequent imperviousness status layers.

For the reference year 2018, the spatial detail of all primary HRLs was increased to 10-m resolution. The great advantage of the increased resolution has led to the appearance of more feature details. On the flipside, this made the new 10-m resolution imperviousness product and its data model inconsistent with the data products for previous years, especially in a statistical accounting sense. Therefore, any assessment and product that is dependent on the time series must be split into two periods, one before 2018 and one starting with 2018.

The change in the spatial resolution of the HRL imperviousness product also concerns the Urban Atlas — a Copernicus local component product. The Urban Atlas nomenclature subdivides urban residential fabric into continuous urban fabric (class code 11100) and four discontinuous urban fabric classes (11210-11240). The HRL imperviousness data set is used to discriminate between those classes. An analysis of the area shares of those urban fabric classes indeed indicates that there is a general trend between 2012 and 2018 of changes, from a class with lower density to a class with higher density, e.g. from class 11240 in 2012 to class 11220 or 11210 in 2018. This does not seem to be a real change, but a side effect of the increased spatial resolution, which leads to polygons being assigned to a more strongly sealed class. This means that there is also an inconsistency in the time series of the Urban Atlas data (ETC/ULS, 2021).

([7]) https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness

1.2.4 Landscape fragmentation

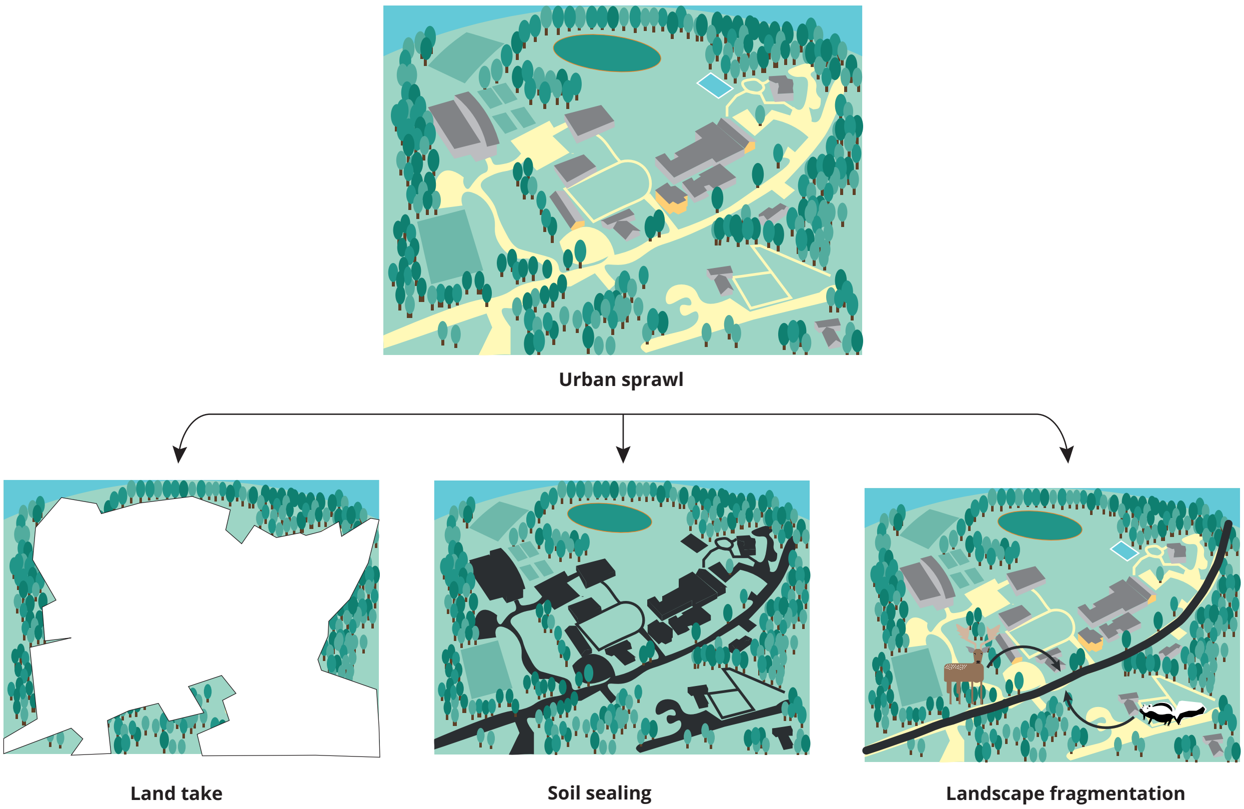
> Landscape fragmentation is the result of transforming large habitat patches into smaller, more isolated fragments of habitats (EEA, 2021a). This process is most evident in urbanised or otherwise intensively used landscapes, where fragmentation is the result of infrastructure development (commuting and travel infrastructure, housing, industrial logistics, energy infrastructure) between and around built-up areas (EEA, 2020).

Large parts of Europe have become highly fragmented as a result of the expansion of urban and transport infrastructure (EEA, 2021a). Areas under great pressure of fragmentation are often found around large urban centres and along major transport corridors. However, remote rural areas are also affected by fragmentation due to the construction of motorways.

Figure 1.3 illustrates how land take, urban sprawl, fragmentation and soil sealing are related using the example of a typical suburban situation.

Data availability at the European level. The fragmentation layer is based on the pan-European high-resolution layer imperviousness data of the CLMS and on the TomTom TeleAtlas road network database. The fragmentation series has been produced for the years 2009, 2012, 2015 and 2018. As the resolution of the imperviousness layer changed between 2015 and 2018, the 2018 layer is not comparable with the previous versions, but can be used as a reference layer for all future updates (every 3 years) ([8]).

Figure 1.3 The relationship between urban sprawl, land take, soil sealing and fragmentation



Source: © Adapted from ETC/ULS, G. Prokop.

([8]) https://www.eea.europa.eu/data-and-maps/data/landscape-fragmentation-effective-mesh-density

1.2.5 Land degradation

Land degradation is mostly understood in terms of a long-term loss in the functionality and productivity of land or land-based ecosystems. The term refers to the degradation of all components of the land system, including soil, vegetation, animals, air and water (WOCAT, 2017).

Land degradation threatens land in several ways (see definition below). Land take and, implicitly, soil sealing are considered quantitative soil losses and are therefore the most severe forms of land degradation. This report assesses land degradation by using land take as a key indicator for land degradation. It has to be stressed that other forms of land degradation such as erosion or compaction are not covered in this assessment.

Examples of forms of land degradation are erosion by water and wind, soil pollution and fertility decline, soil compaction, decline in water quality, vegetation and loss of habitats, and soil sealing due to urbanisation and construction (FAO, 2017). Land degradation assessments differ regarding the forms of land degradation, but the most frequently mentioned topics include soil sealing, the contamination of soil and water, soil compaction and the loss of organic matter in soils, loss of biodiversity, nutrient imbalances, habitat fragmentation, loss of land productivity and the invasion of alien species.

At the European level, there is no established method for land degradation mapping. However, at the global level different methods exist and these are extensively described in *Land degradation knowledge base: policy, concepts and data* (ETC/ULS, 2019).

1.2.6 Land use efficiency

Land use efficiency — as defined in this report — refers to the amount of artificial area per person over time and aims to measure sustainable urban growth. A decrease in the amount of artificial area per person over time indicates that land use has become more efficient, although in rare cases this could be the result of rapid population growth. An increase in the amount of artificial area per person over time indicates inefficient land use or a shrinking population.

In rural areas, the amount of artificial area per capita tends to be much higher than in core cities. The key reason is that people in core cities tend to live in multistorey buildings, whereas in rural areas people usually live in detached houses. In addition, commercial, industrial and transport infrastructure is usually located outside core cities and needs a lot of space.

The amount of artificial area per person decreasing over time indicates that land use is becoming more efficient. In rare cases, a decrease in artificial area per person can also be induced by rapid population growth. The amount of artificial area per person increasing over time suggests inefficient land use or a shrinking population.

The inefficiencies of rapid urbanisation are also considered by United Nations (UN) Sustainable Development Goal (SDG) indicator 11.3.1, which compares land take growth with population growth (UN, 2015).

Data availability at the European level. Information on land use efficiency can be derived from land take (CLMS CLC and imperviousness layers) and population data. These data are available for the EEA-38 and the UK for 2006, 2012 and 2018. Regarding core cities, population data are lacking for Turkish functional urban areas (FUAs).

1.2.7 Land recycling

Land recycling is the reuse of land. It includes the redevelopment of previously developed land (brownfields) for economic purposes, the ecological upgrading of land for the purpose of soft use (e.g. green areas in urban centres) or the re-naturalisation of land (bringing it back to nature) by removing existing structures and/or by de-sealing surfaces (EC, 2014).

Land recycling includes grey recycling and green recycling. The term grey recycling is used when grey urban objects, such as buildings or transport infrastructures, are built on already developed land. Green recycling is the building of green urban areas, such as sport facilities, golf fields, parks, etc. Densification is another form of land recycling that refers to constructing on gaps between buildings or an increasing density of people living in urban areas.

Land take often reflects conflicting claims on land. Land recycling in its broadest sense, i.e. including densification, is considered a response to land take. Land recycling ensures making maximum use of the existing infrastructure instead of building on previously undeveloped land. By reusing land, new land take can be avoided, and ecosystem services can be conserved. Land recycling can prevent the consumption of land that may be valuable for food production or recreation and can be considered a response to the pressures that society puts on land resources, particularly in the urban fringes. Land recycling through densification also contributes to land use efficiency: multistorey buildings occupy less surfaces and host more inhabitants than single-storey buildings and hence allow the more efficient use of land.

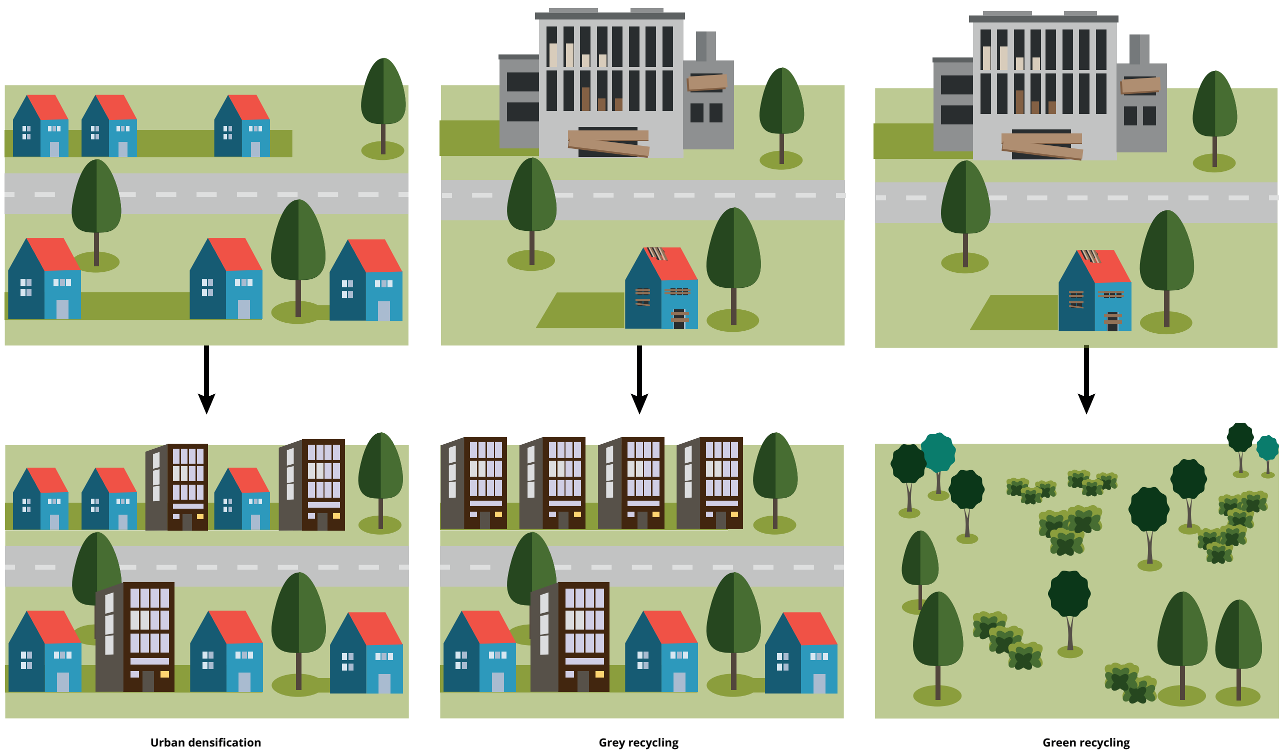
Land recycling could be considered a key planning instrument for achieving the goal of no net land take by 2050. The new EU soil strategy for 2030 (EC, 2021) places the 'reuse' of land in the land take hierarchy, which should be integrated into urban planning at the Member State level to limit land take and soil sealing by the circular use of land. At the same time, land recycling could be key to improving land management and maintaining and developing the green infrastructure that is so important for the provision of ecosystem services. It could also make an important contribution to fulfilling the EU's aim of achieving a circular economy, in which maximum value is derived from resources by the recycling and recovery of materials. Land recycling could also contribute to a green economy, which extends the concept of the circular economy to encourage economic development that is resource efficient and socially equitable, and which respects the limits of the environment.

Reliable quantifications of the potential for land recycling in Europe are still missing, but the potential is estimated to be high. Figure 1.4 shows the three key types of land recycling: urban densification, redevelopment of brownfields and greening of brownfields.

Data availability at the European level. The EEA indicator on land recycling and densification examines land recycling relative to total land consumption (EEA, 2021b).

Land recycling is calculated from a land cover change database. Initially, this was the CLC database, but more recently the Urban Atlas has also been used because of its higher spatial and thematic resolution. However, the changes undertaken to the high-resolution-layer imperviousness product in 2018 (when the spatial resolution changed from 20 m to 10 m) have affected the definition of the different urban density classes in Urban Atlas 2018 (which uses imperviousness data as ancillary data), preventing the EEA from providing an update of the land recycling indicator that compares data from 2018 onwards with previous data. Updates will follow every 3 years from 2018.

Figure 1.4. Types of land recycling



$$\text{Land recycling (ha)} = \frac{\text{land densification} + \text{grey recycling} + \text{green recycling}}{\text{land take}}$$

Source: © Adapted from ETC/ULS, R. Milego Agras.

1.3 Drivers of land take and policy response

Land take has a variety of socio-economic drivers: in some countries, land take is a result of population growth, although in the EU-27 and the UK region, population growth was only around 3 % during the period 2012-2018. Other drivers of land take are the need for transport infrastructure, economic welfare or cultural preferences, e.g. single housing versus flats and the preference for several generations living together versus one-family accommodation (Colsaet et al., 2018). Topography, e.g. steep slopes, which make land development impossible or expensive, also determines where land is developed into urban areas. In this context, land use efficiency — the balance of economic growth with as little exploitation of land resources as possible — is key. Land use efficiency has not yet been well researched, as evidence is lacking.

The multiple determinants that trigger land take are summarised in Table 1.1 and are based on findings from Colsaet et al. (2018).

Land take is a subsidiary policy issue, meaning that Member States act on their own initiative to respect global or EU targets. Despite the proposal for an EU soil protection directive being withdrawn in 2014, various aspects of soil protection have been incorporated into sectoral policies or other policies not related to soil. Land take, however, is addressed through only non-binding policy targets, which are summarised in Table 1.2. The oldest explicit policy target referring to land take requires the EU to 'achieve no net land take by 2050', mentioned in the roadmap to a resource efficient Europe (EC, 2011) and in the Eighth Environment Action Programme (EC, 2020b). It is furthermore noteworthy to mention that land take is now also recognised in other policies, for example in the new biodiversity strategy for 2030 (EC, 2020c) and the new Land Use, Land Use Change and Forestry (LULUCF) regulation([9]). The new EU soil strategy for 2030 (EC, 2021), published in November 2021, requires Member States to set land take targets with the aim of reaching land take neutrality by 2050.

At the global level, land take reduction is recognised in UN SDG 11.3, which stipulates the avoidance of urban sprawl and efficient urbanisation, and in UN SDG 15.3, which demands land degradation neutrality.

At a more regional level, the Alpine Convention called for the minimising of soil sealing in 1998.

Table 1.1 Key land take drivers

Driver	Relevance to land take
Demographic factors	Population growth is one of the most evident and direct factors affecting land take, because of the increased demand for space
Social and cultural factors	Although social processes are often intertwined with other factors, detached housing preferences may lead to, for example, increased land take
Economic factors	Gross domestic product (GDP) growth and rising incomes increase land take through the rising demand for housing, production and leisure spaces
Infrastructure and transport factors	Transport infrastructure is part of land take, as it consumes space. It also favours land consumption by making new areas accessible for other uses such as housing and economic activities and increased automobile use
Policy and institutional factors	Lack of coordination and competition between local administrative units result in increased land take. From a planning perspective, diverse situations may lead to increased land take as a result of insufficient or weak planning or planning oriented towards reducing urban density
Geographical factors	Geographical constraints partly determine the suitability and availability of land for construction. In general, elevation and slope make land more difficult to develop but also more expensive economically

(9) https://ec.europa.eu/clima/eu-action/forests-and-agriculture/land-use-and-forestry-regulation-2021-2030_en

Table 1.2 Policy targets and goals relevant to reducing land take at EU and global levels

Source	Targets and goals
Biodiversity strategy for 2030 (EC, 2020c)	Chapter 2.23: commitment to 'land degradation neutrality' through updating the soil thematic strategy, the strategy for a sustainable built environment and the mission in the area of soil health and food under Horizon Europe
Soil strategy for 2030 (EC, 2021)	Chapter 2: reach no net land take by 2050. To do so Member States should, by 2023, set their own ambitious national, regional and local targets to reduce net land take by 2030
Mission for soil health and food (EC, 2020d)	Objective 3: no net soil sealing and increase the reuse of urban soils for urban development Target 3.1: switch from 2.4 % to no net soil sealing Target 3.2: increase the current rate of soil reuse from the current 13 % to 50 % to help meet the EU target of no net land take by 2050
Roadmap to a resource efficient Europe (EC, 2011)	Milestone 4.6: achieve no net land take by 2050
Land use and forestry regulation for 2021-2030 (EU, 2018)	No-debit rule: The regulation sets a binding commitment for each Member State for the LULUCF sector, that contributes to achieving the objectives of the Paris Agreement and meeting the greenhouse gas emissions reduction target of the EU for the period 2021-2030. The regulation enshrines the commitment for the **first time in EU law** for this period. Moreover, the **scope is extended** from only forests today to all land uses (including wetlands) by 2026. An amendment of the LULUCF Regulation is part of the European Commission's Fit for 55 legislative package, adopted in July 2021 with the aim to make its policies fit for delivering the updated 2030 greenhouse gas emissions net reduction target of 55 % below 1990 levels. It proposes no changes to accounting for emissions from land use in the first compliance period, 2021-2025, but it does propose changes for the second compliance period, 2026-2030.
Transforming our world: the 2030 Agenda for Sustainable Development (UN, 2015)	SDG 11.3: by 2030, enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management in all countries. SDG 11.3.1: measures the ratio of land consumption rate to population growth rate (without target setting). SDG 15.3: by 2030 it foresees to combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world. SDG 15.3.1: measures the proportion of land that is degraded over total land area (without target setting).
Eighth Environment Action Programme to 2030 (EC, 2020b)	Priority objectives on: • decoupling economic growth from resource use and environmental degradation; • pursuing a zero-pollution ambition for a toxin-free environment, including for air, water and soil; and • protecting, preserving and restoring biodiversity and enhancing natural capital, notably air, water and soil, and forest, freshwater, wetland and marine ecosystems.
Soil Protection Protocol of the Alpine Convention (1998)	Article (7): avoidance and mitigation of soil sealing along building activities

Overall, it can be concluded that land take has gained importance in EU policy and that a rapid reduction in land take is urgently recommended in several policy documents. However, binding policy measures are still non-existent.

The new EU soil strategy includes for the first time a 'vision for soil', namely it states that:

By 2050, all EU soil ecosystems are in healthy condition and are thus more resilient, which will require very decisive changes in this decade. By then, protection, sustainable use and restoration of soil has become the norm. As a key solution, healthy soils contribute to address our big challenges of achieving climate neutrality and becoming resilient to climate change, developing a clean and circular (bio)economy, reversing biodiversity loss, safeguarding human health, halting desertification and reversing land degradation (EC, 2021, pp. 2-3).

1.4 From Corine Land Cover to Urban Atlas

Key messages

- As at 2018, the Urban Atlas covered 786 urban regions across Europe. It included 27 land use classes and a minimum mapping unit (MMU) of 0.25 ha.
- The Urban Atlas has a clear advantage over Corine Land Cover data sets, the latter having an MMU of 5 ha.
- The Urban Atlas distinguishes between core cities and commuting areas and allows for the first time a detailed assessment of land use efficiency in 786 urban areas across Europe.

Historically, the EEA land take indicator (EEA, 2021c) was derived from the CLC data sets. The CLC data sets are produced with an MMU of 25 ha. This spatial resolution allows the detection of small-scale changes such as very large parking spaces or the bulky sprawl of cities. However, urban sprawl, i.e. the spreading of artificial urban surface, typically happens on very large scales, e.g. when single houses penetrate the landscape or when narrow roads fragment ecosystems. As the CLC data set is the only pan-European data layer of its kind that allowed for regular change assessments over a 20-year period, the low spatial resolution of the thematic information was ignored. However, with the increasing availability of high-resolution European and national land use/land cover data as well as reference data, the low resolution of the CLC data sets for the monitoring of land take became questionable. The main reason for this was that the CLC data set severely underestimates the area of artificial surfaces and the related changes from non-artificial to artificial land, i.e. land take. This chapter therefore introduces the Urban Atlas, a higher resolution data set that is used in this report to monitor land take in cities and their commuting zones.

1.4.1 Corine Land Cover

Since 1990, the entire surface of Europe has been documented on a regular basis by means of satellite image technology. Since 2000, comparable land cover data have been produced on a 6-yearly basis. The data consider 44 different land cover classes and are based on an MMU of 25 ha for objects and a minimum width of 100 m for linear objects. Status layers are available for 2000, 2006, 2012 and 2018 and are complemented by change layers, which highlight changes in land cover, with an MMU of 5 ha. Country coverage has evolved since 1990: initially, only 27 countries were covered; since 2000, all 38 EEA member countries and the UK have been included. The data layer is freely available ([10]).

1.4.2 Urban Atlas

The Urban Atlas data set ([11]) focuses on urban areas; instead of mapping the entire European surface, the Urban Atlas is confined to FUAs, which include core cities and their commuting zones. The MMU for the urban classes is 0.25 ha and hence the data set is 10 times more accurate than the CLC data set. In total, the Urban Atlas includes 27 land cover classes, of which 17 are urban classes and 10 are rural classes.

The first Urban Atlas data set was produced in 2006 and the data set has evolved continuously since then:

- 2006: the first Urban Atlas layer included 319 FUAs (EU territory) with more than 100 000 citizens.
- 2012: the second Urban Atlas layer was expanded to the European Free Trade Association (EFTA) countries, the western Balkans and Turkey, and included smaller cities with more than 50 000 citizens. In total, 785 FUAs were mapped, and additional data layers were produced (a population estimates layer, a tree layer and a layer of building height) for all European capital cities.
- 2018: the third Urban Atlas layer included three more FUAs, totalling 788 FUAs. In addition, a change layer comparing the land cover changes between 2012 and 2018 was produced.

In total, 788 FUAs are now part of the Urban Atlas data set. About half of these have already been mapped three times (in 2006, 2012 and 2018). Map 1.1 illustrates the difference in granularity between CLC (left) and Urban Atlas (right) data.

