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Mapping and Assessment of Ecosystems and their Services

Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010

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Abstract
This report presents an analysis of the trends in the spatial extent of ecosystems and in the supply and use of ecosystem services at the European scale between 2000 and 2010. In the EU urban land and forests increased while cropland, grassland and heathland decreased. Other ecosystem types underwent smaller changes. The main trends in provisioning, regulating and maintenance, and cultural ecosystem services were assessed using a set of 30 indicators assorted according to the CICES classification. More crops for food, feed and energy were produced in the EU on less arable land. More organic food was grown. Textile crop production and the total number of grazing livestock decreased. Water use relative to water availability remained stable. Timber removals increased but so, too, did the total timber stock. There was an increase in net ecosystem productivity (growing biomass). Several regulating services, but in particular those which are related to the presence of trees, woodland or forests, increased slightly. This was the case for water retention, forest carbon potential, erosion control, and air quality regulation. Pollination potential and habitat quality showed a negative trend. There was a positive trend in the opportunity for citizens to have access to land with a high recreation potential.

Contents

Abbreviations

AQUASTAT:	FAO's global water information system
CAPRI:	Common Agricultural Policy Regionalised Impact Modelling System.
CDDA:	Common Database on Designated Areas
CICES:	Common International Classification of Ecosystem Services
CLC:	Corine Land Cover; Corine means 'coordination of information on the environment'
CoCo:	Complete and Consistent Data Base of the CAPRI model
EEA:	European Environment Agency
ESTIMAP:	The JRC's Ecosystem Services Mapping tool
EU:	European Union
EUROSTAT:	Statistical office of the European Commission
FAO:	Food and Agriculture Organization of the United Nations
FAOSTAT:	Statistical office of the FAO
JRC:	Joint Research Centre of the European Commission
LUCAS:	Land Use/Cover Area frame statistical Survey
LUISA:	The JRC's integrated assessment model: Land-Use based Integrated Sustainability Assessment
MAES:	Mapping and Assessment of Ecosystems and their Services
NEP:	Net Ecosystem Productivity
ROS:	Recreation Opportunity Spectrum
SCI:	Sites of community importance established under the Habitats Directive
SPA:	Special protection areas established under the Birds Directive
SPOT VEGETATION:	A remote sensing program

Summary

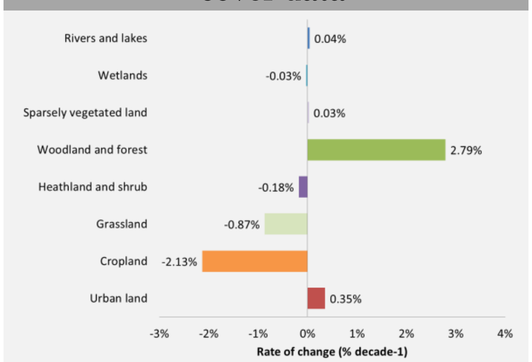
Mapping and Assessment of Ecosystems and their Services (MAES) is one of the keystone actions of the EU Biodiversity Strategy to 2020. The collection and interpretation of high quality and consistent information on the condition of ecosystems and the services provided at different scales is considered essential to support decision making in policies on urban sustainability, climate adaptation, and sustainable management of natural resources. It is also relevant to guide investments in green infrastructure and ecosystem restoration.

This report presents a first analysis of ecosystems and their services at the European scale. In particular, changes observed between 2000 and 2010 in (1) the extent of ecosystems, as derived from land cover and land use data, and in (2) the supply or use of ecosystem services are reported. In addition, this report acts as a reference for a set of ecosystem services maps at the EU scale which can be used for further studies which require spatial data.

Changes in the extent of the surface area of ecosystems (following the MAES typology) are based on changes in land cover. Land cover data sets for which temporal information is available include the Corine Land Cover data, LUISA (the JRC's integrated land use based model) and LUCAS (European field survey program funded and executed by Eurostat). Based on these data, urban land and forests were observed to increase in area while the area of cropland and grassland decreased. Changes in the other ecosystem types were smaller.

The main trends in ecosystem services are summarized in a graphical abstract on the next page. Based on the available data we found positive trends in several ecosystem services which are presumably driven by a complex interaction of changes in agricultural production, afforestation, higher ecosystem productivity and increased protection of nature.