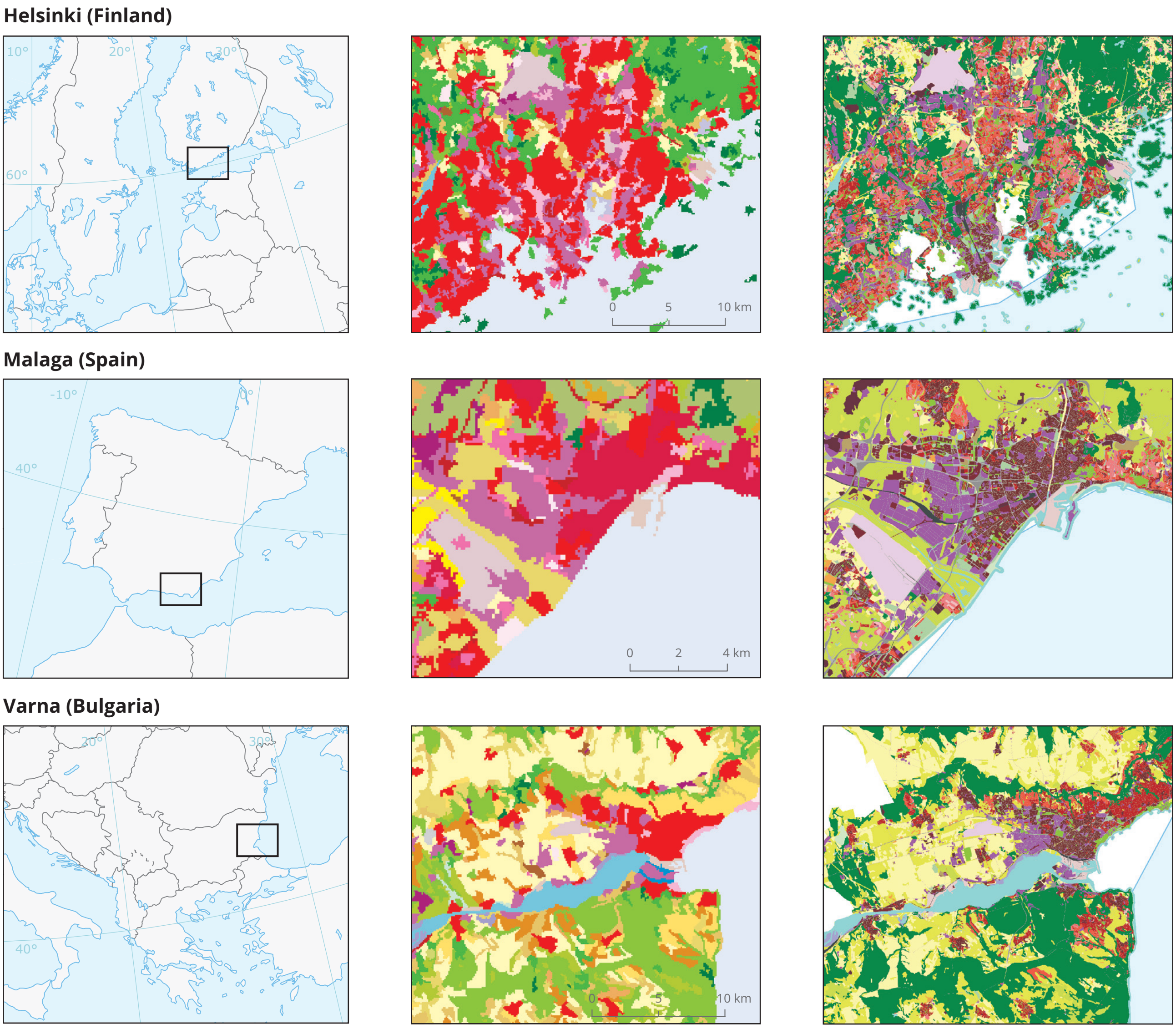
([10]) https://land.copernicus.eu/pan-european/corine-land-cover
([11]) https://land.copernicus.eu/local/urban-atlas

The Urban Atlas data set (see EEA dashboard) is closely linked to the **Urban Audit**, which provides socio-economic statistics for FUAs and is published by Eurostat ([12]).

Here and throughout the report, you can explore the relevant Urban Atlas data sets via a link to the EEA dashboard.

Explore EEA dashboard

Map 1.1 Granularity of CLC (centre) and Urban Atlas (right) data for Helsinki, Malaga and Varna



Reference data: ©ESRI

([12]) https://ec.europa.eu/eurostat/web/cities/data/database

Map 1.1 Granularity of CLC (centre) and Urban Atlas (right) data for Helsinki, Malaga and Varna (cont.)

Granularity of Corine Land Cover (left) and Urban Atlas (right) data for Helsinki, Malaga and Varna

Corine Land Cover 2018

- 111 Continuous urban fabric
- 112 Discontinuous urban fabric
- 121 Industrial or commercial units
- 122 Road and rail networks and associated land
- 123 Port areas
- 124 Airports
- 131 Mineral extraction sites
- 132 Dump sites
- 133 Construction sites
- 141 Green urban areas
- 142 Sport and leisure facilities
- 211 Non-irrigated arable land
- 212 Permanently irrigated land
- 221 Vineyards
- 222 Fruit trees and berry plantations
- 223 Olive groves
- 231 Pastures
- 242 Complex cultivation patterns
- 243 Land principally occupied by agriculture, with significant areas of natural vegetation
- 311 Broad-leaved forest
- 312 Coniferous forest
- 313 Mixed forest
- 321 Natural grasslands
- 323 Sclerophyllous vegetation
- 324 Transitional woodland-shrub
- 332 Bare rocks
- 333 Sparsely vegetated areas
- 411 Inland marshes
- 421 Salt marshes
- 511 Water courses
- 512 Water bodies
- 523 Sea and ocean

Urban Atlas 2018

- 11100 Continuous Urban fabric (S.L. > 80 %)
- 11210 Discontinuous Dense Urban Fabric (S.L. 50 % - 80 %)
- 11220 Discontinuous Medium Density Urban Fabric (S.L. 30 % - 50 %)
- 11230 Discontinuous Low Density Urban Fabric (S.L. 10 % - 30 %)
- 11240 Discontinuous very Low Density Urban Fabric (S.L. < 10 %)
- 11300 Isolated Structures
- 12100 Industrial, commercial, public, military and private units
- 12210 Fast transit roads and associated land
- 12220 Other roads and associated land
- 12230 Railways and associated land
- 12300 Port areas
- 12400 Airports
- 13100 Mineral extraction and dump sites
- 13300 Construction sites
- 13400 Land without current use
- 14100 Green urban areas
- 14200 Sports and leisure facilities
- 21000 Arable land (annual crops)
- 22000 Permanent crops
- 23000 Pastures
- 31000 Forests
- 32000 Herbaceous vegetation associations
- 33000 Open spaces with little or no vegetations
- 40000 Wetlands
- 50000 Water

- No data

2
Land take trends in functional urban areas during the period 2012-2018

Key messages

- **Land take in the period 2012-2018 increased by 2.6 % in the EU-27 and the UK region, affecting 3 581 km^2 of functional urban areas (FUAs).**
- **Almost 80 % of land take took place in commuting zones.**
- **Net land take, calculated by subtracting the area of recultivated land from the area of land taken, in the EU-27 and the UK region amounted to 3 013 km^2, mostly at the expense of croplands and pastures.**
- **The major land take pressure was the expansion of industrial and commercial units, residential areas and construction sites.**

2.1 Land take: overview

Table 2.1 Statistics on land take in FUAs

	EEA-38 and the UK	EU-27 and the UK
Land take 2012-2018 (km^2)	5 330	3 581
Land take as a percentage of 2012 value (%)	3.4 %	2.6 %
Land recultivation 2012-2018 (km^2)	684	568
Net land take (km^2)	4 646	3 013
Land take 2012-2018 per capita (population 2012) (m^2/capita)	16.2	11.5
Land take 2012-2018 per capita (population 2018) (m^2/capita)	15.6	11.5

Land take in the period 2012-2018 affected 3 581 km² of functional urban areas (FUAs) in the EU-27 and the UK region (5 330 km² in the EEA-38 and the UK region; see Table 2.1). Most land was taken from agricultural areas (47 % of all land take), with a loss of 1 694 km², and from pastures (36 % of all land take), with 1 276 km² being converted to artificial areas (Figure 2.1). The area of forests lost was about one fourth of the area of arable lands lost (338 km²); only 79 km² of permanent croplands were lost.

By comparing land take in core cities and commuting areas, it can be observed that 79 % of land take in the EU-27 and the UK region happened in commuting zones (with a similar proportion in the EEA-38 and the UK region) and hence outside core cities (see Figure 2.2). The vast majority of land take happened in the most productive areas (arable lands, pastures and forests), while water bodies, wetlands, land with complex cultivation patterns and open spaces with little or no vegetation were affected little by land take. As a proportion of their 2012 area, pastures and landscape mosaics lost most surface area, with about 0.7 % of these areas being converted to artificial surfaces by 2018. Land take on pastures was also among the highest in terms of absolute value (1 276 km²), indicating that one of Europe's most important biodiversity hotspots (EEA, 2020) and carbon sinks (IPBES, 2018) is under the highest pressure from the spreading of urban areas.

The major land use pressure causing these changes was the expansion of industrial and commercial units, the expansion of residential areas and the expansion of construction sites (Figure 2.2). While the expansion of industrial and commercial sites dominated land take in cities, in commuting zones urban sprawl and the expansion of industrial and commercial sites were equally responsible for most land take.

Figure 2.1 Land take in 2012-2018 in FUAs of the EU-27 and the UK region, by land cover

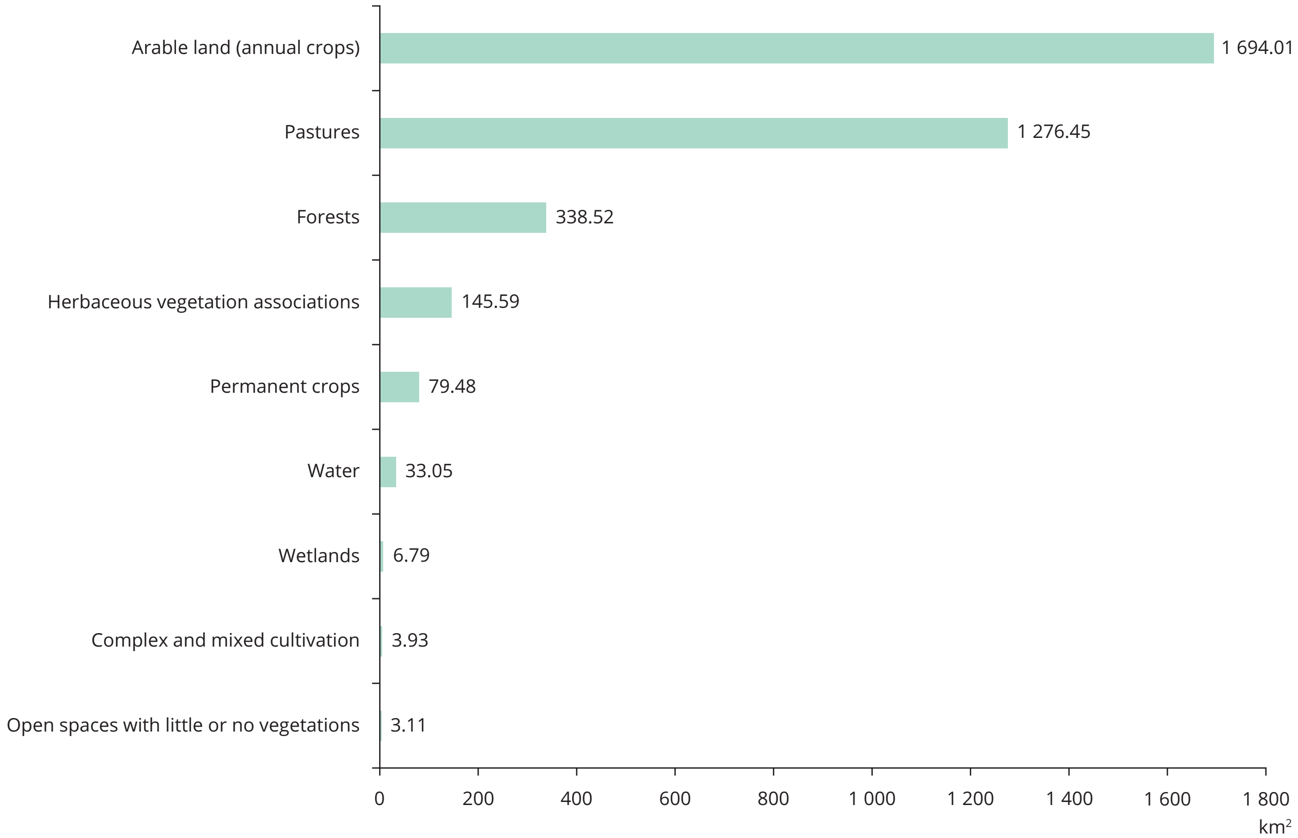
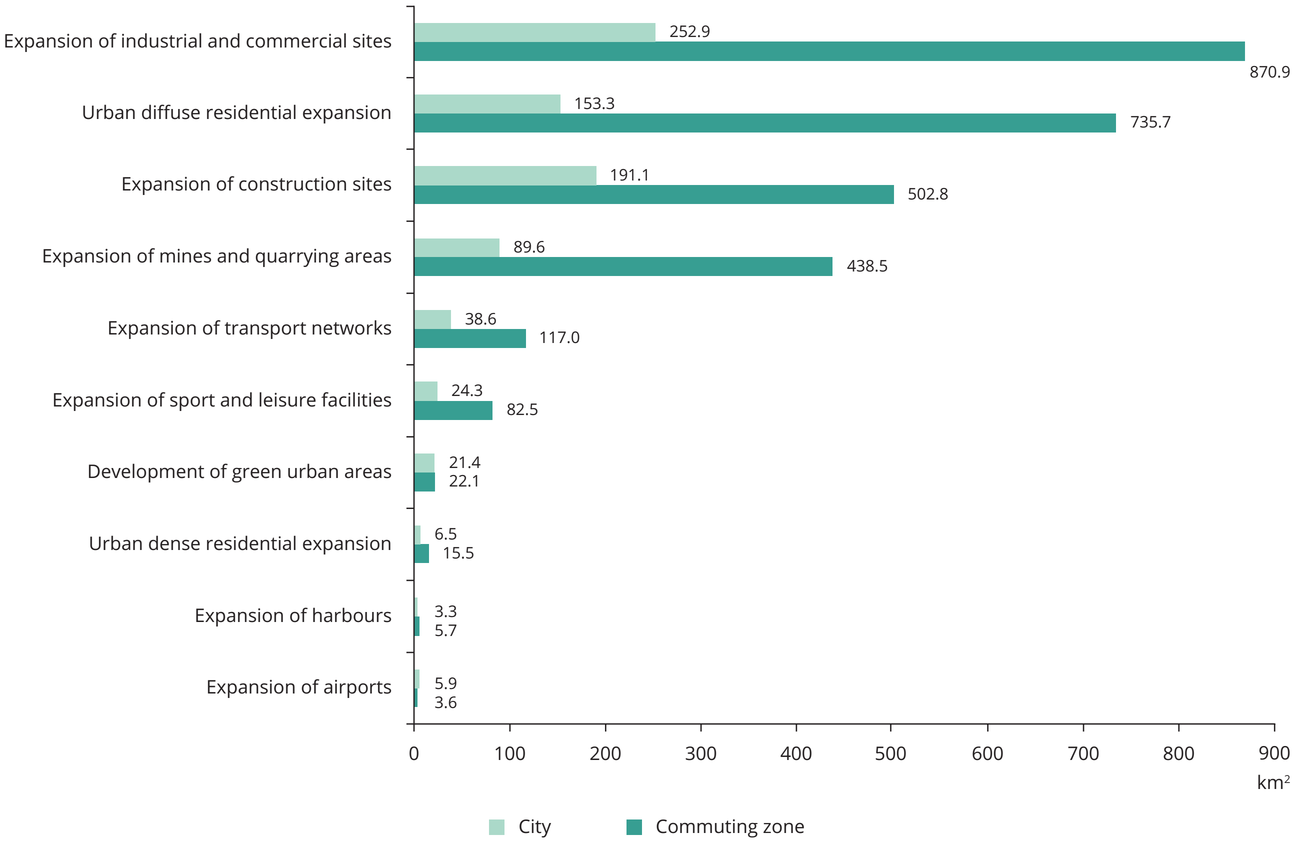
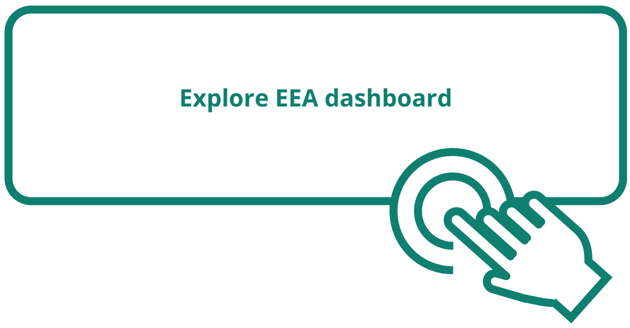


Figure 2.2 Land take in 2012-2018 in FUAs of the EU-27 and the UK region, by land use drivers

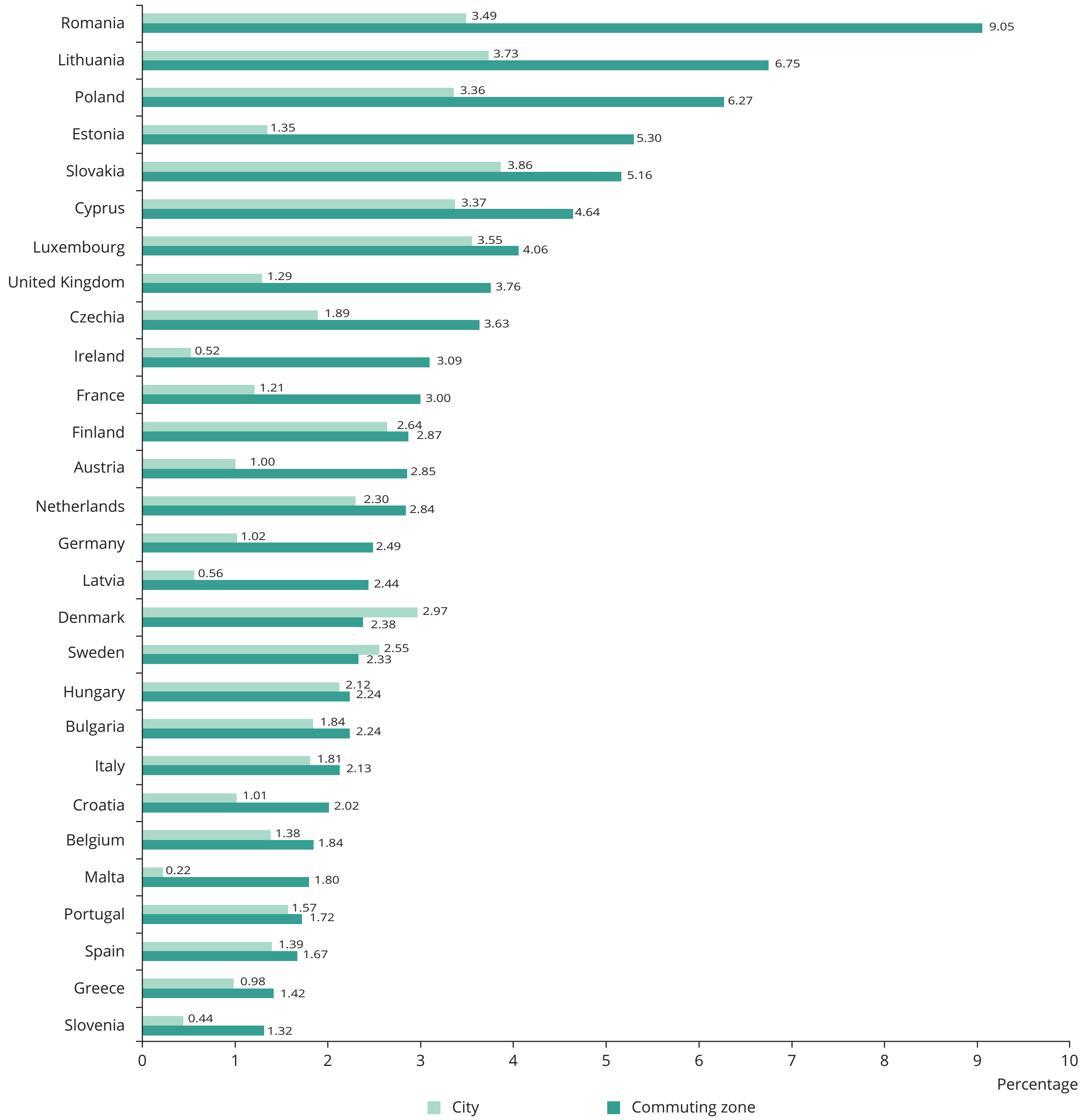


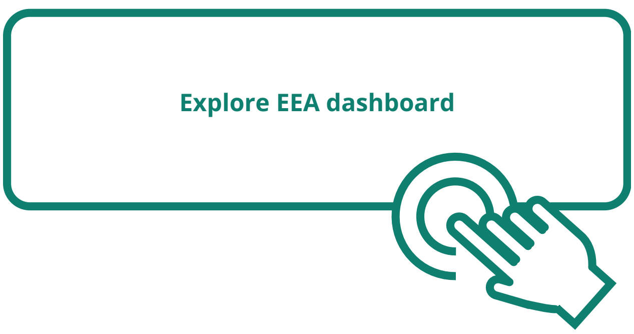


2.2 Country comparisons

- **Land take in commuting areas.** Between 2012 and 2018, the smallest land take increases in commuting areas can be observed in Slovenia, Greece and Spain, with increases of less than 1.6 % (Figure 2.3). The highest increases in land take in commuting areas occurred in Romania, Lithuania and Poland, ranging from 6 % to 10 %.
- **Land take in core cities.** This is generally much lower than in commuting areas, with maximum increases of 3.8 % (Figure 2.3). In many EU countries, the increase in land take in core cities was less than 1 %, as was the case in Austria, Croatia, Estonia, Germany, Greece, Ireland, Latvia, Malta, Portugal, Slovenia and Spain. The highest increases, of more than 3.5 %, took place in core cities in Slovakia, Lithuania and Luxembourg.

Figure 2.3 Land take in 2012-2018 in FUAs of the EU-27 and the UK region by country and FUA structure





2.3 Recultivation and net land take

Land take can be reversed, that is, artificial areas can be converted to natural or semi-natural areas. A decrease in land take can be due to effective policy measures, but also economic recession. This process can be summarised as 'recultivation' and is indicated with negative bars in Figure 2.4. The difference between land take and land recultivation is known as 'net land take'. In the period 2012-2018, recultivation amounted to 145 km² in core cities and 423 km² in commuting areas (Table 2.2). The conversion of already developed sites to agricultural land is the largest contributor to recultivation, but agriculture rotation and the creation of semi-natural areas also contribute (Figure 2.4).