Change in the extent in the surface area of ecosystems based on land cover data



The major land cover trend is increasing urban land and afforestation at the cost of croplands and grasslands.

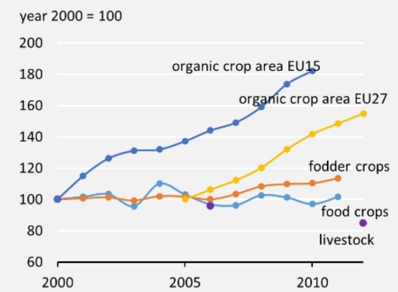
Many provisioning services showed increasing trends. More crops were produced on less arable land. Organic farming gained importance. More timber was removed from forests with increasing timber stocks.

The increasing extent of forests resulted in positive influences on erosion control, carbon storage, water retention, air quality regulation and recreation. Indicators for these services remained stable or showed upward trends.

More nature was protected in 2010 than in 2000 but in contrast, the trends of two ecosystem services indicators which are directly related to biodiversity, pollination and habitat quality, were worsening.

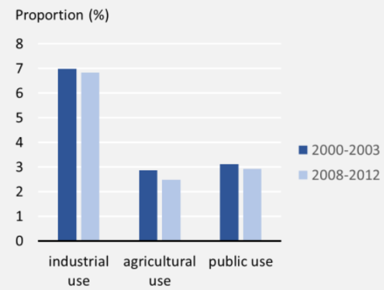
Main trends in ecosystem services in the EU between 2000 and 2010

Food and fodder



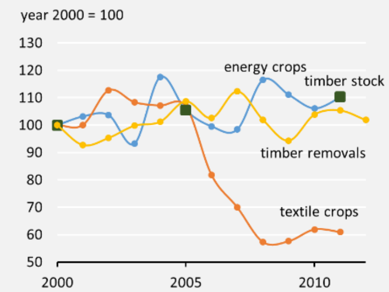
Food and fodder crop production increased, even when agricultural area decreased. More organic food is grown. Numbers of livestock decreased.

Water



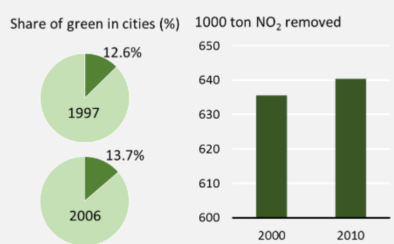
The proportion of renewable water use decreased slightly in all sectors.

Materials, timber and energy



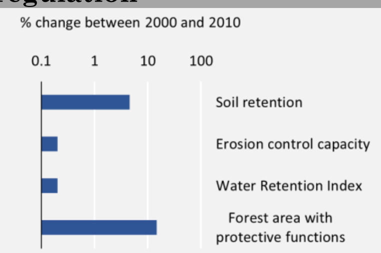
Afforestation in Europe resulted in increasing timber stocks and higher removals. Energy crops fluctuated while textile crops slashed.

Air quality regulation (in cities)



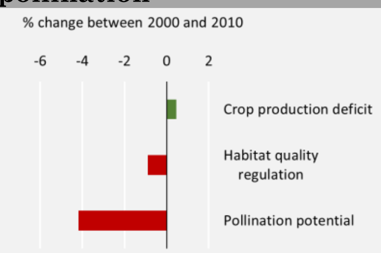
Cities expanded, on average, their green area. Trees captured 1% more NO_2 in 2010 relative to 2000.

Erosion control and water regulation



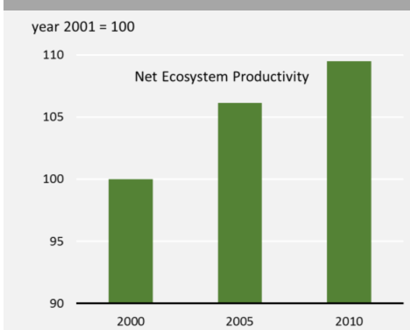
The area of protective forest expanded. Soil retention increased. Modelled erosion control and water retention capacities remained equal.