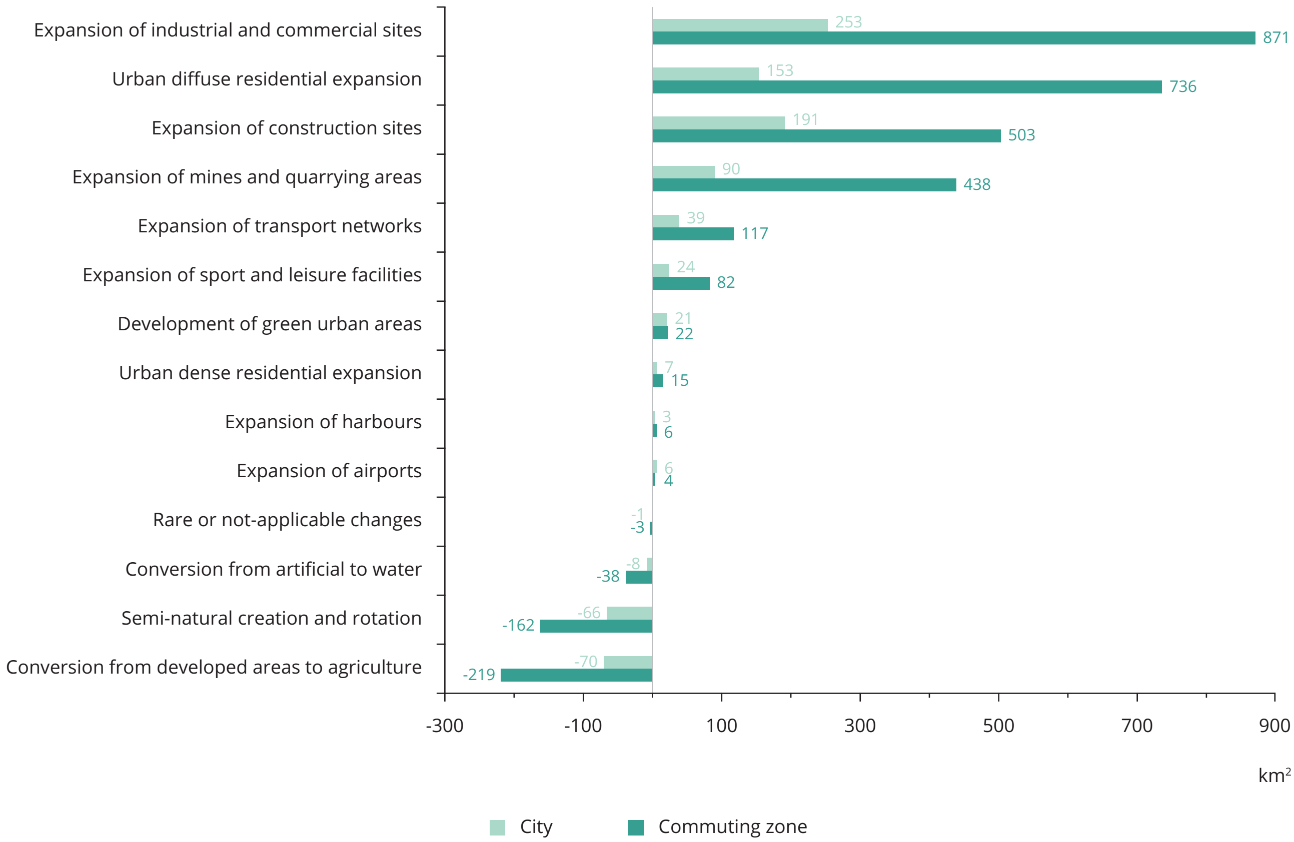
The key contributors to the formation of artificial areas are indicated in Figure 2.4. The largest contributor in commuting areas was the expansion of industrial and commercial sites (871 km²), followed by the expansion of commuting areas (736 km²). In core cities, the largest contributor to the formation of artificial areas was again the expansion of industrial and commercial sites (253 km²), but here the expansion of construction sites ranked second (191 km²).

While on average land take increased by only 2.6 % in the EU-27 and the UK region between 2012 and 2018, in some urban areas the rate of converting semi-natural areas to urban land cover was much higher. In Suwalki (Poland), Gela and Battapaglia (southern Italy) and Alba Lulia (Romania), the increase in land take was slightly above 15 % (Map 2.1). Italy had the largest variation in land take: along with one of the highest land take values, it also had very low values, with the increases in land take in Massa and Trieste being below 0.3 %, which is 10 times less than the EU average. Some other FUAs in Germany and Spain also showed very low land take values; those in Spain were the lowest in Europe. Few countries showed a narrow range of land take values, with a low average land take rate, notably Slovenia and Malta, although the small size of these countries also contributes to the low variance in the values.

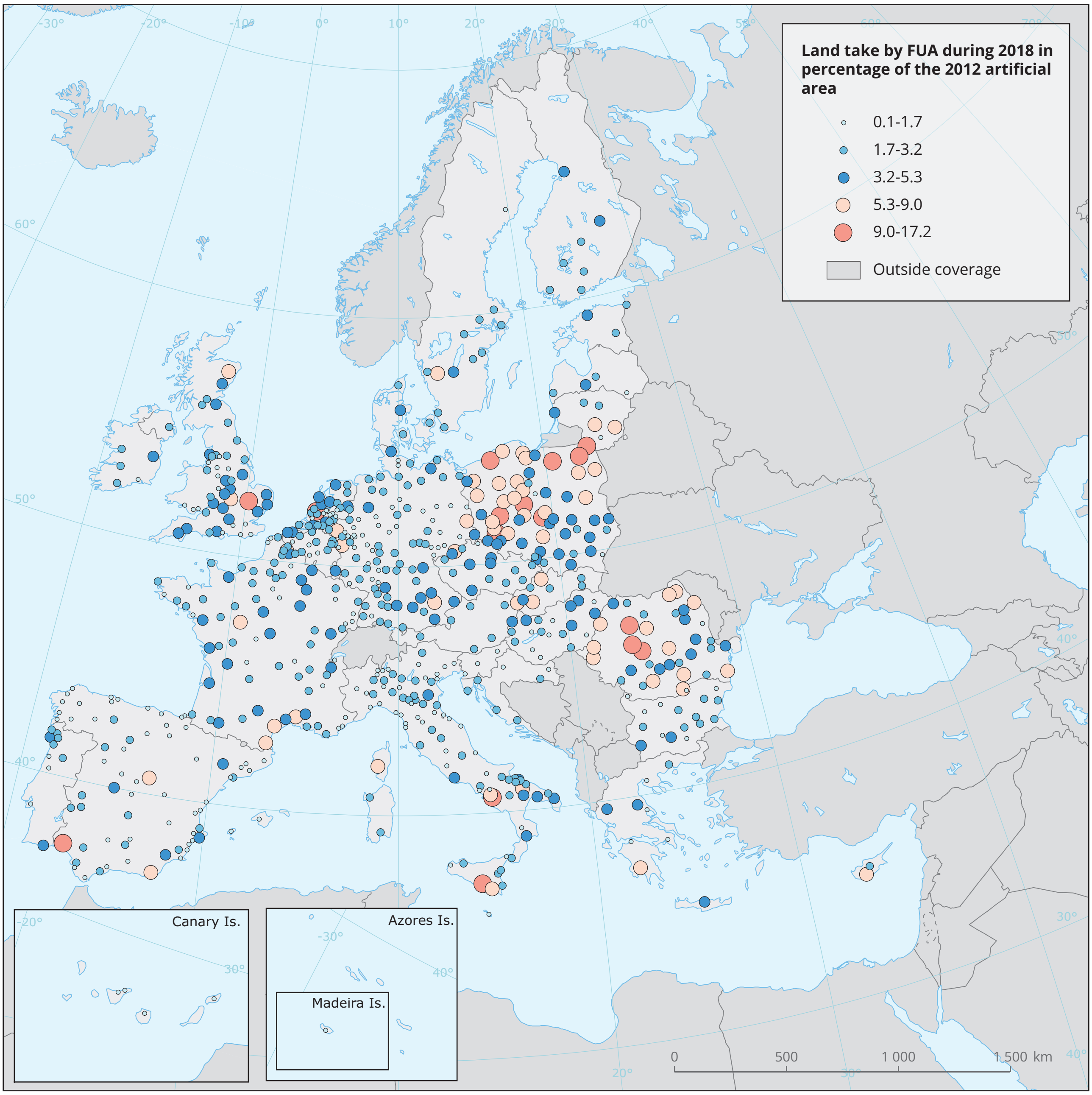
Table 2.2 Recultivation and net land take in FUAs

Area	Increase in artificial area (km²)	Decrease in artificial area/recultivation (km²)	Net land take (km²)
Core cities	787	145	642
Commuting areas	2 794	423	2 371
Total FUA	**3 581**	**568**	**3 013**

Figure 2.4 Change in artificial area (in km²) between 2012 and 2018 in the EU-27 and the UK region by land use and FUA structure



Map 2.1 **Land take in 2012-2018 in FUAs of the EU-27 and the UK region, as a percentage of the area of artificial surfaces in 2012**



Reference data: ©ESRI

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3 Land use efficiency

Key messages

- **Functional urban areas (FUAs) represent 23 % of the EU-27 and the UK territory but host 75 % of its population.**
- **Land use efficiency, that is, the creation of artificial areas as a proportion of population size, is in general improving in both core cities and commuting areas.**
- **However, far less artificial area is used per citizen in core cities than in commuting areas, with 218 m² being used per capita in core cities and 691 m² per capita in commuting areas.**
- **Regional distinctions show that land use efficiency is highest in southern Europe, with 273 m² per capita, and lowest in northern Europe, with 651 m² per capita, although northern Europe has shown an improving trend since 2012.**

In the context of this report, the term 'land use efficiency' focuses on the use of artificial areas in functional urban areas (FUAs) in relation to the number of inhabitants. As a way of quantifying land use efficiency, the amount of artificial area per capita is used. It has to be stressed that the thresholds have neither been discussed nor defined yet. At the time of writing, it was possible to only compare the land use efficiency of defined regions and group them into regions with high, low or average values for land use efficiency relative to one another. The use of artificial area per capita is also addressed in the Sustainable Development Goal (SDG) 11.3.1 indicator on land consumption per capita. In this chapter, land use efficiency is considered in the context of the SDG 11.3.1 concept: urban green areas are not considered when addressing artificial areas.

Low land use efficiency means that few people use a lot of artificial area and hence the amount of artificial area per capita is high. This is typically the case in remote rural areas, where buildings have only one or two storeys and the road network is frequented by few people.

High land use efficiency means that small amounts of artificial area are used by many inhabitants. This is only possible when buildings have several storeys and the built infrastructure, in particular the road network and public transport, are frequented by many people. Very high land use efficiency can be observed in city centres of very large metropoles.

A drawback of high land use efficiency is that sealing rates are also high and hence the areas of unsealed surfaces and vegetation cover are low.

3.1 EU trends

FUAs represent 22.9 % of the EU territory but host 75 % of its population (Table 3.1). Between 2012 and 2018, there was a 3 % increase in the EU population, which was slightly higher than the 2.2 % growth rate of artificial areas. When the population increases more than the artificial surface area, land use becomes more efficient. However, an increasing population increases the pressure on land because of the subsequent need for infrastructure, transport and housing.

To fulfil global and EU policy objectives, such as 'no net land take by 2050' (see also Table 1.2), it is advisable to establish guidance values for land use efficiency for most common settlement types, in particular for urban fringes and small towns in rural areas, considering a good balance between efficient land use and sufficient green space to allow a good quality of life.

Average values for FUAs in the EU-27 and the UK show that land use efficiency slightly improved between 2012 and 2018 (see Figure 3.1), with the number of artificial surfaces used per inhabitant decreasing by 5 m² (from 423 m² per capita to

418 m² per capita). As the population of FUAs increased by 2.4 % in this period, and the increase in artificial surfaces was somewhat less (2.1 %), it can be assumed that the increase in land use efficiency was due to more people living in the same accommodation, houses or flats. This may reflect densification measures implemented by local administrations, where more flats are built in high-rise buildings and therefore more people can be concentrated in the same artificial surface unit. On the other hand, this may also reflect changes in living preferences, that is, families being more likely to stay together in the same accommodation.

However, although land use efficiency improved between 2012 and 2018, with slightly more people using the available artificial surfaces in 2018 than in 2012, the creation of artificial surfaces and hence the sealing of soils in urban areas still increased (see Table 3.1). The largest increase in artificial areas per capita was due to the creation of industrial, commercial, public/military and private units, with an increase of 115 000 ha in this period (see Figure 3.1). By 2018, these areas occupied 84 m² per capita, which, however, is an increase of only 0.2 m² in artificial areas used per inhabitant. Nevertheless, commercial and industrial sites use urban land least efficiently, as on those sites many artificial surfaces are needed for one person.

Table 3.1 FUA statistics for land use efficiency

	EEA-38 and the UK	EU-27 and the UK	Unit
Number of FUAs	786 (a)	662 (a)	No
Total FUA area	1 268 580	1 002 005	km²
Area of cities in FUAs		145 317	km²
Area of commuting zones in FUAs		856 688	km²
Total area	5 831 634	4 377 725	km²
FUA area/total area	21.8	22.9	%
FUA population 2012 (b)	329 018 505	311 969 642	capita
FUA population 2018 (b)	342 473 073	324 853 205	capita
FUA population change 2012-2018	13 714 038	11 340 037	capita
Increase in FUA population 2012-2018	3.1	3.0	%
FUA population/total population	74.0	75.0	%
Land consumption per capita 2012	541.5	423.4	m²/cap
Land consumption per capita 2018	449.5	417.9	m²/cap
Change in land consumption per capita	-2.1	-5.5	m²/cap

Notes: (a) Ponta Delgada (PT007) excluded due to no data in 2012.

(b) https://ec.europa.eu/eurostat/web/cities/data/database

Source: EEA (2020b).

Discontinuous dense urban fabric accounted for the second most inefficient use of artificial land in 2018, with 71 m² of artificial land used per inhabitant. However, despite the approximately 32 000 ha increase in the discontinuous dense urban fabric, the artificial area per capita decreased by almost 2 m², indicating improving land use efficiency.

The largest increase in artificial surfaces per inhabitant was due to construction sites (increase of around 1.9 m² per capita; see Figure 3.1). Most areas were built where population density tended to be higher and hence it can be assumed that these developments concern the building of new accommodation. The second largest increase (of 1.28 m² per capita) was seen in areas where mineral extraction and dumping took place; this is probably because fewer people live in those areas or because people tend to move away from those areas because of pollution.

The slightly improving land use efficiency trends are also visible if the statistics are disaggregated for core cities and commuting areas (see Figure 3.2). Land use efficiency improved by 3.2 m² per capita in cities, while in commuting zones the improvement was four times higher. The data also indicate that land use efficiency is in general much higher in core cities than in commuting zones: in 2012 and 2018, inhabitants in cities used 68 % less artificial area than in commuting areas.

Figure 3.1 Change in artificial area per capita between 2012 and 2018 in FUAs of the EU-27 and the UK region, by land use process

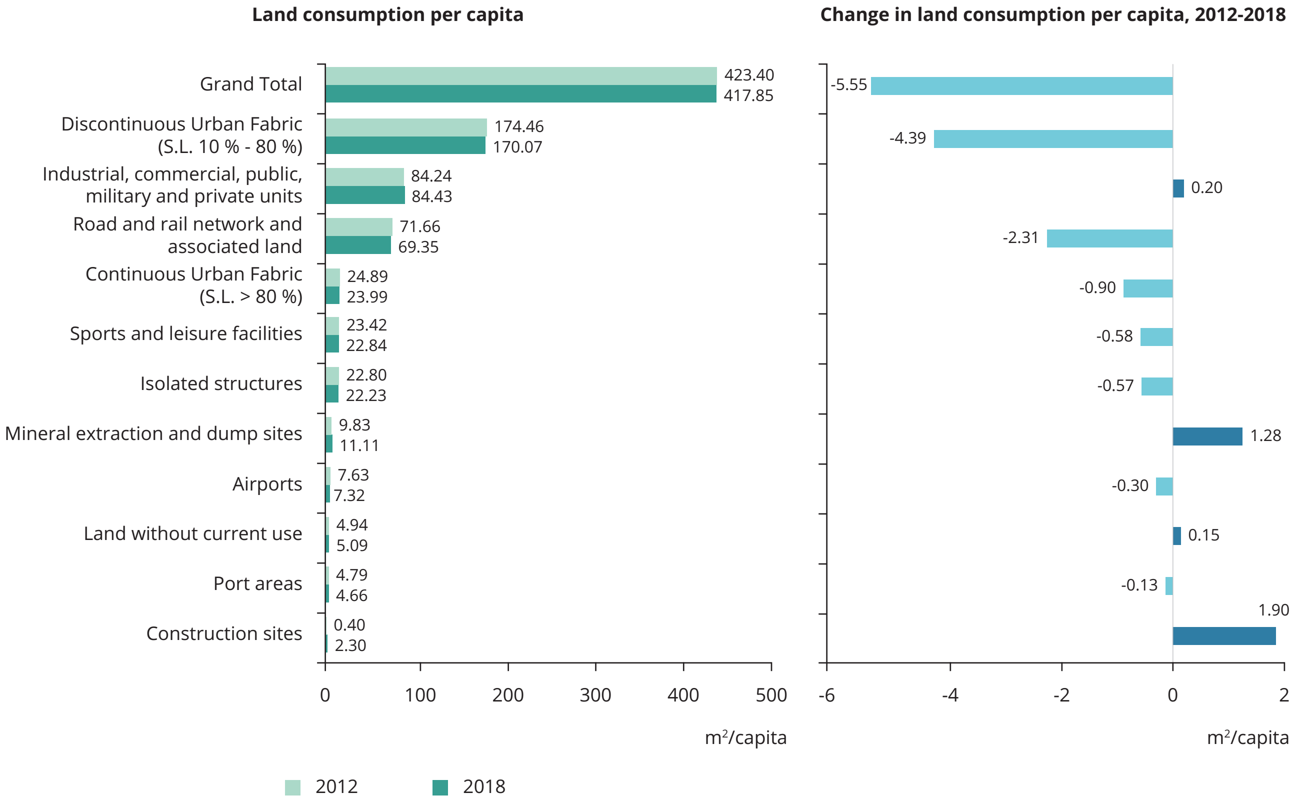

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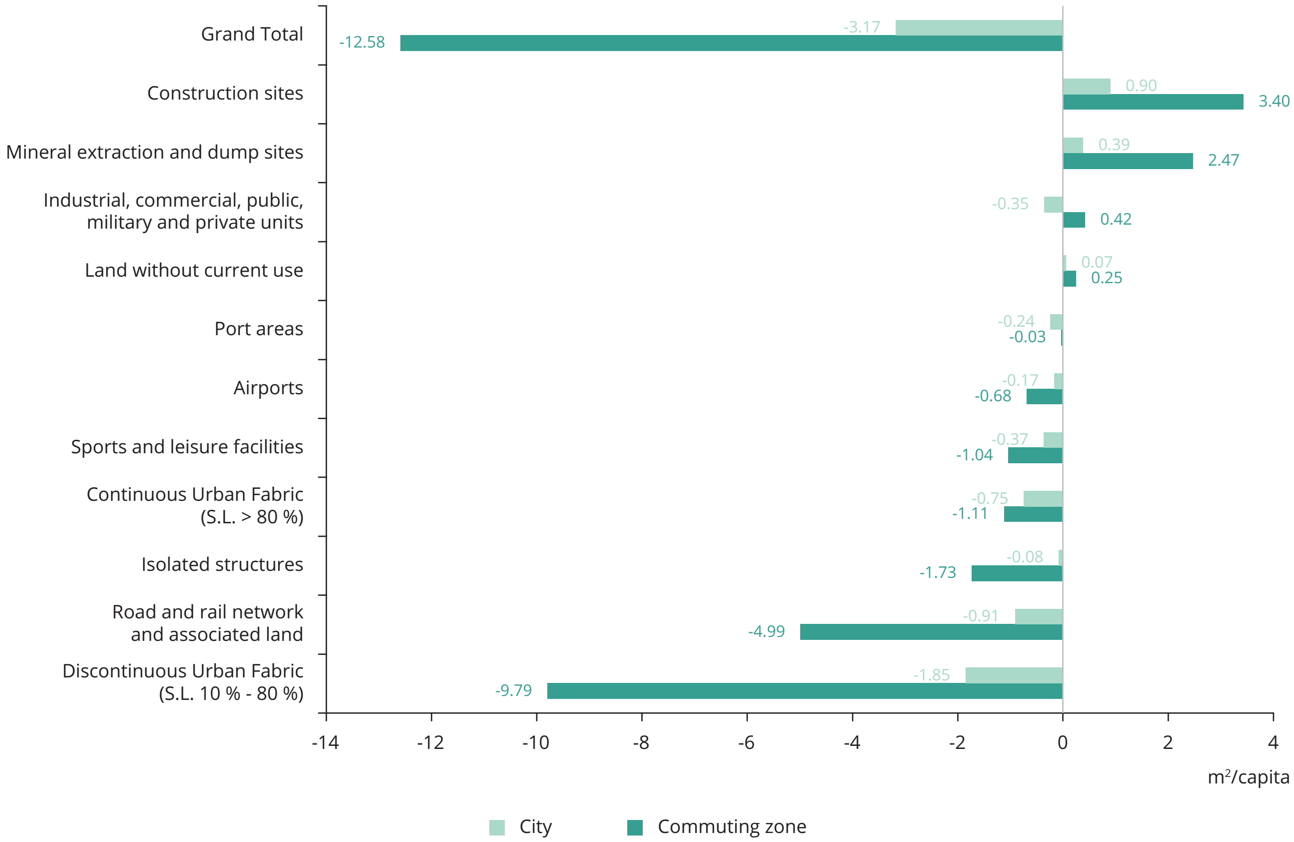
Figure 3.2 **Change in artificial area per capita between 2012 and 2018 in FUAs of the EU-27 and the UK region, by FUA structure and land use process**



3.2 Country trends

Among the EU Member States, the FUAs in Malta followed by Romania, Greece and Spain had the lowest rates of artificial area per capita in 2018 (Figure 3.3). Hence, on average, land use efficiency in 2018 was higher in these countries than in others, because more inhabitants were concentrated in the available artificial areas. At the other end of the spectrum is low land use efficiency, with high artificial area per capita, i.e. where relatively few people use existing artificial surfaces. In 2018, Finland followed by Latvia, Ireland and Denmark used their land areas in the least efficient way, with more than 680 m^2 of artificial surfaces used by each inhabitant.

Among the abovementioned countries, Finland shows an improving trend, with an average decrease in artificial surface used of 6.3 % per capita since 2012 (see Figure 3.3). This decrease is among the largest of the EU-27 and the UK region, with only Malta, the United Kingdom, Luxembourg and the Netherlands showing larger decreases (up to 10 % in the Netherlands). This increasing land use efficiency, with more people using existing artificial surfaces, is beneficial and if it continues will reduce pressure on land.

On the other hand, the highly inefficient use of land in Latvia, Ireland and Denmark is the result of an increasing trend in the amount of artificial surface per capita, with as much as a 7 % increase in Latvia. In these countries, the inefficient use of land is expected to continue to increase unless national policy measures counteract this trend by limiting urban sprawl and investing in reusing urban land for housing and industrial sites (densification of urban areas).

The highest increase in artificial area per capita between 2012 and 2018 happened in the FUAs in Czechia, which reached 18 %. As shown in Figure 3.3, the largest increase was in the commuting zones of FUAs in Czechia, so this more inefficient use of land was most probably due to urban sprawl.

Land use efficiency is especially critical in commuting zones, where on average more semi-natural or unsealed land is still available than in core cities. This land can support biodiversity, carbon sequestration and climate change adaptation, hence supporting more resilient ecosystems. The Baltic countries Estonia and Latvia, as well as Finland, Bulgaria and Cyprus, used their suburbs least efficiently in 2018 (see Figure 3.4). Land use efficiency amounted to slightly over 1 700 m² per capita in Estonia, Latvia and Finland, indicating that a lot of artificial area is used per person in these countries. In Finland, land use efficiency showed an increasing trend in commuting zones between 2012 and 2018, indicating an increase in the number of people using existing artificial surfaces. In the commuting zones of Cyprus, Latvia, Bulgaria and Estonia, however, land use became more inefficient, indicating an increase in pressures on ecosystems within and surrounding the FUAs.