Habitat maintenance and pollination



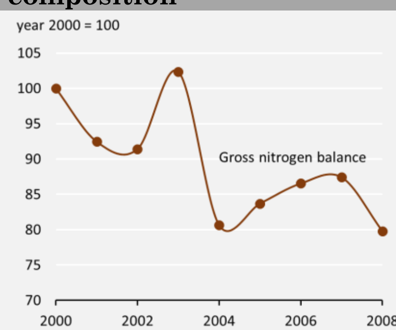
Despite increasing production levels of crops in need of pollinating insects, pollination potential declined across the EU. Habitat quality (regulation) slightly declined.

Climate regulation



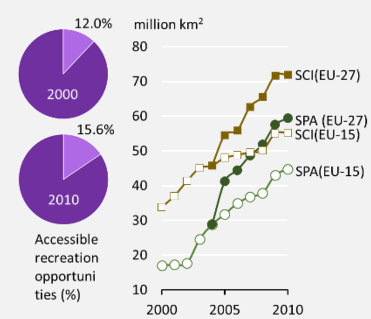
Net ecosystem productivity in the EU has increased with about 10%. Forest carbon potential increased with 1.7%.

Soil formation and composition



All countries report a surplus in nitrogen on cropland (inputs exceed outputs) but the surplus is decreasing.

Recreation



More high provision and easily accessible land for outdoor recreation value has become available for citizens. More area is protected in 2010 than in 2000.

This report is an important step towards a more comprehensive assessment of ecosystem services at European scale. Several questions remain unanswered which require a more in-depth assessment of the data that were used in this study in combination with additional data on biodiversity and the condition of ecosystems.

The indicators used in this study report the supply or use of ecosystem services. A subsequent analysis needs to compare the results of this study with indicators which measure the demand for ecosystem services to test whether or not ecosystem services are used at sustainable levels. This sustainability perspective needs to be incorporated to avoid a simplistic use of the different indicators.

Importantly, there is an urgent need to identify the synergies and trade-offs that exist between ecosystem services and ecosystem condition to support biodiversity policy and to prioritize restoration efforts.

1 Introduction

1.1 MAES: Mapping and Assessment of Ecosystems and their Services

Ecosystems provide European citizens with numerous benefits. Trees and forests clean air and water from pollutants; wetlands attenuate the impact of floods and storms; mountains provide places for recreation and unforgettable memories. At the global scale, oceans and rainforests maintain a livable climate and provide enormous reservoirs of biodiversity providing an effective insurance against emerging problems including new diseases.

To ensure that these benefits continue to flow from ecosystems to people, Target 2 of the EU Biodiversity Strategy to 2020 aims to maintain or enhance ecosystem and their services. This target was necessary as ecosystems and their ecosystem services are globally being degraded and used unsustainably. The Millennium Ecosystem Assessment reports (*1*) were among the first to provide scientific evidence that at the global scale 15 out of 24 examined ecosystem services were being degraded and/or used unsustainably including fresh water, capture fisheries, air and water purification, and regulation of regional and local climate.

Comparably, more recent assessments conducted in Spain (*2*) and the UK (*3*) concluded that 45% and 30%, respectively, of their evaluated ecosystem services have been deteriorated at national scale. The most severely affected ecosystems in Spain include riparian and coastal ecosystems as their ability to provide their related ecosystem services is reported to have been deteriorated by more than 50% in the past fifty years. Similarly, the UK National Ecosystem assessment states that the provision of food from marine fisheries is lower now than at any time in the past century, 17% of the UK's coast is suffering erosion, and over the past fifty years there has been a substantial change in the nutrient status of waters and soils which consequently affects the delivery of both regulating and provisioning ecosystem services. On the more positive side, both reports agree that forest and mountain ecosystems are those better conserving their functions in the face of degradation increasing pressures.

Under Action 5 of the EU Biodiversity Strategy to 2020, EU Member States are called to map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020. Action 5 is implemented by the working group MAES on Mapping and Assessment of Ecosystems and their Services. In line with the Millennium Ecosystem assessment (MA), the objective of the EU assessment is to provide a critical evaluation of the best available information for guiding decisions on complex public issues.

Guided by a set of broad and specific policy questions, the working group developed ideas for a coherent analytical framework to ensure consistent approaches are used. The report adopted in April 2013 (*4*) proposes a conceptual framework linking biodiversity, ecosystem condition and ecosystem services to human well-being. Furthermore, it develops a typology for ecosystems in Europe and promotes the CICES classification for ecosystem services (www.cices.eu).

Following the adoption of an analytical framework, it was tested based on the outcomes of six thematic pilots (*5*). Four of these pilots focused on Europe's main ecosystem types: agro-ecosystems, forest ecosystems, freshwater ecosystems and marine ecosystems. In these pilots EU services worked hand in hand with Member States to make a review of national and European data and indicators to assess the condition of ecosystems, to quantify biodiversity and to map and assess their services.

1.2 Objectives of this report

This report builds on this earlier work of the MAES working group and provides a first assessment of the status and trends of ecosystem services in the EU. The objectives of this report are twofold:

1. This report provides a further test of the MAES analytical framework. The second MAES report (5) delivered a set of indicators to be used for ecosystem assessment. Here these indicators are used to detect and analyse ***trends in the spatial extent ecosystems and in the supply and use ecosystem services at European scale****. In addition, new indicators are presented, in particular to assess regulating and maintenance ecosystem services.*

2. This report acts as ***a reference for a set of ecosystem services maps*** *at the EU scale which can be used for further and other assessments and studies*

Measuring trends in ecosystem services is not so evident. There are several reasons for this.

Firstly, ecosystem services are the flows of biomass, energy and information from ecosystems to humans and represent actual work performed by ecosystems (*6*), affecting environmental conditions for humans. These flows are hard to observe and measure, but they can be inferred from observations or measurements of changes over time in stocks, structure and spatial patterns.

Many indicators for ecosystem services which have been used in assessments are in particular based on aggregate changes in the extent of the ecosystems which provide the services or the changes in the human demand for ecosystem services. In addition, most data are available for provisioning ecosystem services such as food, water or timber as these natural resources are reported to statistical offices (*7*).

Assessments of regulating and maintenance services require, in principle, field measurements or modelling studies in order to quantify the role of ecosystems in delivering regulating services.

Available data to measure the status and trends of nature-based tourism and recreation are increasingly collected whereas many other cultural services which relate to ethical or religious perceptions of nature are in essence not, or at least hard, to quantify.

Secondly, although the implementation of Action 5 of the biodiversity strategy will improve the knowledge base on ecosystems and their services there is at present no consistent data repository at the European scale with accounts and indicators on ecosystem services. Any assessment remains very much dependent on gathering data from different data sources.

Thirdly, ecosystem services are often assessed at local and regional scales but upscaling this information is not always possible.

1.3 Assessment approach

1.3.1 What is included in this assessment?

This assessment examines the trends in ecosystems and ecosystem services based on data which were available for the first decade of the 21st century.

This assessment uses the two typologies which are developed by the MAES working group (*4*), i.e. the MAES ecosystem typology for ecosystems and CICES, the common international classification of ecosystem services.

The assessment of the trends in the extent of different ecosystems is based on the assumption that they can be derived from land cover and land use changes. Although a first version of a European ecosystem map has recently become available[1], this report still uses global and European land cover land use datasets which have been updated through time.

The assessment of the trends in the quantities of the supply, the use or the demand of different ecosystem services is, where possible, based on publicly available data which are published by supranational agencies such as FAO, the Food and Agriculture Organization of the United Nations or Eurostat, the EU's statistical office. Remote sensing data also provide a source for deriving consistent and spatially resolved data which can be used to assess ecosystem services. A third option to assess ecosystem services is based on modelling which is also used in this assessment, using ESTIMAP, the JRC's model for mapping ecosystem services (*10*).

1.3.2 Limitations

Marine ecosystems and marine ecosystem services are not considered. Our information on freshwater ecosystems is limited and in essence deals only with water provision but not with the many regulating services which are delivered by rivers and lakes.

[1] http://projects.eionet.europa.eu/eea-ecosystem-assessments/library/draft-ecosystem-map-europe/ecosystem-map-v2-1

The indicators of this report describe essentially the supply side of ecosystem services. Find good data for mapping and assessing the demand for services, and in particular for regulating ecosystem services, is still challenging.

Furthermore this assessment is only based on data and models. We have not consulted stakeholders who often can contribute valuable, expert-based knowledge at lower spatial scales.

This report did not assess the state or the condition of ecosystems. The European Environment Agency will provide an assessment of ecosystem condition, in parallel to this report. This assessment of ecosystem condition will be the basis for a comparison with this assessment of ecosystem services in order to test the assumption that ecosystems need a good status to provide multiple ecosystem services.