Figure 3.3 Land use efficiency in 2018 (m² artificial area/capita) and change in land use efficiency compared with 2012 (as a percentage of 2012 values) in FUAs of the EU-27 and the UK region, by country

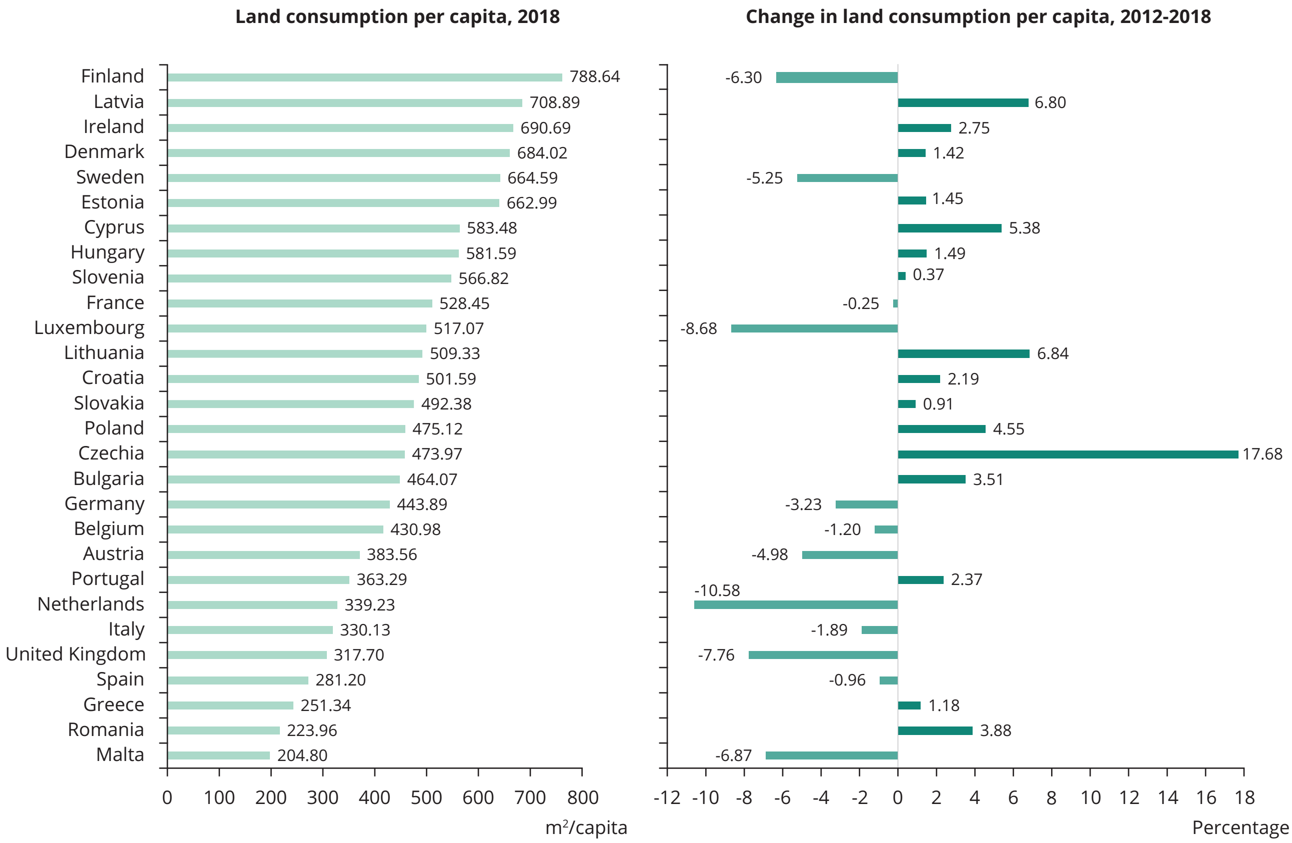


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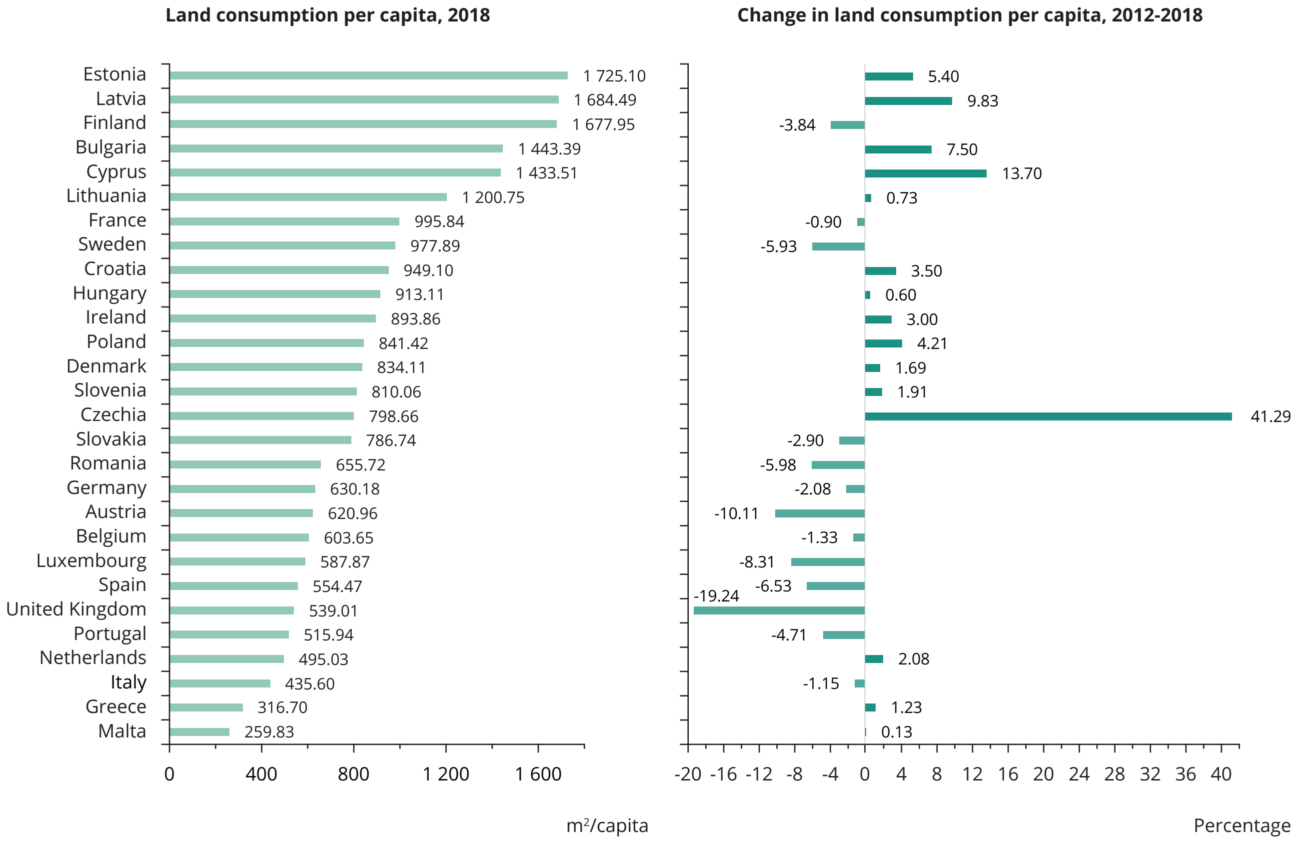
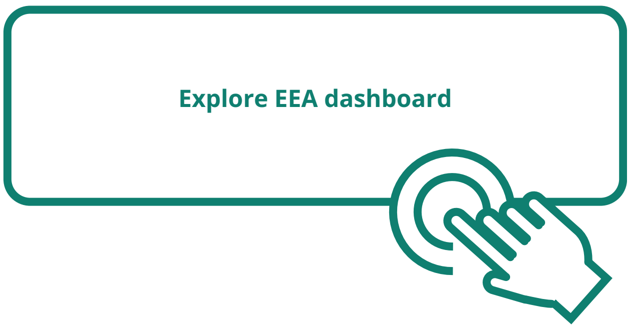
Figure 3.4 **Land use efficiency in 2018 (m^2 artificial area/capita) and change in land use efficiency compared with 2012 (as a percentage of 2012 values) in commuting zones of the EU-27 and the UK region, by country**

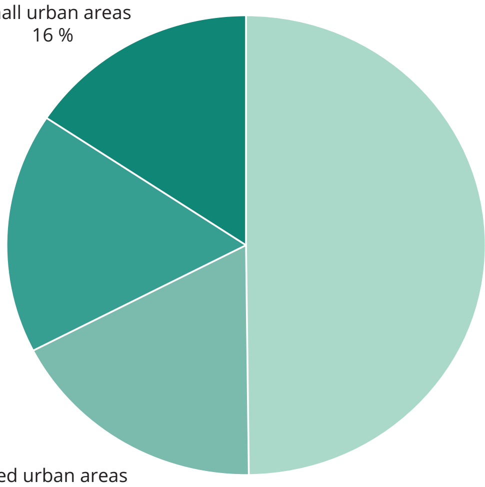




3.3 Land use efficiency according to functional urban area size category

The Organisation for Economic Co-operation and Development (OECD) established four size classes for FUAs, which were adapted for the European situation, as cities in Europe are in general smaller than in other regions of the world (OECD, 2012). Figure 3.5 shows how the FUA population of 324 million inhabitants is distributed over the four size classes. The majority of the FUA population lives in the largest category 'large metropolitan areas' (162 million people, corresponding to 50 % of the total FUA population). However, small FUAs are dominant in quantity, and although they host only 16 % of the EU's FUA population almost every second FUA hosts fewer than 250 000 inhabitants.

Figure 3.5 The 2018 FUA population by FUA size class



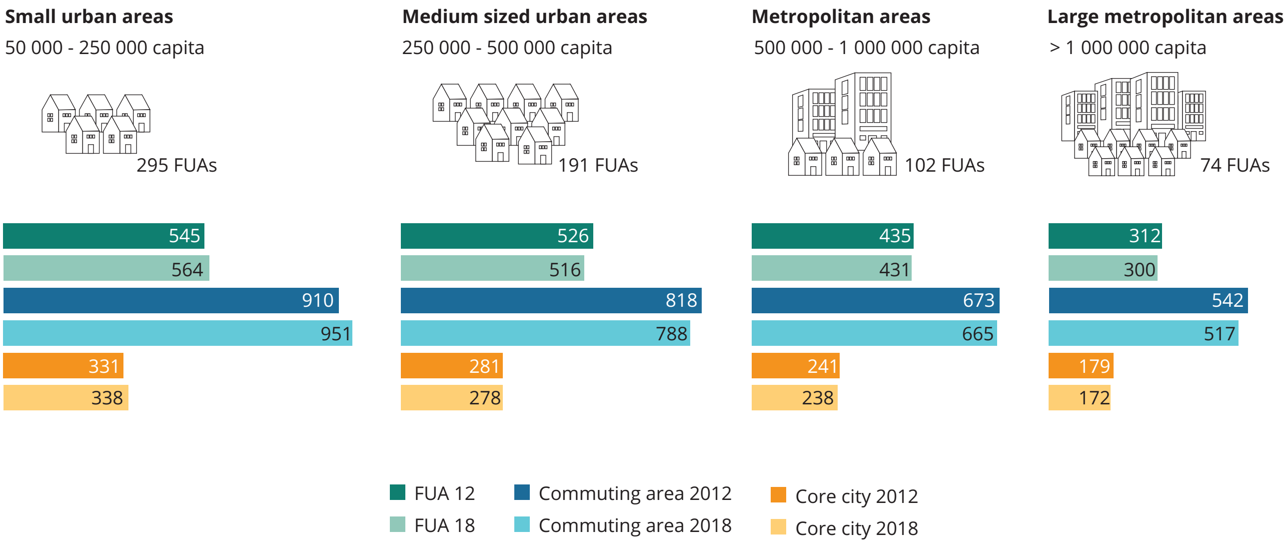
FUA size class	2018 population	No of FUAs
Small urban areas (50 000 - 250 000)	50 883 046	340
Medium-sized urban areas (250 000 - 500 000)	57 186 898	180
Metropolitan areas (500 000 - 1 million)	54 9657 46	80
Large metropolitan areas (> 1 million)	161 817 515	62
Grand Total	324 853 205	662

Figure 3.6 indicates the amount of artificial area per capita within each size class and the change between 2012 and 2018.

Only 16 % of the FUA population lives in a small urban area, ranging from 50 000 to 250 000 inhabitants. In this category, the amount of artificial area is higher than in other categories, with 564 m² per capita, and it increased by 19 m² between 2012 and 2018. Furthermore, increasing trends in the amount of artificial area per capita can be observed in this size class in both core cities and commuting areas.

Large metropolitan areas host 50 % of the FUA population. In this size category, the amount of artificial area per capita is 300 m². This declined by 12 m² per capita between 2012 and 2018, which indicates improving land use efficiency. This decreasing trend can be observed in both commuting areas and core cities.

Figure 3.6 Artificial area per capita in 2012 and 2018 by FUA structure and size category



3.4 Land use efficiency according to socio-cultural zones

Five socio-cultural zones were used to further assess land use efficiency in 662 FUAs of the EU (see Box 3.1).

North Europe is the most sparsely populated region, with only 23 FUAs. In this region, however, the highest population growth between 2012 and 2018 can be observed (6.1 %). Furthermore, the amount of artificial area per capita is higher in this region than in any of the other European regions considered, at 701 m² per capita, although with a declining trend (a decrease of 25 m² since 2012).

Central Europe is the most populated, with 244 FUAs. Population growth between 2012 and 2018 amounted to 2.6 %, while artificial areas remained stable. The amount of artificial area per capita is the second highest (after north Europe), at 466 m² per capita, and this has remained stable since 2012.

South-east Europe has only 52 FUAs. Very remarkable is the fact that the population in this region shrank by 0.3 % between 2012 and 2018, probably because of emigration. Artificial areas grew by 2.3 %, which corresponds to the EU-27 and the UK average. The amount of artificial area per capita is lowest in this region, at 303 m² per capita, although this increased by 8 m² between 2012 and 2018, mostly owing to emigration from the region.

Box 3.1 Socio-cultural zones

Welfare, governance structures and cultural aspects are among the key factors that affect land take. A more detailed assessment of land take for the main European regions was carried out as defined by Jordan (2005). In this classification, socio-cultural aspects are used as common denominators to define five main European regions. Historic governance structures and religion are the key criteria of this classification (Jordan, 2005).

Region	No of functional urban areas	2018 population
Central Europe	244	127 436 422
North Europe	23	14 399 484
South Europe	180	98 761 950
South-east Europe	52	19 360 695
West Europe	163	123 321 600
Total	662	383 280 151

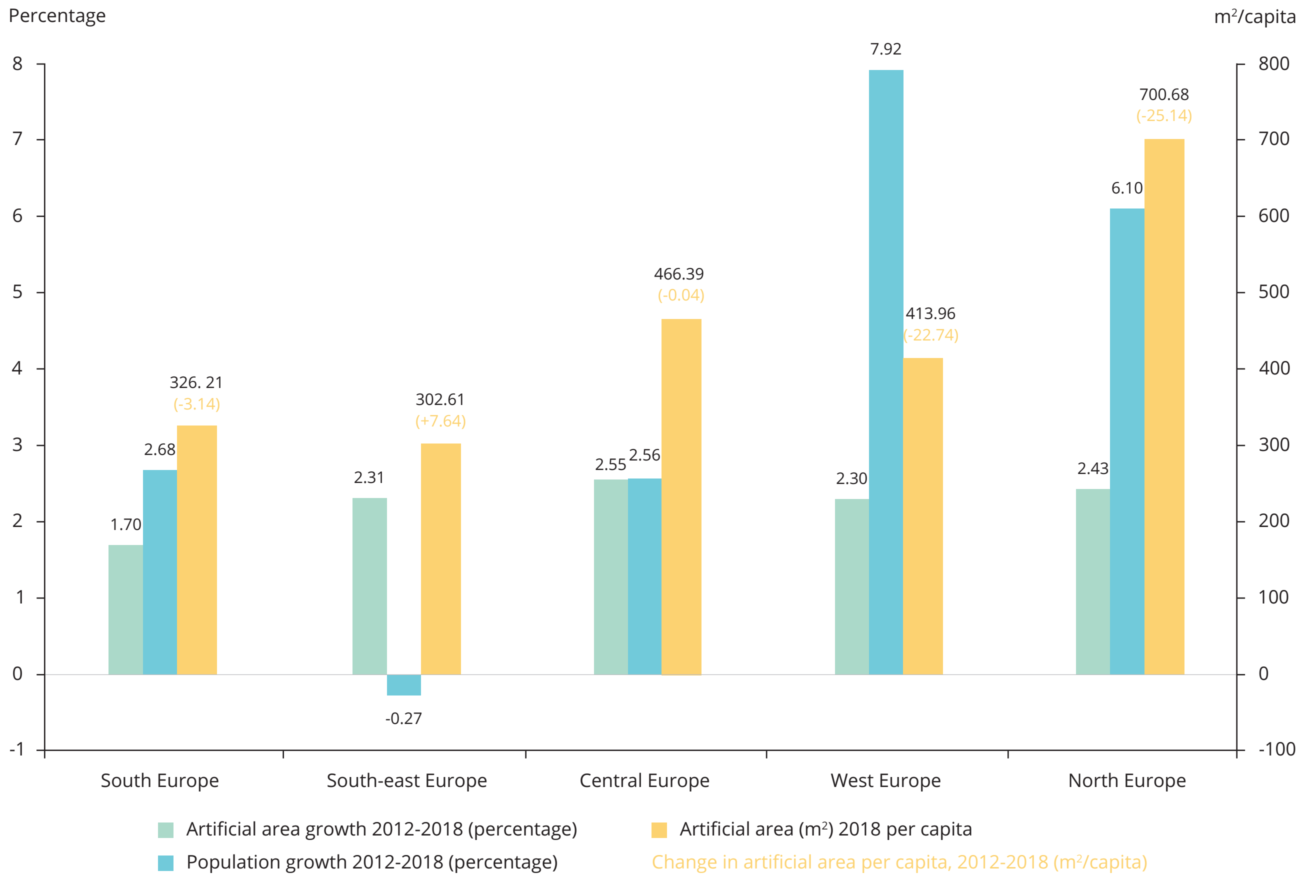
Sources: Jordan (2005) and https://commons.wikimedia.org/wiki/File:Grossgliederung_Europas-en.svg

South Europe is a large region, with 180 FUAs. Both population growth and growth in the size of artificial areas were below the EU average between 2012 and 2018. The amount of artificial area per capita is the second lowest in the EU region, at 326 m² per capita, and this has declined slightly (by 3 m²) since 2012.

West Europe has 163 FUAs and is the second largest region population-wise. In this region, population growth between 2012 and 2018 amounted to 7.9 % and this was more than twice the growth in artificial areas (2.3 %). Artificial area per capita amounts to 414 m² and shows a declining trend (decreasing by 23 m² since 2012).

These five socio-cultural zones were used to further assess land use efficiency in 662 FUAs of the EU-27 and the UK (see Figure 3.7).

Figure 3.7 Change in land take and population in the main European regions, after Jordan (2005)



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4
Impacts of land take and soil sealing

Key messages

- **46 % of functional urban areas (FUAs) are strongly fragmented, affecting mostly croplands and grasslands, with an average habitat size of 0.25 km^2. By contrast, rural areas have an average habitat size of 1.4 km^2.**
- **Land take in protected areas within FUAs is 10 times less than that in unprotected areas within FUAs.**
- **Between 2012 and 2018, the area of soil sealed in FUAs of the EU-27 and the UK increased by 1 467 km^2. One fifth of this newly sealed soil was of high productivity potential and almost two thirds was of medium productivity potential.**
- **At the same time, this new sealing caused a loss of carbon sequestration potential, amounting to 4.2 million tonnes of carbon, and a potential loss of water-holding capacity of 672 million m^3.**

The EU biodiversity strategy to 2020 called on Member States to map and assess ecosystems and their services (Maes et al., 2013). As such, an EU-wide ecosystem assessment — Mapping and Assessment of Ecosystems and Their Services (MAES) — was launched to provide harmonised information on the condition of ecosystems and biodiversity and their capacity to provide ecosystem services. To support this process, the EEA produced a data set that maps broad ecosystem types and their associated habitats at European level (EEA, 2019). The impacts on ecosystems of land take and sealing are conceptualised in this report by aggregating the areas affected by terrestrial MAES ecosystems.

For the assessment, soil sealing was estimated by assuming a certain level of sealing of the Urban Atlas classes (see Annex 2 for description). Values are therefore indicative and should not be taken as statistically accurate accounts of sealing increase.

4.1 Landscape fragmentation of functional urban areas

One of the results of land take and soil sealing is the creation of traffic and other infrastructure that blocks the movement of wildlife, i.e. landscape fragmentation. An important consequence of fragmentation is the increased isolation of the ecosystems in the newly formed fragments. Breaking structural connections decreases resilience and the ability of habitats to provide various ecosystem services. Furthermore, it prevents wildlife from accessing resources and reduces habitat area and quality, and it may isolate some wildlife populations, resulting in smaller and more vulnerable fractions. Reducing habitat degradation and fragmentation may ensure that those habitats that remain are more capable of supporting biodiversity. Finally, yet importantly, fragmentation not only directly affects fauna and flora, but also indirectly influences human communities, agriculture, recreation and overall quality of life. Fragmentation decreases landscape quality and changes the visual perception of landscapes, thus decreasing the attractiveness of landscapes for recreational activities.

The EEA fragmentation indicator (EEA, 2021a) measures fragmentation by assessing the density of continuous, i.e. unfragmented, semi-natural landscape objects (i.e. meshes). This is calculated by dividing the number of meshes by a unit area. If the landscape is not fragmented, i.e. if it consists of a completely continuous landscape, the mesh density (denoted as seff) is 1. If the number of natural and semi-natural landscape elements in a unit area increases, the landscape becomes more fragmented and hence the value of seff increases. The higher the density of the meshes, the more fragmented the landscape. Here, seff is reported as meshes/km^2 instead of meshes/1 000 km^2. With a simple conversion (1/seff), the size in km^2 of the continuous landscape elements can also be calculated.

The territory of functional urban areas (FUAs) in the EU-27 and the UK amounts to roughly 1 million km^2, of which 46 % is classified as highly fragmented, as opposed to 21 % of land outside FUAs being highly fragmented (Table 4.1). High and very high fragmentation is defined in the supporting information section of the EEA indicator. In terms of landscape continuity (measured by effective mesh size), there are on average approximately four landscape elements per km^2 in FUAs, indicating that within FUAs a landscape object is 0.25 km^2 on average. Outside FUAs (cities and commuting zones), the landscape is much more continuous, with 0.7 elements for each km^2; hence, in contrast to FUAs, in rural areas the average size of a landscape object is 1.4 km^2. Commuting zones are 10 % less fragmented than cities (44 % as opposed to 53 % fragmented); however, in terms of landscape continuity, there are 2.2 meshes/km^2 in the suburbs as opposed to 14.7 meshes/km^2 in cities.

Croplands and grasslands were the ecosystems most affected by strong fragmentation in 2018 (not considering urban ecosystems), with around 46 % of cropland areas and 38 % of grassland areas being highly fragmented (Table 4.2). Although strong landscape fragmentation affects only 24 % of forest areas, in terms of landscape continuity forests and woodlands are affected most, as on average 0.8 landscape elements can be found in each km^2 of forests. In other words, forest objects in FUAs are on average 1.25 km^2, whereas cropland objects are on average 3.3 km^2 and grassland landscape elements are around 4 km^2 on average (calculated as 1/No of meshes).

Of the EU Member States and the UK, landscape fragmentation is lowest in the FUAs of Finland, Latvia, Estonia and Sweden, being on average around or less than 1 mesh/km^2 (Figure 4.1). Hence, in these countries, habitats are much more contiguous than in other parts of Europe, being at least 1 km^2 in extent. Malta, Belgium, the Netherlands and the United Kingdom have the most fragmented FUA landscapes, although the variation in fragmentation between these countries is very large. Malta has the most fragmented landscape, with 17 habitats per 1 km^2, on average, which is around double the landscape fragmentation of the FUAs in Belgium and the Netherlands (around nine landscape objects per km^2) and much above the EU average (between 2.7 and 5.5 objects per km^2, with a 95 % confidence interval). Converting effective mesh size to a measure of continuous area indicates that in Malta the area of an average habitat is around 0.06 km^2, compared with the EU average of around 0.25 km^2.

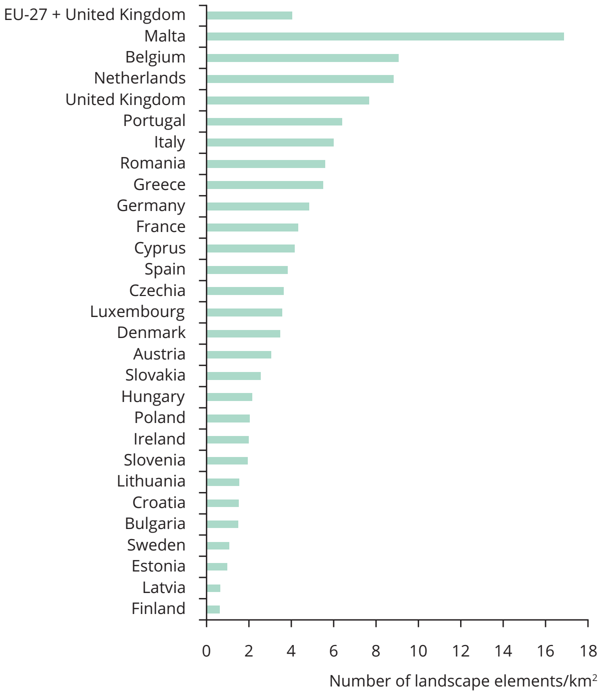
Table 4.1 Landscape fragmentation in 2018 in FUAs in the EU-27 and the UK region, by FUA structure and outside FUAs

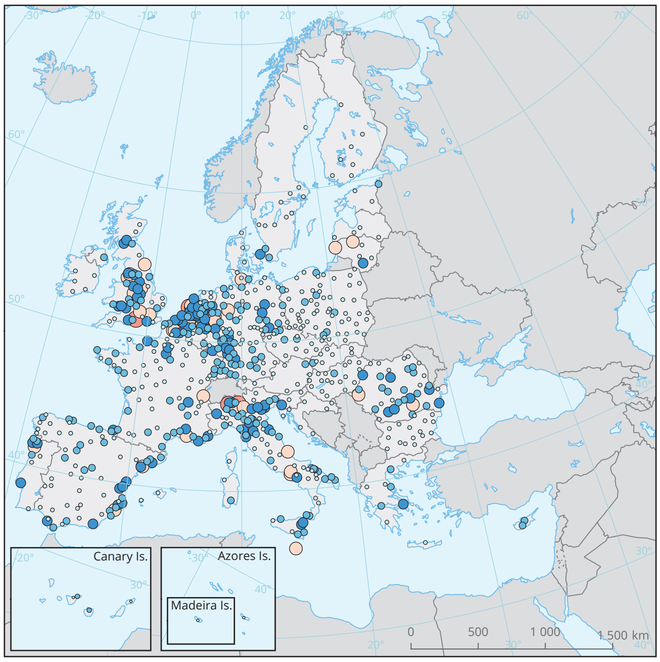
Area	Average number of meshes/km^2	Absolute area with high or very high fragmentation (km^2)	Relative area with high or very high fragmentation (%)
City	14.7	78 102	53
Commuting zone	2.2	384 075	44
Total FUA	4.1	462 177	46
Non-FUA	0.7	743 346	21

Table 4.2 Fragmentation in FUAs in the EU-27 and the UK by MAES land stock type in 2018

MAES land stock type	Average number of meshes/km^2	Absolute area with high fragmentation (km^2)	Relative area with high fragmentation (%)
Cropland	0.301	253 006	46
Grassland	0.246	56 443	38
Heathland and shrub	0.56	2 830	9
Inland wetlands	0.28	778	6
Sparsely vegetated land	0.22	983	3
Woodland and forest	0.81	85 534	24

Figure 4.1 Landscape fragmentation in 2018 in FUAs in the EU-27 and the UK region, by FUA structure and outside FUAs





Reference data: ©ESRI

Fragmentation in 2018 in FUAs, by country

Effective mesh density (number of landscape elements/km²)

0.1-3.5 | 3.5-7.6 | 7.6-14.1 | 14.1-25.9 | 25.9-44.7

Outside coverage

Explore EEA dashboard

4.2 Land take and fragmentation in protected areas of functional urban areas

Protected areas encompass a wide variety of natural and semi-natural environments. Historically, they have taken many forms, from indigenous communities' sacred sites and medieval hunting reserves to more modern national parks and nature reserves. These different forms reflect the different needs that these areas were created to serve. A protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature and the associated ecosystem services and cultural values (Dudley, 2008).

In Europe, three different types of protected area network exist: Natura 2000, the Emerald Network (non-EU countries) and the European inventory of nationally designated areas (also known as the Common Database on Designated Areas (CDDA)). At the EU level, through the Birds and Habitats Directives, the Natura 2000 network was established. Its purpose is primarily to ensure the conservation of targeted species and habitats of European interest. The CDDA is an Eionet core data flow maintained by the EEA that holds information about national protected areas and the national legislative instruments that directly or indirectly create protected areas. The Emerald Network was launched by the Council of Europe under the framework of the Bern

Convention. The Emerald Network and Natura 2000 are based on the same principles and are thus fully compatible with each other. They help to develop a coherent approach to the protection of natural habitats and species in Europe.

In the EU-27 and the UK region, approximately 25 % of the total area of FUAs is classified as protected, which is approximately 245 000 km^2 (Table 4.3). In this chapter, protected areas under different classifications are considered, i.e. Natura 2000 sites under EU law and nationally designated sites. Approximately 13.5 % of the FUA territory is covered by Natura 2000 sites, corresponding to 135 307 km^2. CDDA sites, which aim to fulfil national objectives of the EU Member States, cover about 18 % of the FUA territory and amount to 181 686 km^2. The same protected area can be covered by both protection regimes, i.e. it can be protected as a Natura 2000 site as well as a CDDA site. Therefore, the sum of the two areas does not equal the total size of protected areas.

In the period from 2012 to 2018, land take in protected areas within FUAs amounted to 318 km^2, corresponding to approximately 0.13 % of total protected areas within FUAs. The majority (88 % or 281 km^2) was concentrated in commuting zones. Outside protected areas, land take in the same period was 10-fold more (at 3 263 km^2) than in protected areas. This indicates that designating protected areas is an effective measure for protecting ecosystems against urbanisation.

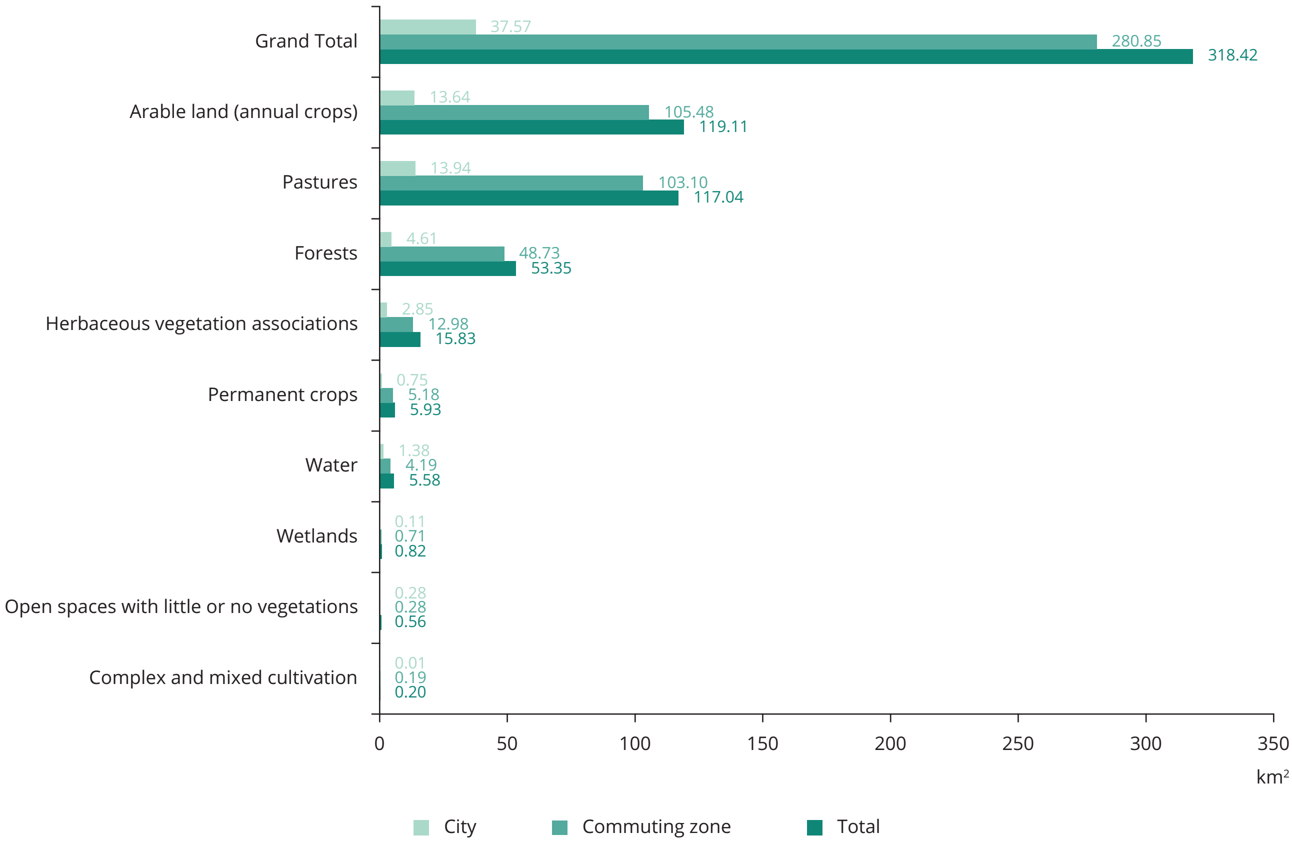
Regarding the land cover classes affected (Figure 4.2), approximately 70 % of land take in protected sites was on arable lands and pastures, whereas less than half of land take in protected sites affected forests (17 % or 5 335 ha converted to artificial areas). Interestingly, these proportions were mirrored in the proportions seen for CDDA sites, while pastures designated as Natura 2000 sites were less affected, with their conversion to artificial areas being only around two thirds that of the conversion of arable lands. Natura 2000 areas seem to conserve forests well: land take was significantly lower in forests in Natura 2000 sites (13 % or 1 272 ha of all land take in Natura 2000 sites) than in CDDA areas (19 % of land take or 4 753 ha).

Table 4.3 Protected areas in FUAs, EU–27 + UK

Category	Area (km^2)	Percentage (%)	Land take (km^2)
Total FUA area	1 002 005	100.0	
Natura 2000 area within FUAs	135 307	13.5	98
CDDA area within FUAs	181 686	18.1	254
Total protected areas	245 173	24.5	318
Protected areas within cities in FUAs	26 187	10.7	14
Protected areas within commuting zones in FUAs	218 986	89.3	84

Note: Protected areas can be covered by both Natura 2000 and CDDA; hence, they partially overlap. Therefore, the sum of the two areas is not equal to the total size of protected areas. This was taken into account in the calculation of the total protected area, and the overlapping areas were included only once in the calculation. In this study, the CDDA version 2020 and Natura 2000 version 2019 were used.

Figure 4.2 **Land take in 2012-2018 in protected areas of the FUAs of the EU-27 and the UK region, by land cover and FUA structure**



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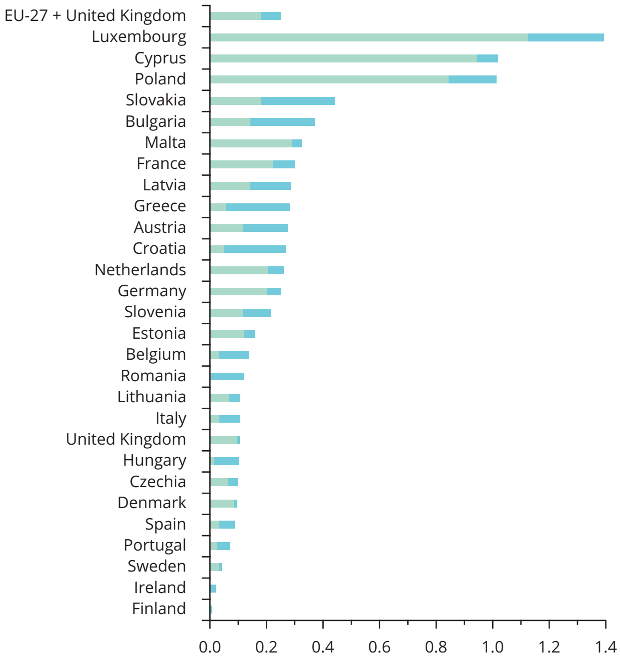
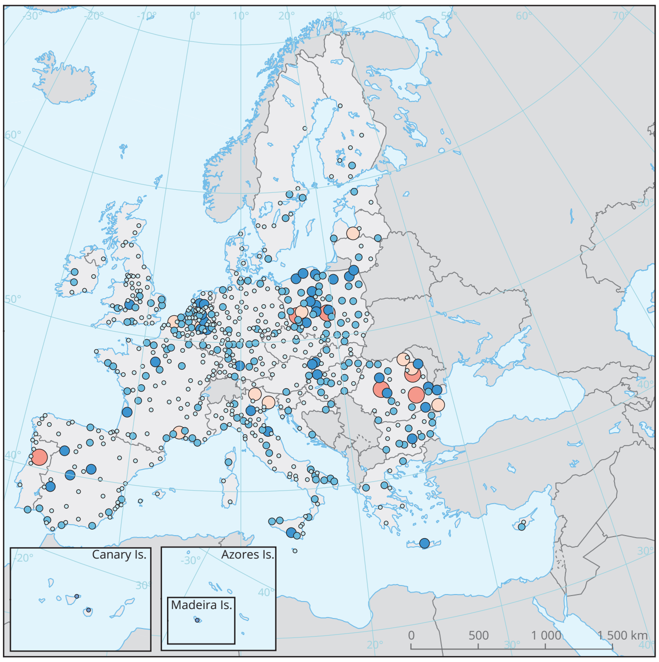
Land cover types that were least affected by land take in protected areas (Figure 4.2), and that lost the smallest amount of their 2012 area, were wetlands, where only 82 ha, or 0.01 %, of their 2012 area was converted to urban areas. The major land use pressure causing these changes in protected areas was urban residential sprawl and the expansion of industrial and commercial units (each amounting to around 27 % of land take in protected areas).

Land take in protected areas was not equally distributed across EU countries (see Figure 4.3). Between 2012 and 2018, land take in Natura 2000 sites increased artificial surfaces the most in Luxembourg, Slovakia, Bulgaria, Greece and Croatia (between 0.27 % to 0.22 %), whereas the lowest increases were observed in Denmark, Finland, Sweden and the United Kingdom (each 0.01 %). In nationally designated areas of cities (CDDA sites), land take increased the artificial surfaces most in Luxembourg, Cyprus and Poland (1.13-0.85 %), whereas the lowest increase occurred in Romania, Finland and Ireland.

Romania and Poland also experienced the largest increases in artificial surfaces in protected areas of suburban areas. Compared with already existing artificial surfaces, the smallest increases due to land take (< 1.3 %) were seen in southern Europe (Slovenia, Malta, Portugal and Spain) and in Finland and Denmark. If Natura 2000-only areas are considered, land take increased artificial areas by up to 13 % in Romania, around 11 % in the Netherlands and 9 % in Estonia, whereas least impact was seen in Denmark, Finland and Sweden (< 1 % increase in artificial areas). The increase in land take in Natura 2000 areas was larger in cities than in commuting zones in Slovakia, Cyprus, Bulgaria, Hungary, Italy and Sweden, whereas in all other countries land take in Natura 2000 areas was higher in commuting zones.

Figure 4.3 **Land take in 2012-2018 in protected areas of FUAs of the EU-27 and the UK region, by country and protection type**





Reference data: ©ESRI

Land take in protected areas of FUAs in 2018, by country and protection type

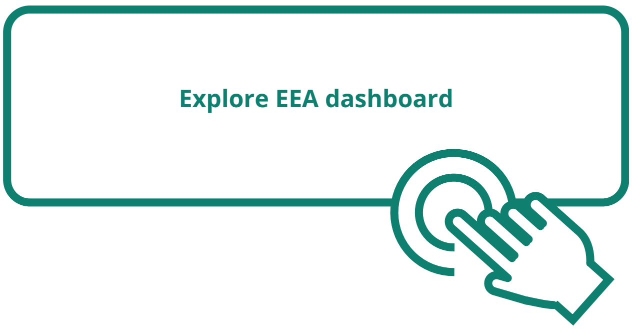
Percentage of 2012

Common Database in Designated Areas (CDDA)

Natura2000

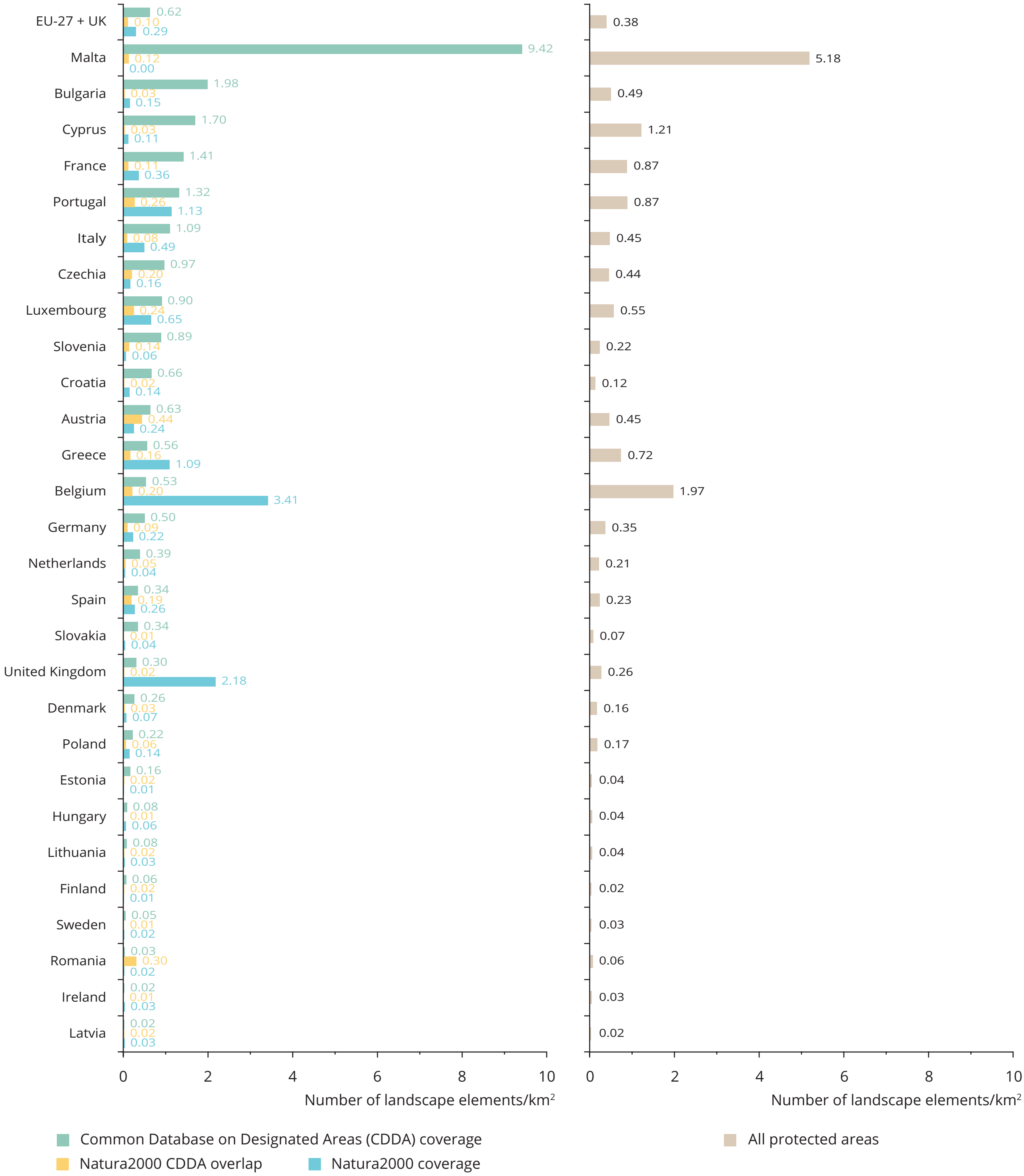
≤ 2.4 | 2.4-6.2 | 6.2-16.6 | 16.6-33.4 | 33.4-55.2

Outside coverage



Fragmentation has a high impact on biodiversity and hence the fragmentation of protected areas is further addressed here. In the EU-27 and the UK region, landscape fragmentation in protected areas in FUAs amounted to approximately 0.4 meshes/km², indicating that landscape elements in protected areas are on average 2.5 km². The fragmentation of protected areas in 2018 varied very widely across the EU-27 and the UK region. It was highest in Malta, Belgium and Cyprus, with as many as six landscape objects/km² per protected area in Malta and less than two objects for each protected km² in Belgium and Cyprus (Figure 4.4). In these three countries, landscape fragmentation was significantly higher (with a 95 % confidence interval) than the EU-27 and UK average in protected areas (between 0.1 and 1 landscape objects/km²). Protected areas in the Baltic countries, Finland, Sweden, Ireland and Hungary had the lowest landscape fragmentation in their protected areas in 2018, with less than 0.05 landscape objects/km². Hence, in these countries habitats without boundaries that allow wildlife movement are at least 20 km² in protected areas, as opposed to Malta and Belgium, where habitats in protected areas are on average only 0.2-0.5 km².

Figure 4.4 Fragmentation in 2018 in protected sites of FUAs of the EU-27 and the UK region, by country



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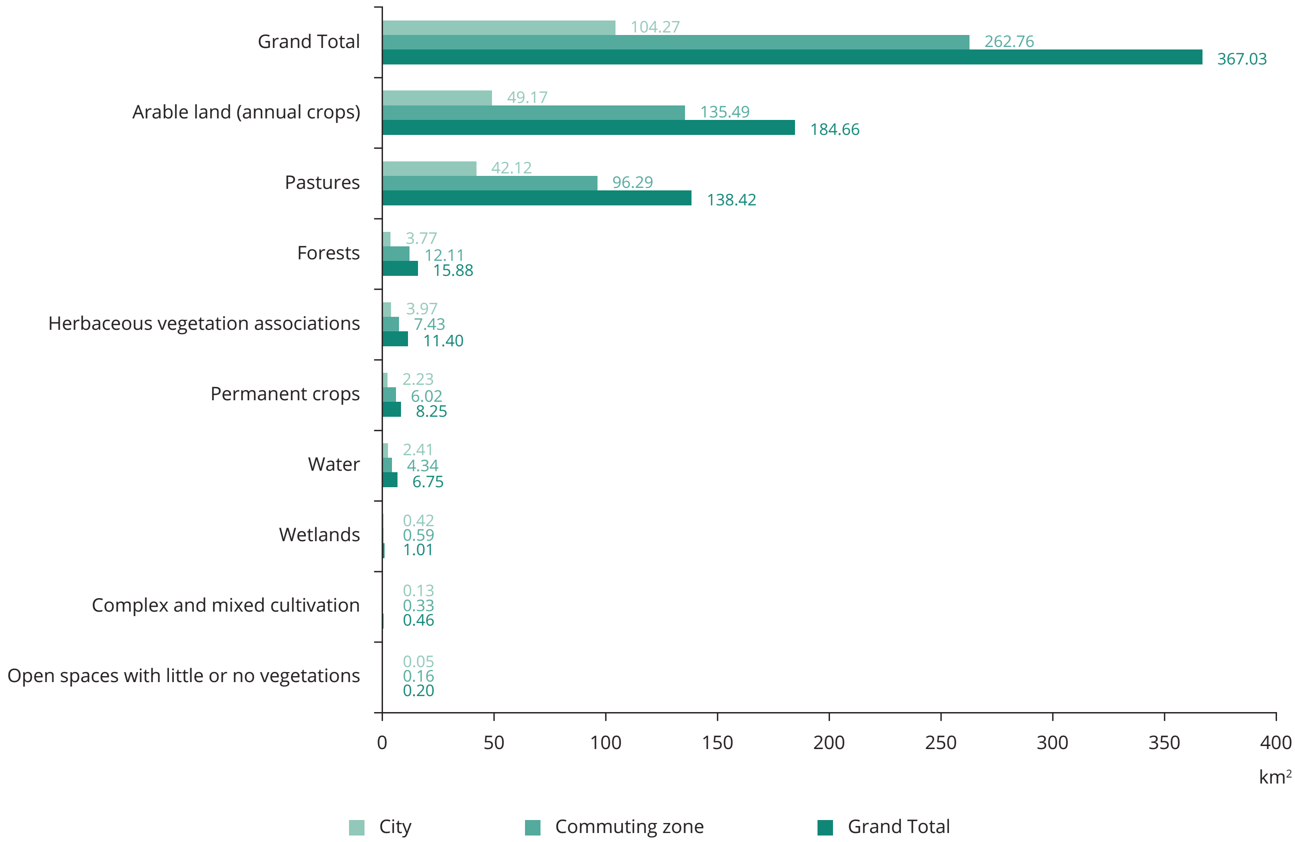
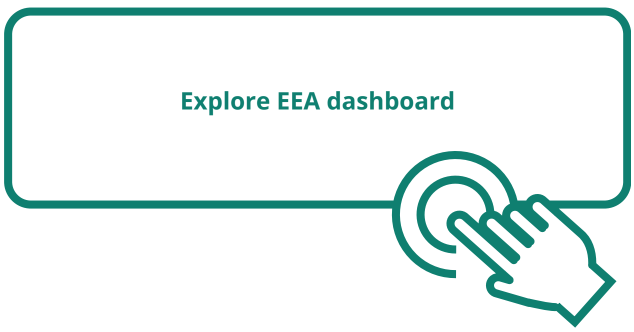
4.3 Land take and soil sealing in floodplain ecosystems

For historical reasons, most European cities have developed close to rivers, because of the need for water supply, the possibility to transport goods, the fact that soils in river basins are usually very fertile and the flat topography, which is suitable for buildings. This means that soils in and around cities fulfil many human demands, one of which is the function to store water. This aspect is further assessed in Section 4.6. This section assesses the amount of flood-prone areas in FUAs and to what extent they are threatened by land take.

Approximately 9 % (92 519 km²) of total FUAs in the EU are in flood-prone areas. Approximately 15 % of floodplains were artificial land in 2018 and, hence, to some extent, were sealed and compacted, jeopardising floodplains' ability to store water and modulate flood damage. Between 2012 and 2018, land take in flood-prone areas within FUAs amounted to 367 km², with approximately 79 % (263 km²) of land take concentrated in commuting zones (Figure 4.5). Similar to land take in protected areas, half of land take took place on arable lands (185 km²) and 38 % on pastures (138 km²) (see Figure 4.5). Although outside floodplains 10 % of land take affected forests, within floodplains only 4 % affected forests. Proportionally (as a percentage of the total area in 2012), agriculture mosaics and pastures lost most area because of land take in floodplains, amounting to a reduction of between 3 % and 2 % in their overall area.

Figure 4.5 Land take in 2012-2018 in floodplains of the FUAs of the EU-27 and the UK region by land cover type and FUA structure

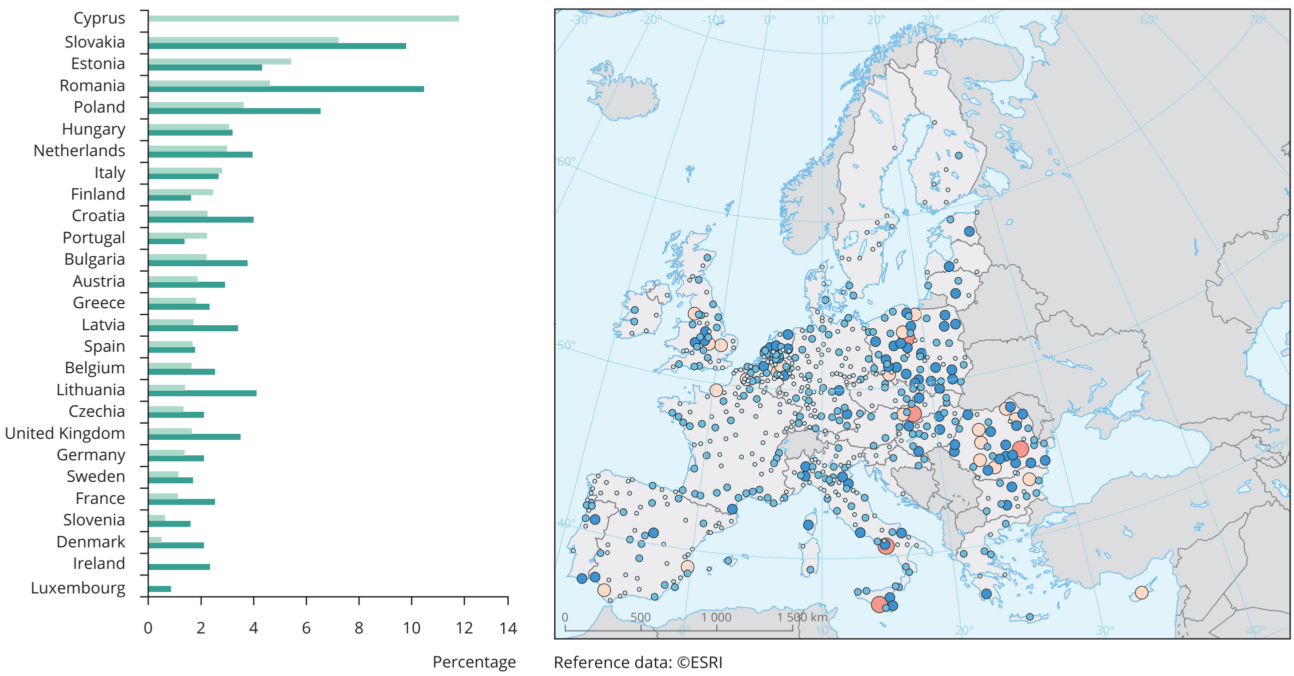




Around 33 % of land take in floodplains was the result of the expansion of industrial and commercial sites, while the expansion of construction sites accounted for 21 % of the land take (Figure 4.5). The expansions of residential areas and of mines and quarrying areas were still significant drivers of land take processes in floodplains, with a share of around 17 % each. There were no significant differences between floodplains and other FUAs with regard to land take processes, and floodplains being in cities or commuting zones did not have an impact on the processes either.

Land take in floodplains in FUAs between 2012 and 2018 had a distinct distribution in Europe (Figure 4.6). Between 2012 and 2018, the largest increases in the size of artificial surfaces in floodplains were seen in Cyprus, Slovakia, Estonia, and Romania (above 10 %, Figure 4.6). In these countries, and in some others (notably Poland, Hungary, the Netherlands, Italy, Finland), the areas of artificial surfaces increased more in floodplains than in other parts of FUAs. One reason for this could be that floodplains in these countries are very large because of their flat topography and hence a larger proportion of the FUAs that are next to rivers belong to floodplains. Furthermore, in these countries land take in city floodplains was comparable to land take in floodplains of commuting zones (Figure 4.6), which further increases negative impacts of climate change induced heavy rains.

Figure 4.6 **Land take in 2012-2018 in floodplains of the FUAs of the EU-27 and the UK region by country and FUA structure**



Reference data: ©ESRI

Land take in floodplains (in % of 2012), by countries and by FUA structure in the EU-27 and the UK, 2012-2018

City | Commuting zone | 0.0-2.1 | 2.1-4.9 | 4.9-10.2 | 10.2-21.9 | 21.9-49.5 | No data | Outside coverage

Note In Cyprus, all land take within floodplains occurs in city areas and none in commuting zones. In Luxembourg, land take in floodplains occurs in the commuting zone only.

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Land take is one of the major causes of habitat destruction in floodplains and therefore potentially has an impact on biodiversity. Furthermore, sealing soils with impermeable surfaces in urban floodplains increases the intensity and related impacts of floods because the excess water cannot infiltrate the underlying soil. Soil sealing exacerbates these impacts and jeopardises protection from excess water, resulting in the destruction of biodiversity, economic consequences and the loss of human life. Therefore, soil sealing on and fragmentation of floodplains are further investigated here, as these are major processes in floodplains resulting in land degradation.

The fragmentation of floodplains in the EU-27 and the UK is on average 4.3 meshes per km^2, i.e. floodplains in the EU-27 and the UK contain habitats that are around 0.23 km^2 in size on average (Figure A4.2). As is commonplace in FUAs, the extent of landscape fragmentation in floodplains across Europe varies widely. For example, there are 18 landscape objects in 1 km^2 in Belgium, which is four times above the EU-27 and UK average. Floodplain fragmentation in Luxembourg and the Netherlands is two times above the EU-27 and UK average. In Finland and Estonia, on the other hand, floodplain habitats are much larger, at 4 km^2 and 2 km^2 on average, respectively.

The estimated average increase in sealing in FUA floodplains during 2012-2018 was 2.4 %, amounting to around 146 km^2 (Annex 4.3). By 2018, an estimated 6 187 km^2 of land was sealed in floodplains in the EU-27 and the UK. This absolute increase in sealed areas was mostly because of new industrial, commercial and public areas, and the expansion of residential areas and construction sites. In relative terms, however, mining, dump sites and construction sites contributed most to land sealing in floodplains, by as much as 45 % compared with 2012. These activities sealed 880 ha of pastures and herbaceous vegetation associations, and 348 ha of arable lands in floodplains of the EU-27 and the UK.

4.4 Biomass productivity and loss in functional urban areas

Biomass productivity is an indicator showing the fertility level of land. Fertility level is largely dependent on climatic conditions and soil properties. Productivity plays a crucial role in food security and in the provision of renewable raw materials such as timber and fibres. Furthermore, soil fertility is linked with a series of other soil-related ecosystem services, from air purification and nutrient cycling to habitat provision, the filtering and absorption of chemicals, climate regulation, etc. With the loss of fertile soils, all the abovementioned services are damaged at the same time. Soil fertility may vary from place to place, depending on local soil properties, such as texture, pH and the content of organic material in the topsoil. Land properties like climatic conditions, topography and soil management modify the level of productivity to various degrees.

The pattern of land use types is traditionally related to productivity classes: fertile lands are cropped, while grasslands and forests are managed on less fertile lands or those with difficult topography. Land take and soil sealing affect all soils, but fertile soils are very prone to these processes, as they are situated in flat areas, where, historically, cities have emerged.

Biomass is a good approximation of the potential of land to supply ecosystem services (Ivits and Cherlet, 2013). When comparing biomass productivity loss in European urban areas between 2012 and 2018, both the amount of soil sealing and the quality of affected lands need to be considered. In this report, quality is characterised by Earth observation-derived estimated land productivity, as explained in Box 4.1. Productivity can be approximated by Earth observation-derived vegetation indices, which yield information on land cover functional composition in relation to dynamics of ecosystem function and land use (Ivits et al., 2013).

Roughly 50 % of all FUAs belong to medium-productivity lands, whereas around 25 % of the FUAs belong to low-productivity lands and 25 % to high-productivity lands. The sealing of land in FUAs of the EU-27 and the UK had affected approximately 60 000 km^2 of land in total (excluding rivers, lakes and marine inlets) by 2018 (Figure 4.7). Of this land, approximately 66 % (around 38 000 km^2) was of medium productivity and only about 18 % and 16 % was of low and high productivity, respectively.

In 2018, approximately 72 % of sealed land in FUAs was found to be medium-productivity urban ecosystems (around 43 000 km^2). Among the remaining ecosystems, croplands were most affected in 2018, accounting for a share of 18 % of total sealing; moreover, of the croplands affected, most were of high or medium productivity. Grasslands, one of Europe's biodiversity hotspots and having a large carbon sequestration potential (EEA, 2020), accounted for 3 160 km^2 of land sealed by 2018 (5 % of all sealing); this mostly occurred on high-productivity lands. When assessing the different MAES classes, it can be observed that, in absolute terms, land consumption on croplands, on grasslands and in woodlands and forests occurred on high- and medium-productivity lands more than on low-productivity lands between 2012 and 2018 (see Figure 4.7).

Box 4.1 Assessment of land productivity loss by means of Earth observation data

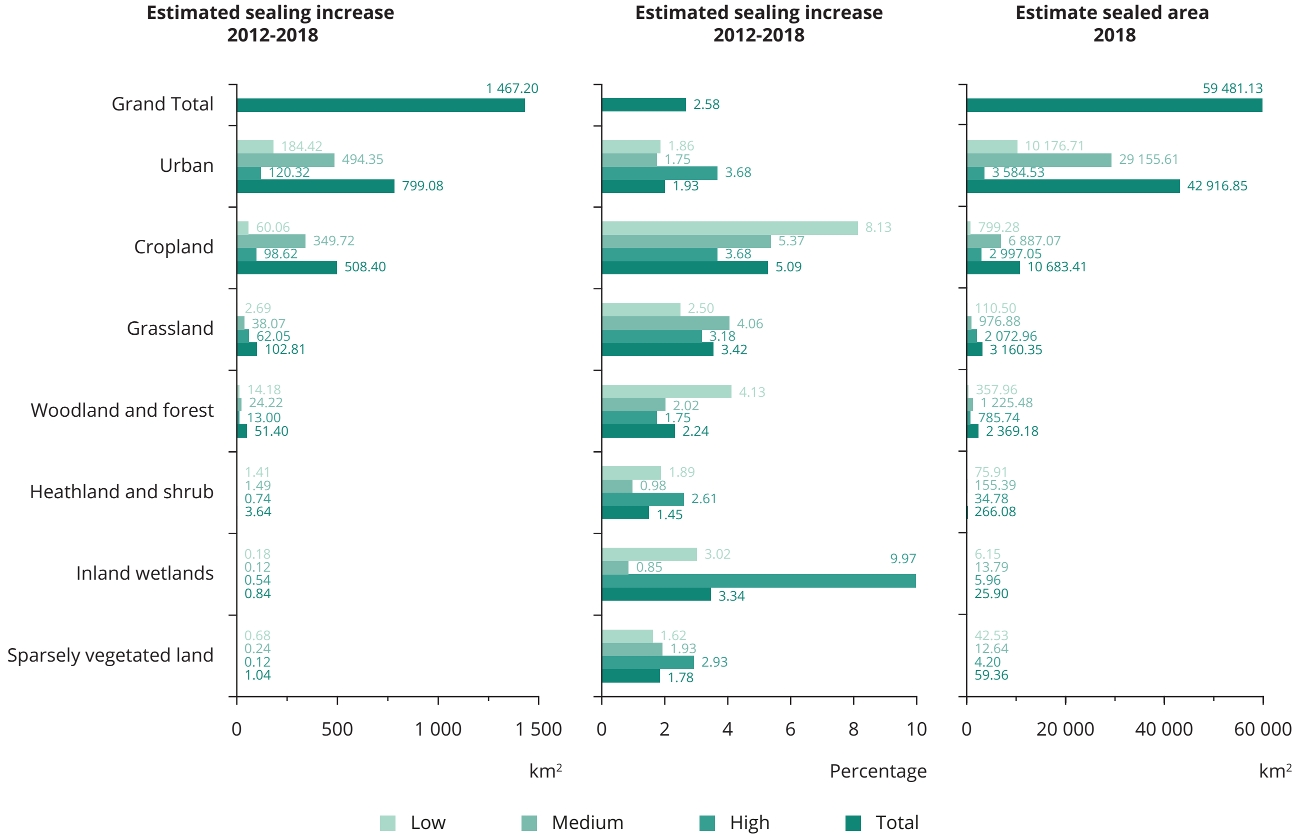
Land productivity loss in functional urban areas (FUAs) was assessed, and an analysis of the extent and productivity of land take was performed.

Biomass productivity was determined by the vegetation phenology and productivity data suite from the Copernicus Land Monitoring Service (CLMS) ([a]). This data set is available for the years 2000-2019 (yearly updates are expected from 2022 onwards) and has a resolution of 500 m. Long-term average productivity levels for each 500 m grid cell were computed and subsequently classified into three percentile classes: low productivity (< 25th percentile), medium productivity (> 25th percentile and < 75th percentile) and high/prime productivity (> 75th percentile). These values were used as approximated values of the potential productivity of lands.

Note: ([a]) https://www.eea.europa.eu/data-and-maps/indicators/land-productivity-dynamics/assessment

During the period 2012-2018, sealing increased by an estimated 2.6 % in FUAs (excluding rivers and marine inlets) of the EU-27 and the UK region (Figure 4.7). Although the increase in sealing between 2012 and 2018 was largest in urban ecosystems (accounting for around half of all sealing increase), as expected, sealing in FUAs occurred at an alarming rate on croplands, with 35 % of all sealing happening here. The increase in sealing on grasslands amounted to only 7 % of the total sealing increase; however, compared with 2012, around 3.4 % more grasslands were sealed by 2018. The increase in the sealing of wetlands was very low in absolute terms; however, with a 10 % sealing increase relative to 2012, the sealing rate was the highest in the EU-27 and the UK region. As wetlands store large amounts of carbon and provide important habitats, this pattern is worrying. According to the principle of sustainability, if necessary, mostly low-productivity lands, which are less relevant for biodiversity and carbon sequestration, should be subject to land consumption. However, soil sealing happens mainly on high- and medium-productivity land; therefore, this principle seems to be disregarded in many areas of Europe.

Figure 4.7 **Impact of sealing on biomass productivity, based on estimated sealing, between 2012 and 2018 by MAES ecosystem and biomass productivity class (in ha and percentage of 2012)**



4.5 Estimated loss of soil carbon sequestration potential

Soils store more carbon than the atmosphere and terrestrial vegetation combined (FAO and ITPS, 2015). Soil organic carbon (SOC) is a result of the accumulation of decomposed litter from organisms living above and below ground. Carbon is bound in soil organic matter, often called humus material, of which around 58 % is carbon. The SOC pool is rather dynamic, with soils losing or gaining carbon depending on environmental conditions and soil management. In fact, large shares of carbon emissions by humans, up to an estimated 20 % globally, are sequestered by soil. On the other hand, because of human-induced land use changes, greenhouse gases — of which large portions are carbon dioxide and methane from decomposed soil organic matter — are released into the atmosphere. One third of all anthropogenic greenhouse gas emissions released between 1750 and 2011 originated from land use changes (IPCC, 2014).

SOC plays a significant role in the global carbon cycle and thus also in climate regulation. Furthermore, SOC is important for developing soil structure, which is a key property for controlling soil water. SOC is also key to storing nutrients, enhancing underground biodiversity, and filtering and buffering exogenous materials, such as pollutants, arriving to soil. Because of all these functions, SOC is one of the key soil quality indicators. However, the growing global recognition of its importance is largely due to its key role in climate regulation. Therefore, it is most important to maintain the soil's capacity to sequester carbon from the atmosphere and enhance the SOC pool. Sealed surfaces lose all these functions, as these surfaces are no longer available for growing vegetation and therefore lose their ability to increase their carbon pool. The loss of soils' potential to sequester carbon is one of the negative consequences of soil sealing.

The impact of soil sealing on soil functions was recently studied in European areas (Tóth et al. 2022), which is further elaborated here. The total estimated carbon sequestration potential of soils in FUAs of the EU-27 and the UK region (excluding marine inlets and transitional waters, rivers and lakes) is around 49 million t (Figure 4.8). By 2018, there were approximately 61 000 km^2 of sealed surface in the FUAs of the EU (see Figure A4.3), and an estimated increase in sealed surfaces between 2012 and 2018 (approximately 1 467 km^2) led to a loss in soil carbon sequestration potential of approximately 4.2 million t or 4 t/ha (Figure 4.8). Around half of the lost carbon sequestration potential was from urban ecosystems. Approximately 34 % (around 1.6 million t) of the soil carbon sequestration potential loss was estimated to have been lost from croplands, reflecting both the large carbon sequestration potential of croplands and their high rate of sealing. Sealing of grasslands accounted for around 12 % (approximately 539 000 t) of lost soil carbon sequestration potential and around half of that can be attributed to a sealing increase in woodlands and forests, because comparably fewer forest areas were sealed during the period 2012-2018. In the case of croplands and woodlands/ forests, most soil carbon sequestration potential has been lost on medium-productivity lands because the increase in soil sealing was the highest in these soils. In the case of grasslands, however, the sealing of the highest productivity lands resulted the loss of most carbon sequestration potential.

Box 4.2 Methodology

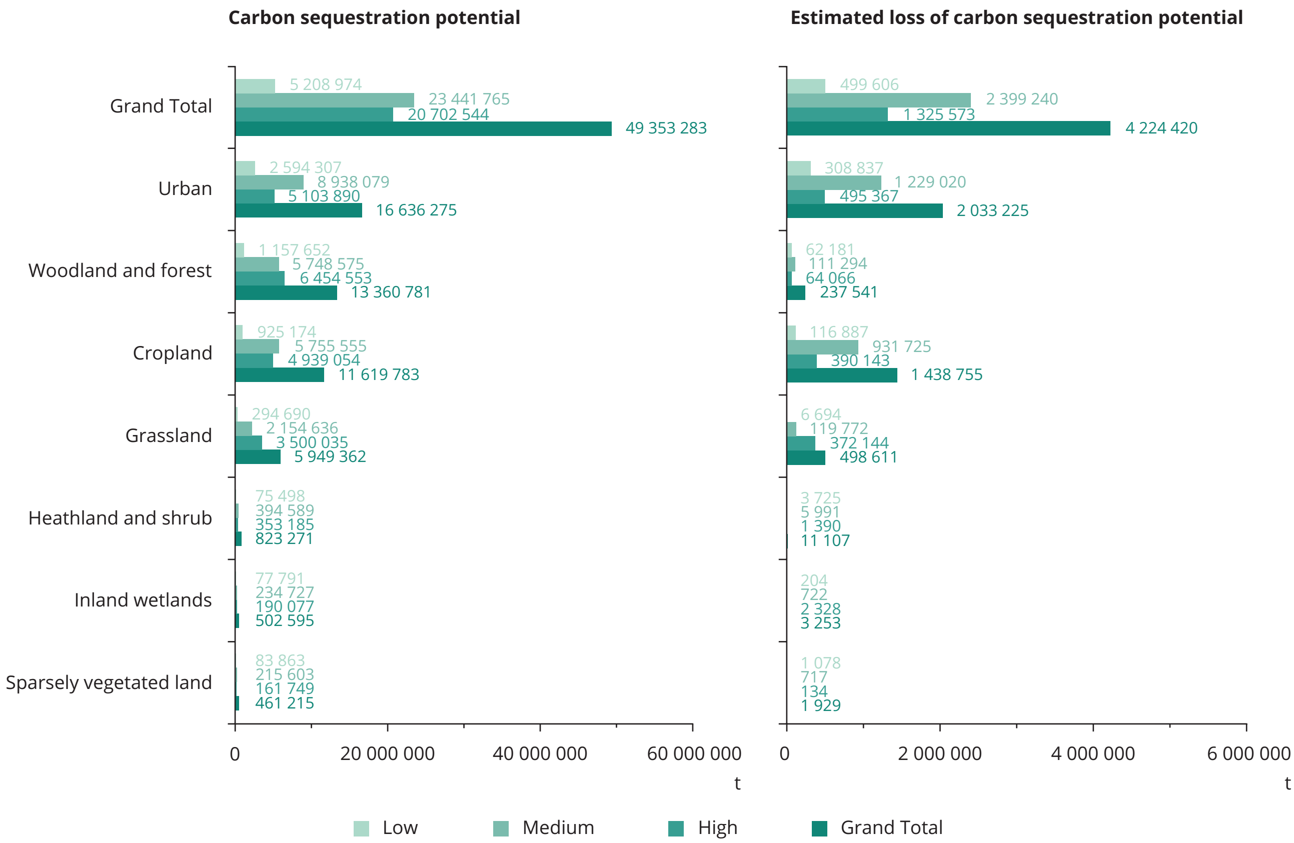
The calculation of the loss of soil carbon sequestration potential is based on the assumption that no more carbon can accumulate in sealed soils.

Losses were determined by estimating soil sealing change between 2012 and 2018. As mentioned in Chapter 1 (see Box 1.1), changes in soil sealing between 2012 and 2018 cannot be determined easily, as the resolution of the Corine Land Monitoring Service (CLMS) data set has changed. For this reason, the increase in soil sealing between 2012 and 2018 was estimated based on Urban Atlas classes for 2012 and 2018.

To estimate the 'lost potential' to sequester carbon by soils, the potential soil organic carbon (SOC) saturation map based on Lugato et al. (2014) and the European coverage of the Global Soil Organic Carbon Map (FAO and ITPS, 2018) were used. Based on the assumption that no more carbon can accumulate in sealed soil, the lost potentials are calculated from the actual concentrations (FAO and ITPS, 2018) and the relative potentials until saturation capacity (Lugato et al., 2014).

Note: The carbon sequestration values reported here are estimates. They are used to assess the impacts of soil sealing and are not cross referenced with national databases.

Figure 4.8 **Estimated loss of carbon sequestration potential in FUAs of the EU-27 and the UK caused by sealing during 2012-2018, disaggregated by MAES ecosystem and biomass level**



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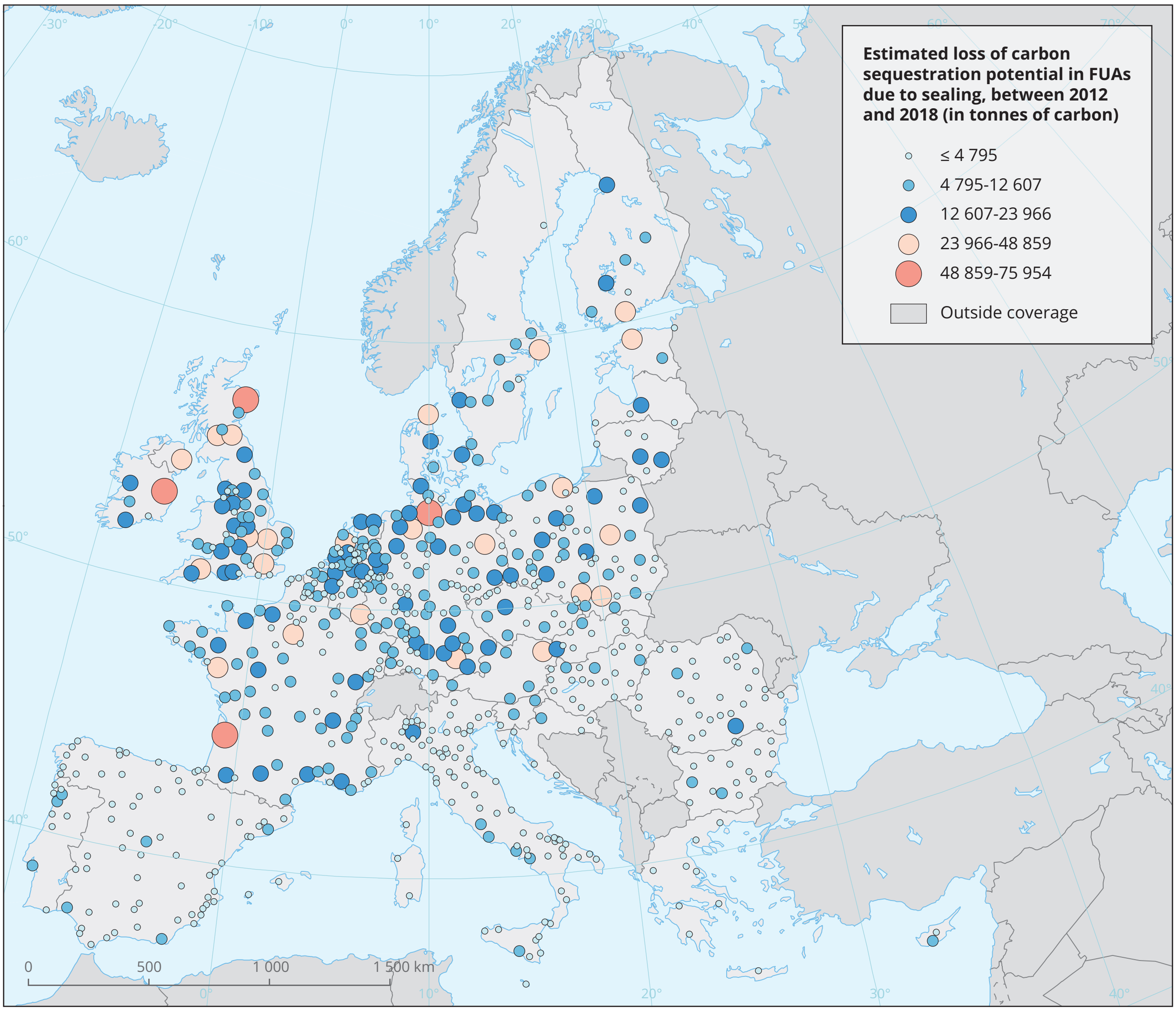
Map 4.1 illustrates the estimated loss of carbon sequestration potential due to sealing during 2012 -2018, for each Functional Urban Area. Largest loss of carbon sequestration potential is estimated in Bordeaux, Dublin, Aberdeen and in Hamburg. In these FUAs above 60 thousand tonnes of carbon are estimated to be lost due to sealing the land surface. In Amsterdam, Munich and Bremen the estimated loss of carbon sequestration potential is between 40 and 50 thousand tonnes, still being among the FUAs with largest loss. On the other end of the spectrum are south European FUAs from Spain, Italy France as well as Frankfurt, Solingen and Remscheid from Germany and Valletta from Montenegro. In all these FUAs the loss of potential to sequester carbon by soils is estimated below 100 tonnes during 2012-2018.

Map 4.1 **Estimated loss of carbon sequestration potential in FUAs due to sealing in the EU-27 and the UK region between 2012 and 2018 (in tonnes of carbon)**



Reference data: ©ESRI

Note: Carbon sequestration potential is estimated based on Lugato et al. (2014) and FAO and ITPS (2018) as described in Box 4.2.

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4.6 Impact on water-holding potential of soils

About half of the volume of soil is pore space, which can hold and transfer water. Water from rainfall enters the soil, which retains this water. The amount of retained water is largely dependent on physical soil properties, such as texture and structure. Chemical properties such as carbon content and salt concentration also modify the capacity of soil to hold water. The amount of water that can be retained by the top 1-m layer of healthy soils may vary between 0.3 and 0.6 m^3/m^2; in extreme cases, some soils in Europe can have as little as 0.17 m^3/m^2 or as much as 0.99 m^3/m^2 of saturated water content (Weynants et al, 2013). The water-holding capacity of soils has multiple benefits, from supporting plant growth to controlling local climate. Water available within 1 m of the surface is essential for living organisms above and below the ground. The first 1-m layer of soil, starting from the surface, is also crucial for controlling water run-off, as it receives and keeps most of the water entering the surface and is thus key to preventing floods. Sealed surfaces prevent water infiltration to the subsoil and terminate most ecosystem services. The negative impacts of this will be both direct and indirect, from heat island effects to increased flood risk.

Matric potential is the energy needed to pull water out of the soil. Saturated water content refers to a water content at matric potential of 0 cm, in practice meaning that all pore spaces are filled with water. In reality, saturated water content is a temporal phenomenon. It lasts until the water supply to the soil body equals the water lost. Water can be lost by drying caused by gravitation, evaporation or uptake by plants. Moisture from deeper layers in special conditions may move to the topsoil through capillary rise from deep layers. In more exceptional cases, the water table may reach the topsoil resulting permanent water logging.

In this report, saturated water content was used to provide a quantitative estimate of the potential effect of soil sealing on the topsoil to hold water (see Box 4.3). While this measure can be most relevant in relation to sealed surfaces continuously covering large areas, it can be effective on scattered areas with inclusions of sealed land too. In the era of an increasing probability and magnitude of flood events due to changing climatic conditions in Europe, it is especially important to assess mitigation and adaptation options and the human-induced harms that hinder these options. Soil sealing is one of the main human actions that leads to increased flood risk and the loss of ecosystems' mitigation potential in the case of flood events.

The estimated loss of potential water storage between 2012 and 2018, due to soil sealing, in FUAs of the EU-27 and the UK is estimated to amount to around 670 million m^3 (Map 4.2). The estimated loss in potential was highest in those areas of the FUAs where the general impact of soil sealing was the highest (Figure 4.9). Thus, approximately 56 % of the loss of potential water storage was observed in complex areas of industrial, commercial, public and military units, which can be assumed to be areas with very high proportions of sealed, impermeable surfaces. Another large contributor to the potentially lost water-holding capacity (29 % of the lost potential) in FUAs was discontinuous urban fabric, which is yet another land cover type with a high proportion of impermeable surfaces. Although construction sites accounted for only 12 % of the loss, these areas have increased by approximately 435 % during the period 2012-2018 (see Annex 4.4); if this trend continues, it is expected that their impact will be higher in the future.

Box 4.3 Methodology

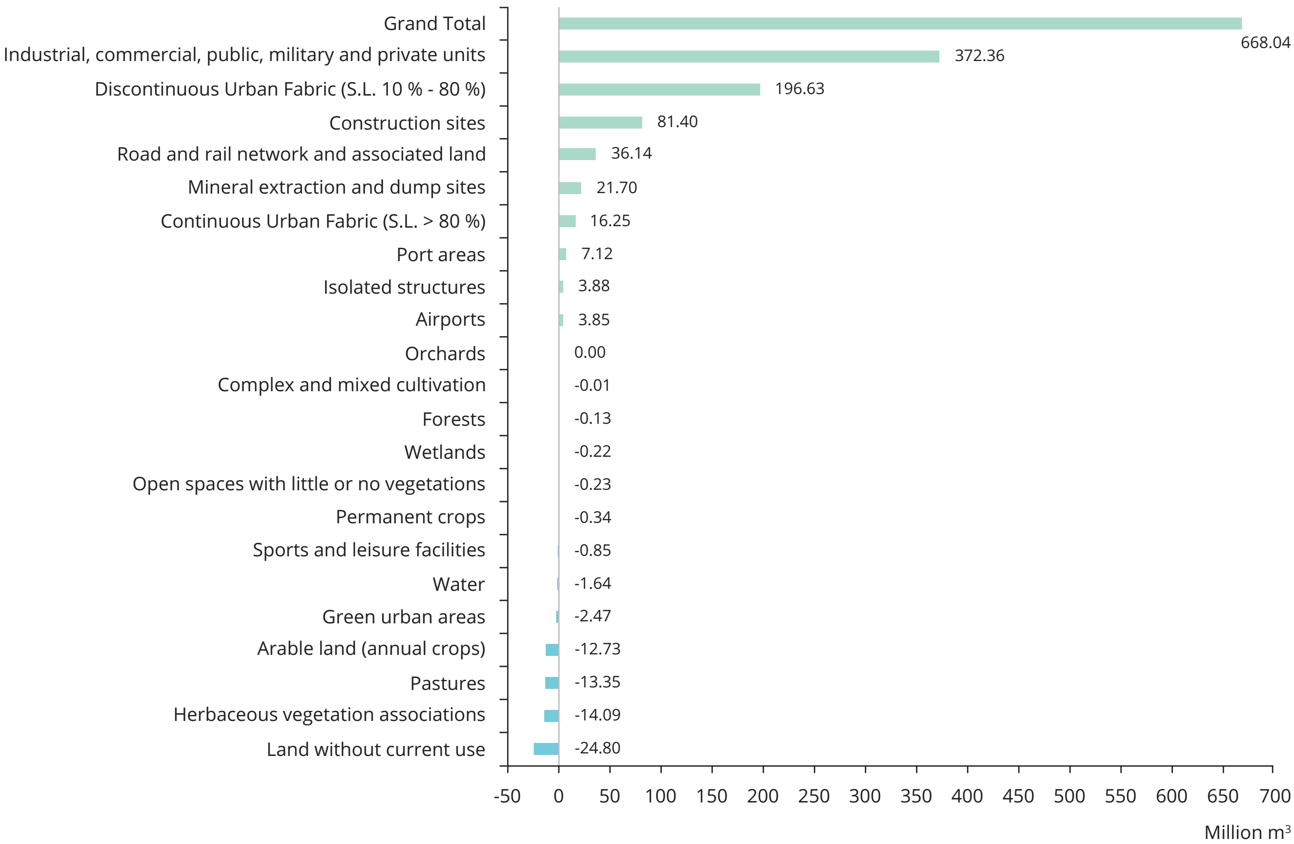
The calculation of the soil water-holding capacity potentially lost is based on the assumption that, in sealed soils, subsoil water storage is very limited.

While gravitational forces remove water from topsoil, sealed surfaces prevent infiltration. The amount of upwards movement of water from subsoil layers by capillary rise is limited to specific conditions. The greater the area extent of the surface impervious layer, the higher the possibility that partial recharge by subsurface horizontal flow will decrease substantially too. This report addresses the potential loss of saturated water content in contrast to its full capacity, i.e. when sealing results in the total loss of the possibility of soil water recharging of the topsoil.

The data on **saturated water content** were derived from the three-dimensional soil hydraulic database of Europe at 250-m resolution (Tóth et al., 2017). This data set indicates the water-holding capacity of soils expressed as a percentage of the top 1 m, which can also be expressed in m^3.

Note: Water-holding capacity of soils will not disappear if their surface is sealed, but this capacity will not be accessible for water. In this report we regard the sealed topsoil's water-holding capacity as potentially lost for water storage.

Figure 4.9 **Estimated loss of water-holding capacity in FUAs of the EU-27 and the UK caused by sealing during 2012-2018, disaggregated by land cover type**



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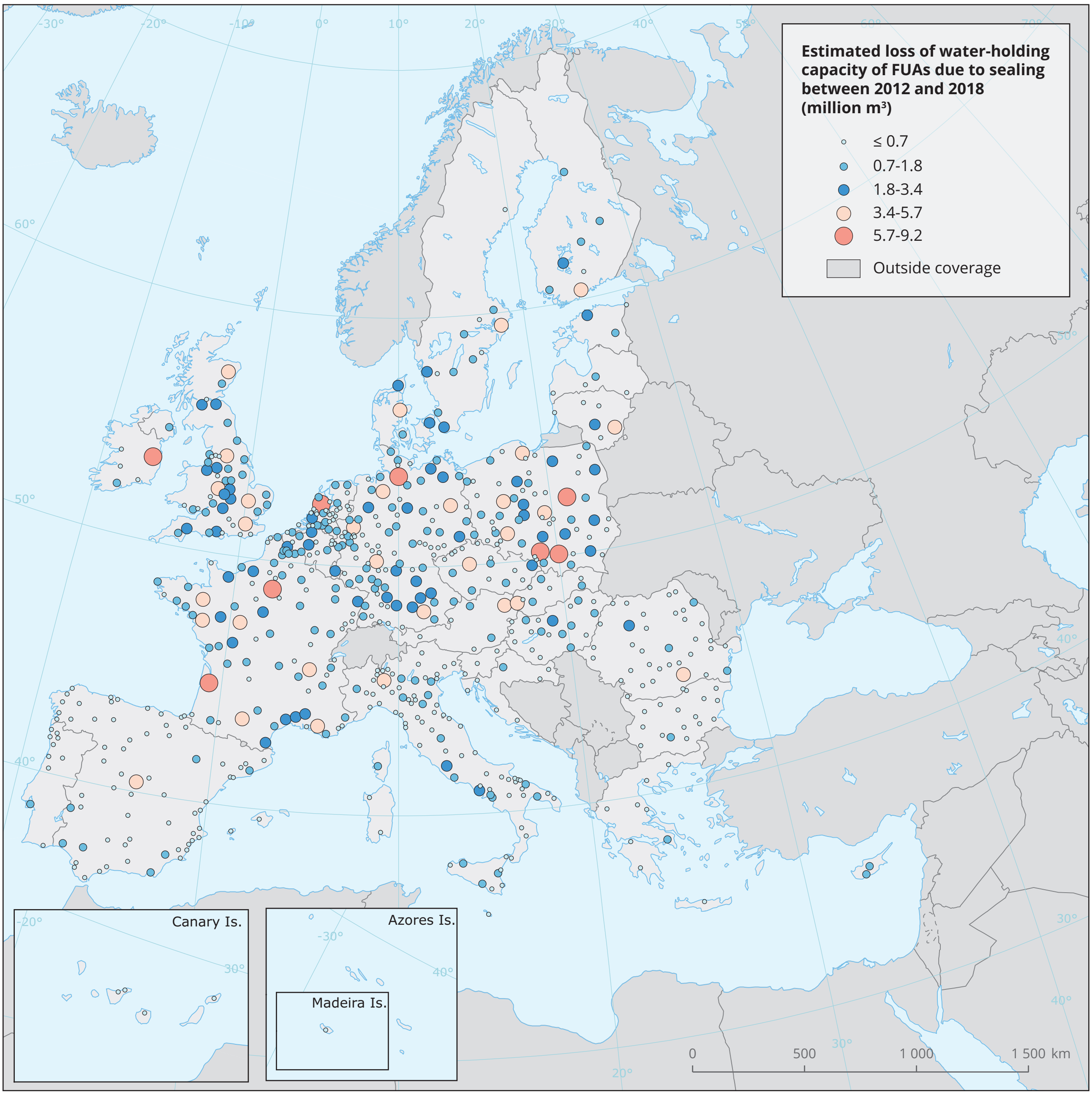
On average, up to 10 000 m³ of water-holding capacity was potentially lost per FUA. The highest losses, with up to more than 5.6 million m³ per FUA, were estimated for Warsaw, Kraków, Amsterdam, Berlin, Gdańsk, Dublin, Katowice, Hamburg, Bordeaux and Paris. This amount per FUA is equivalent to more than 8 days of non-stop flow of the River Loire (which has a watershed of 117 356 km²).

Sealing soils with impermeable surfaces in floodplains blocks the infiltration of excess water into the underlying soil during flooding events and hence increases the intensity and related impacts of floods. The estimated average increase in sealing in FUA floodplains was 2.4 %, amounting to around 145 km². This is estimated to have potentially resulted in the loss of up to around 67 million m³ of water storage capacity loss in floodplains of the EU-27 and the UK region. The loss of potential water-holding capacity in FUAs is estimated to be highest in Nitra (Slovakia), where soil sealing increased by 21 %, potentially cutting off around 1 million m³ of water-holding capacity from surface infiltration. In Cambridge (United Kingdom) and in Battipaglia (Italy), the estimated lost potential amounts to around 500 000 m³ of water-holding capacity, resulting from around 17 % and 40 % increases in floodplain sealing in these FUAs, respectively.

Map 4.2 **Estimated potential loss of water-holding capacity in FUAs caused by sealing in the EU-27 and the UK region during 2012-2018**



Reference data: ©ESRI

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5
Conclusions

Modern life is deeply linked to land take through the need for housing, commercial and industrial areas, transport infrastructure, power lines and pipelines.

Land take trends in European functional urban areas (FUAs) reveal that European and global objectives regarding climate protection and biodiversity restoration are at risk. Recent data show that land take and soil sealing happen mainly on high- and medium-productivity lands, affecting biodiversity, increasing fragmentation and decreasing carbon sequestration. According to the principle of sustainability, the use of low-productivity lands is preferred over higher productivity lands when decisions are taken on sites for new construction. Hence, sustainability is disregarded in many areas in Europe.

Recent land take trends presented in this report also indicate the increase in diffuse residential expansion. This type of urbanisation is often accompanied by additional infrastructural development in the commuting zones of FUAs, which reshape the hydrological characteristics of the small watersheds where the urban expansion occurs. Consequently, both pluvial and flash flood risks are increasing in exposed areas. The observed trends are not only affecting sustainability but also go against resource use efficiency.

Europe cannot continue this trend, as the continuous loss of ecosystem functions renders it increasingly vulnerable when it comes to food self-sufficiency and natural disasters. How can Europe continue to thrive economically and at the same time consume as little land as possible?

Set individual short-term and long-term land take targets. Unlike many other policy areas, land and land take have not had specific policy targets. The new EU soil strategy for 2030 requires Member States to set land take targets with the aim of reaching land take neutrality by 2050 (no net land take). With the availability of high-resolution data from the Urban Atlas, Member States can set individual targets, both for the short term and the long term, and monitor progress.

Preserve the best land in terms of productivity, carbon sequestration potential and water-holding capacity. The preservation of highly productive land with high biodiversity value, carbon sequestration potential and water-holding capacity is essential for achieving the goals of climate change, disaster risk management and food security policies. Furthermore, according to the principle of sustainability, low-productivity lands are preferred over higher productivity lands when decisions are taken on where to build. However, the results of this report reveal that land with premium biomass productivity and high water-holding capacity is prone to land take and hence is not being adequately protected. In addition, continued land take and sealing lead to the loss of soils for the sequestration of carbon, notably cropland and grassland soils. Regional zoning plans should explicitly identify such land and impose building restrictions or a compensation requirement. This is particularly true for land in floodplains and protected areas.

Increase land use efficiency. Land use efficiency is determined by the amount of artificial area used per capita. The assessments in this report reveal that in many European FUAs land use efficiency is low, particularly in commuting zones. However, the trend suggests an improving situation, and this needs to gain further momentum. This could be achieved by reusing already built-up land and by strengthening inner urban development in favour of more efficient land use. This could be reached, in turn, by using already developed land and establishing green urban areas to support biodiversity, carbon sequestration and infiltration in floodplains, and to provide cooling effects to counteract other climate change impacts, such as extreme temperatures. Adequate policy instruments and funding incentives need to be established to support more efficient land use. Promoting land use efficiency requires good examples and could be supported by living labs and lighthouses, as required by the implementation plan of the EU research mission 'a soil deal for Europe'.

Compensation. In the future, building activities on new soil will be unavoidable. However, these activities should be as economical as possible and avoid the best land. It is easy to agree that agricultural productivity lost by sealing fertile land can be compensated for only by ensuring higher input intensity on low-quality lands. If this compensation is possible at all, it would have a series of environmental consequences, arising from the additional fertilisation needed to raise the productivity level of marginal lands. Likewise, the establishment of a productive forest is not feasible on poor-quality land, even after land recycling. Experience of compensating for lost soil functions is lacking and should be investigated through research at European level.

The development of new policies and the consistent implementation of existing land protection regulations are needed if the quality of land resources is to be preserved for future generations.

Abbreviations

CDDA	Common Database on Designated Areas (a European inventory of nationally designated areas)
CLC	Corine Land Cover
CLMS	Copernicus Land Monitoring Service
FUA	functional urban area
HRL	high resolution layer
LCR	land consumption rate
LULUCF	land use, land use change and forestry
MAES	Mapping and Assessment of Ecosystems and Their Services
MMU	minimum mapping unit
PGR	population growth rate
SDG	Sustainable Development Goal
Seff	mesh density
SOC	soil organic carbon
UN	United Nations

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Annex 1 Interpretation of land use efficiency values

In detail, land use efficiency is defined as the ratio of the land consumption rate (LCR) to the population growth rate (PGR):

LCR/PGR = [((At + *n* − At) / At) / *T*] / [*ln(Popt + n / Popt) / y*],

where:
LCR = land consumption rate
PGR = population growth rate
At = total areal extent of the consumed land for the first year
At + n= total areal extent of the consumed land for the last year
T= number of years between= At + n and At
Popt = total population in the first year
Popt + *n* = total population in the last year
y = number of years between the two measurement periods
ln = logarithm

The rates of change in land consumption and population can assume positive values if both the numerator and denominator increase in the given period (At < At + n, Popt < Popt + n). If both land consumption and population changes are negative (e.g. if more land is recultivated than taken, together with a decreasing population), the rate of the change will be negative.

Increasing land consumption

Considering recent land take trends, it is not likely that land consumption will become negative. Following the assumption of increasing land consumption (LCR ≥ 0), the sign of the LCR to PGR ratio mostly follows population variation, i.e. the denominator, as below:

(1) LCR/PGR = 0: land consumption did not vary in the period considered.

(2) LCR/PG > 0:

- 0 < LCR/PGR < 1: both land consumption and population change are positive, but the population increases more than land consumption.
- LCR/PGR > 1: both land consumption and population change are positive, but land consumption increases more than the population.

(3) LCR/PGR < 0:

- -1 < LCR/PGR < 0: population change is negative and, in absolute value, greater than the land consumption increase.
- LCR/PGR < -1: population change is negative and, in absolute value, the decrease in population is less than the increase in land consumption.

Decreasing land consumption

Negative land consumption rates (LCR < 0) may, however, still occur, for example as result of recultivation or land recycling (EEA, 2021b), in which case the indicator may take the following values:

(1) LCR/PGR > 0:

- 0 < LCR/PGR < 1: both land consumption and population change are negative, but the population decreases more than land consumption.
- LCR/PGR > 1: both land consumption and population change are negative, but land consumption decreases more than the population.

(2) LCR/PGR < 0:

- 0 > LCR/PGR > -1: population is increasing and it is greater than the absolute value of the of land consumption decrease.
- LCR/PGR < -1: population is increasing and it is less than the absolute value of land consumption.

The interpretation of the indicator may become quite cumbersome, because the understanding of the various change combinations is not straightforward, as they can take a variety of positive and negative combinations. Therefore, in addition to the above definition, the calculation of a second indicator is suggested, such as:

LCR/PGR = (At + *n*/*Popt* + *n*) - (At / *Popt*)

Annex 2 Estimating soil sealing from the Urban Atlas classes

Because of the impossibility of obtaining the actual imperviousness change between 2012 and 2018, this report has estimated the soil sealing or imperviousness change in functional urban areas (FUAs) using the Urban Atlas as an ancillary data set. A sealing share (average percentage of sealing within the class) has been assigned to each Urban Atlas class based on the product specification as well as on expert advice. These sealing shares, detailed in Table A2.1, have been utilised to calculate an estimated change in sealed or impervious land between 2012 and 2018.

Table A2.1 Sealing share per Urban Atlas class

Urban Atlas class code	Urban Atlas class name	Estimated sealing share (%)
11100	Continuous urban fabric (S.L. > 80 %)	90
11210	Discontinuous dense urban fabric (S.L. 50-80 %)	65
11220	Discontinuous medium density urban fabric (S.L. 30-50 %)	40
11230	Discontinuous low density urban fabric (S.L. 10-30 %)	20
11240	Discontinuous very low density urban fabric (S.L. < 10 %)	5
11300	Isolated structures	10
12100	Industrial, commercial, public, military and private units	60
12210	Fast transit roads and associated land	40
12220	Other roads and associated land	40
12230	Railways and associated land	40
12300	Port areas	80
12400	Airports	60
13100	Mineral extraction and dump sites	10
13300	Construction sites	30
13400	Land without current use	5
14100	Green urban areas	5
14200	Sports and leisure facilities	5
21000	Arable land (annual crops)	0
22000	Permanent crops	0
23000	Pastures	0
24000	Complex and mixed cultivation	0
25000	Orchards	0

Table A2.1 Sealing share per Urban Atlas class (cont.)

Urban Atlas class code	Urban Atlas class name	Estimated sealing share (%)
31000	Forests	0
32000	Herbaceous vegetation associations	0
33000	Open spaces with little or no vegetations	0
40000	Wetlands	0
50000	Water	0

Note: S.L., sealing layer.

Source: Own elaboration, from Urban Atlas specifications.

Annex 3
Key facts about functional urban areas

	EEA-38 and the UK	EU-27 and the UK	Unit
Number of FUAs	785	661	No
Total area of FUAs	1 268 580	1 002 006	km²
Total area (EEA/EU)	5 831 634	4 377 725	km²
FUA area/EEA area	21.8	22.9	%
Total population 2018 (EEA/EU)	624 167 074	510 763 046	inhabitants
FUA population 2012	329 018 505	311 969 642	inhabitants
FUA population 2018	342 473 073	324 853 205	inhabitants
FUA population/total population	74.0	75.0	%
Population change 2012-2018	13 714 038	11 340 037	inhabitants
Increase of population 2012-2018 (%)	3.1	3.0	%
FUA artificial area 2012	155 573	138 744	km²
FUA artificial area 2018	160 378	141 756	km²
FUA artificial area 2012-2018	4 646	3 013	km²
Increase FUA artificial area 2012-2018	3.0	2.2	%
Land take 2012-2018	5 330	3 581	km²
Inverse land take 2012-2018	684	568	km²
Net land take	4 646	3 013	km²
Land take 2012-2018 per capita (population 2012)	16.2	11.5	m²/inhabitants
Land take 2012-2018 per capita (population 2018)	15.6	11.5	m²/inhabitants
Land take 2012-2018 per capita (population 2012)	16.2	11.5	m²/inhabitants
Land take 2012-2018 per capita (population 2018)	15.6	11	m²/inhabitants
Estimated sealing 2012-2018	205	147	km²
Estimated sealed area 2018	6 609	5 948	km²
Artificial area in FUAs per capita 2012	348	373	m²/inhabitants
Artificial area in FUAs per capita 2018	347	370	m²/inhabitants

Note: FUA, functional urban area.

Annex 4
Additional statistics

Figure A4.1 Drivers of land take in flood prone areas of functional urban areas in the EU-27 and the UK, 2012-2018

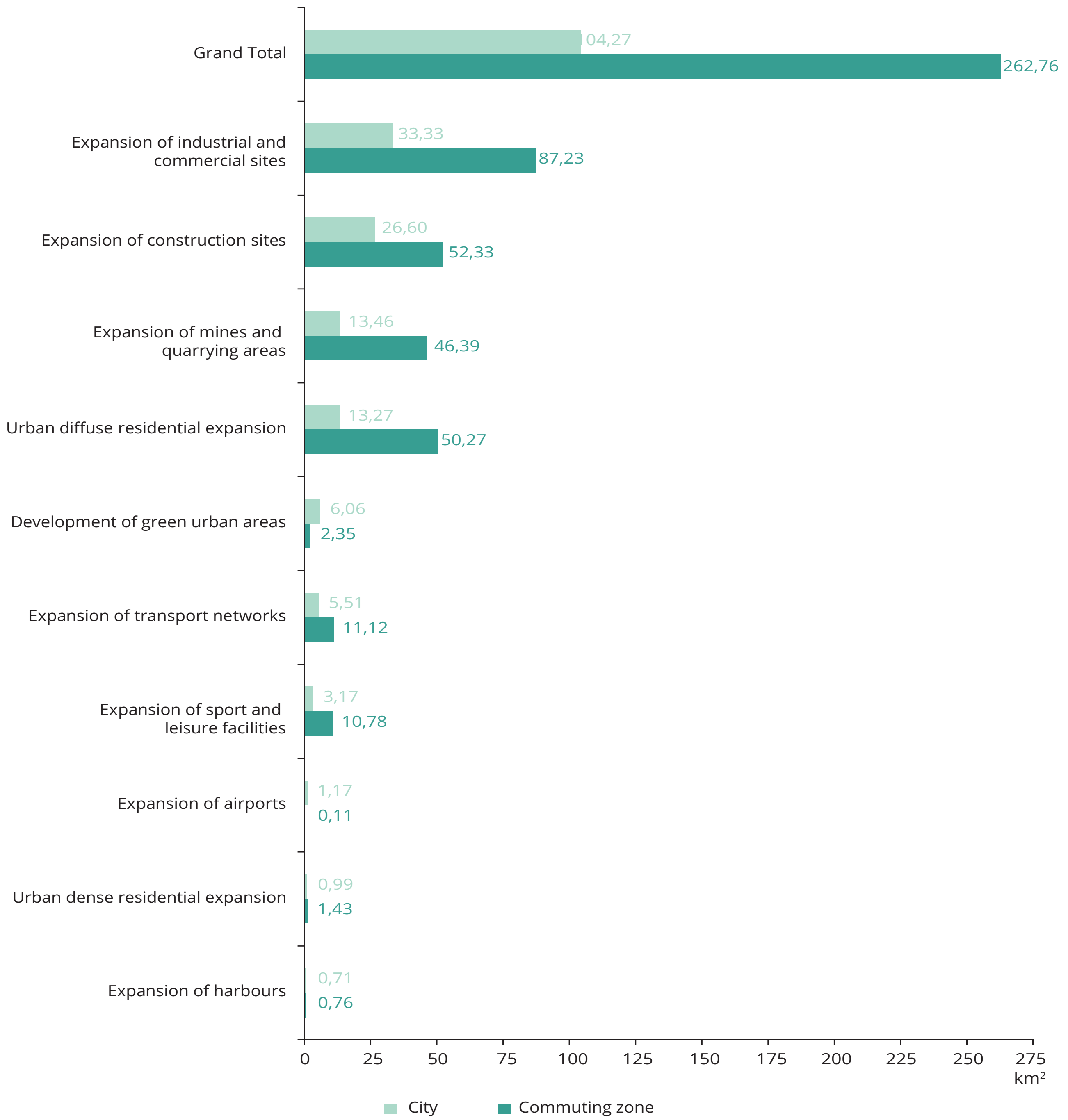


Figure A4.2 **Fragmentation in flood prone areas of functional urban areas by country and FUA structure in the EU-27 and the UK**

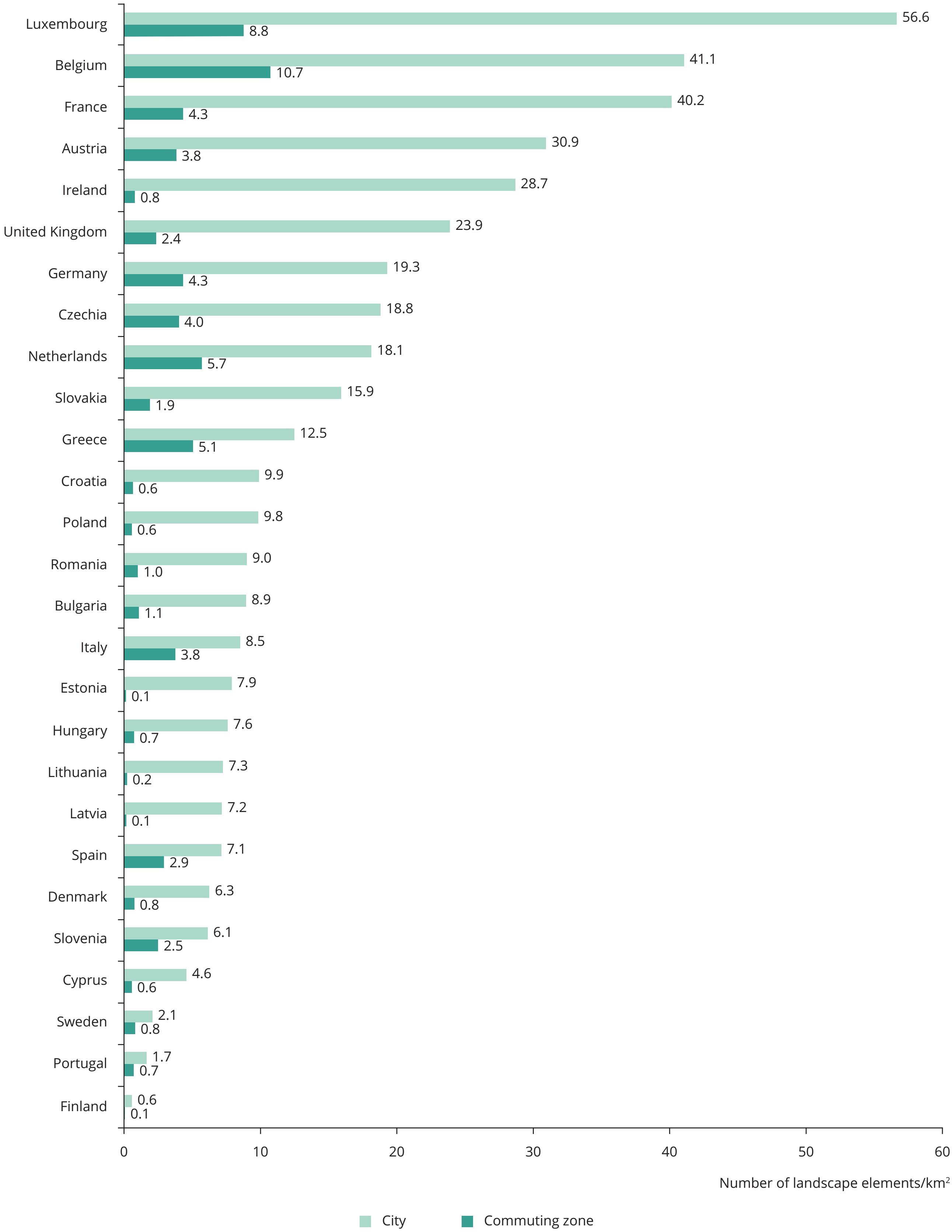


Figure A4.3 Estimated soil sealing and sealing increase in floodplains by land cover type in the EU-27 and the UK, 2012-2018

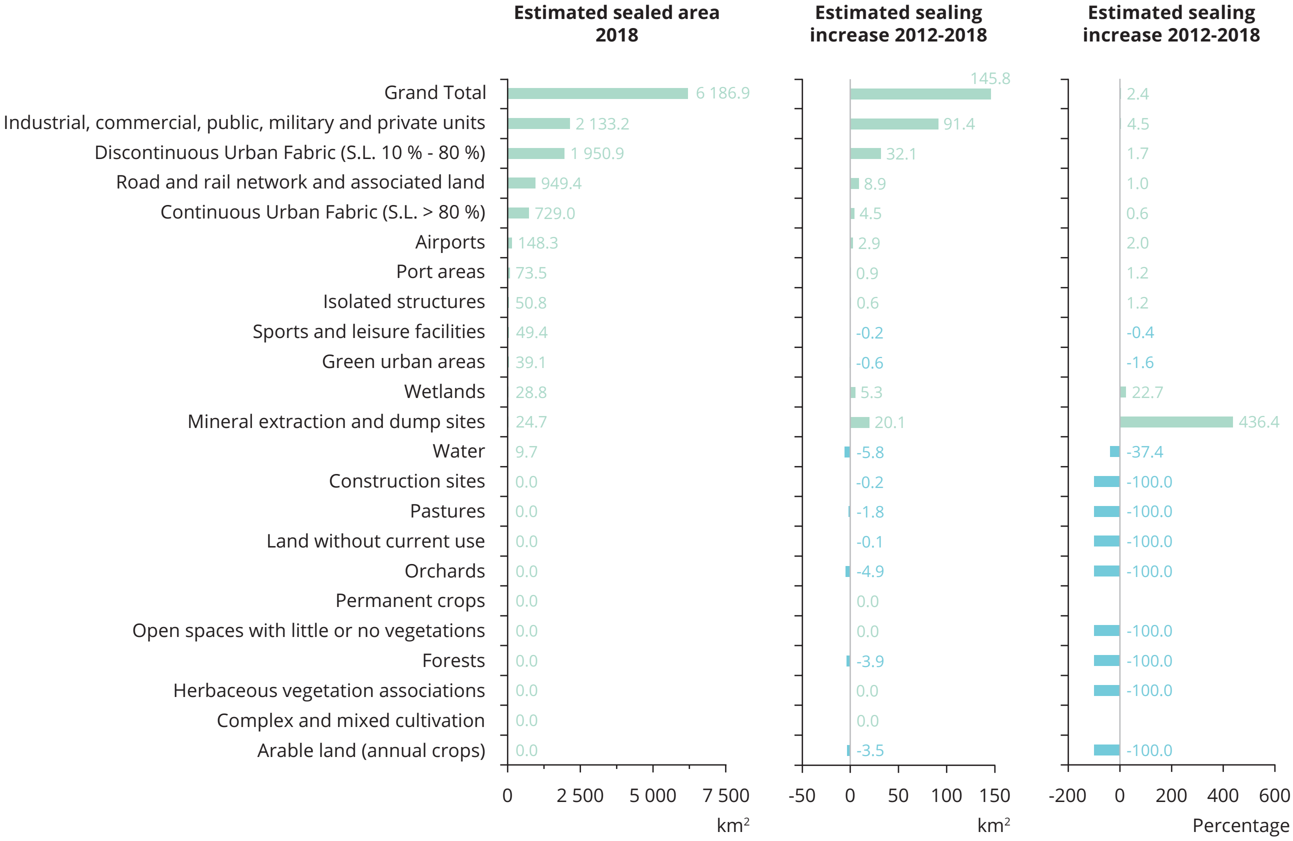
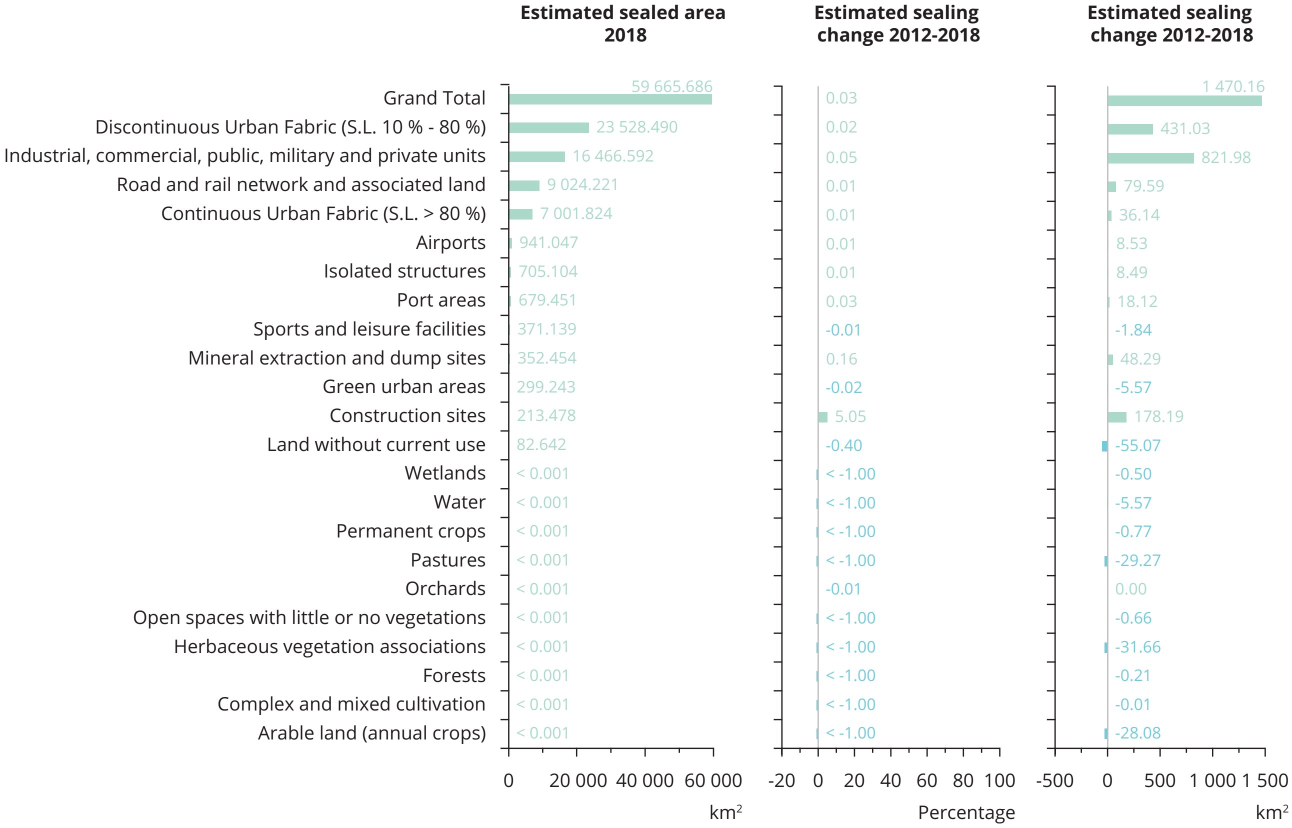


Figure A4.4 Soil sealing and sealing increase in functional urban areas by land cover type in the EU-27 and the UK, 2012-2018



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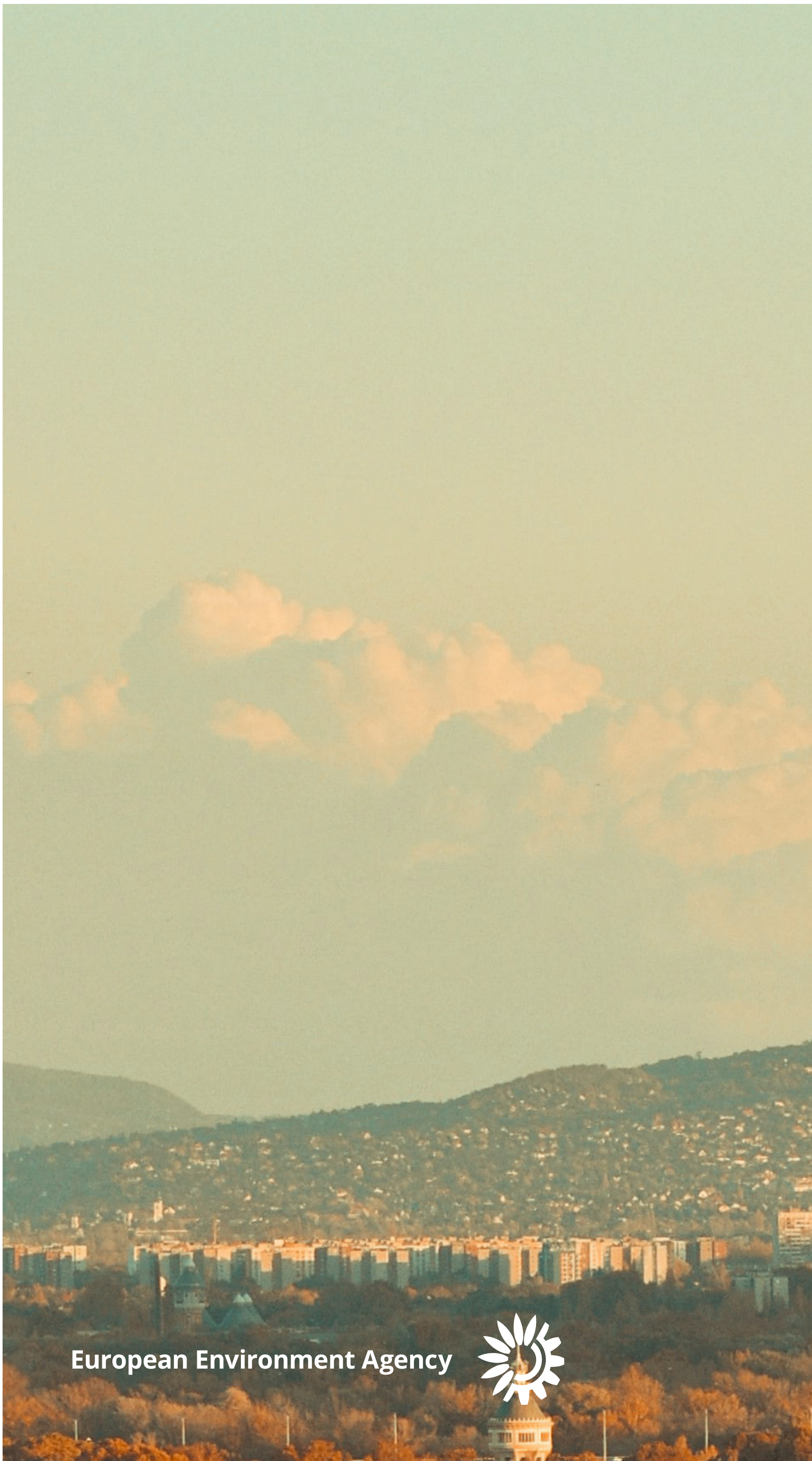
Land take and land degradation in functional urban areas

2022 — 73 pp. — 21 x 29.7 cm

978-92-9480-465-5
doi:10.2800/714139

TH-AL-22-001-EN-N
doi:10.2800/714139



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