1.3.3 Geographical scale and extent

The geographical extent of this assessment is the European Union. We provide an analysis of the change in the indicators at two scales: the EU and the Member States. Most focus of this report goes to the aggregated EU scale but for every Member State the report contains a one page profile which contains the change for most indicators as well as a very brief summary.

During the assessment period the EU enlarged considerably. In 2000, the EU consisted of 15 Member States (EU-15). In 2004, 10 more countries joined (EU-25). In 2007 Bulgaria and Romania accessed (EU-27). Croatia is currently the last country which joined the EU (EU-28). Wherever we mention EU, we refer to the EU-28. In several cases, the indicators only cover parts of the EU but when this happens it is consistently mentioned in the text.

This report also acts as a reference for a set of maps of ecosystem services which are provided to the public and interested users through the Ecosystem Services Partnership Visualization Tool. Indicators which are available at country scale were downscaled to a reference grid of 10 km covering the EU while mapped data which is derived from other sources are provided at their original resolution.

1.3.4 Measuring change

This report measures change in the surface area of ecosystems and in the quantity of the supply or use of different ecosystem services as the percent difference between two years, preferably between 2000 and 2010. This was not always possible, due to data constraints or simply because many countries were in 2000 not a member state. In order to compare all the changes among all indicators, we converted the percent difference between two years to the percent difference per 10 years.

The two following equations are used throughout the document to report changes:

In case of indicators with absolute units (e.g. ha, m^3, ton), change (%) is measured as:

$$\frac{X_{end}-X_{start}}{X_{start}} \times 100$$

where X_{start} and X_{end} are the values for the indicator at the first and last year of the assessment, respectively.

In case of indicators which have percentage as a unit, change (%) is simply calculated as the difference between the values of the indicators at the last and first year of the assessment.

To convert to a decadal percent difference we multiplied the percent change with the following ratio:

$$\frac{t_{end} - t_{start}}{10}$$

Where t_{end} is the last year of the assessment and t_{start} the first year of the assessment.

2 Trends in ecosystems

Changes in land cover and land use (LCLU) have a profound impact on biodiversity and the delivery of ecosystem services. This assessment thus starts by evidencing the changes in land cover and land use that took place in the EU during the first decade of the 21st century. In particular the trend in the surface area of ecosystems at aggregated level is presented here.

2.1 Ecosystem typology and data sources

The MAES ecosystem typology is used to combine different LCLU classes into eight ecosystem types (Table 1). This typology was proposed by the European Environment Agency and is published in the first MAES paper on the analytical framework (*4*).

Whereas ecosystems are more than just land cover or land use, we are limited to using LCLU data to assess trends over time. A first pan-European ecosystem map is available[2] based on the spatial overlay of different data sets including land cover and land use information, soil data and a habitat typology of the European Nature Information System[1]. However, a trend analysis cannot be performed yet. Instead, we used several land cover land use data sets for which regular updates are available (Table 1). In the EU the Corine Land Cover (CLC) data set and the LUCAS survey represent two important and useful sources to assess temporal trends in land cover and land use (Table 2) but none of the two datasets covered the entire study period (2000 – 2010).

CLC updates are available for 1990, 2000 and 2006[3] but only for the latter two years the dataset covers the entire EU[4]. The update for 2012 is foreseen to be released in 2015. Data in vector format are also available to map the changes between 2000 and 2006[5]. This map has a higher resolution that the 2000 and 2006 raster data. The LUCAS surveys started in 2006 with updates in 2009 and 2012 but the use of different sampling designs makes it difficult to compare the 2006 results with those for 2009 and 2012. Therefore we only considered the two latter years in this study using only overlapping sampling points.

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[2] ETC/SIA 2014. Developing conceptual framework for ecosystem mapping. ETC/SIA working paper. Available at: http://projects.eionet.europa.eu/eea-ecosystem-assessments/library/draft-ecosystem-map-europe

[3] http://www.eea.europa.eu/data-and-maps/figures/land-cover-2006-and-changes

[4] Data for Greece for 2006 are missing which is accounted for when presenting country profiles.

[5] The CLC 2006 was updated including the artificial land uses of the refined version of the CLC2006 (*8*) which provide more detailed information about these land uses. Since the layer of changes reported by the EEA presents more updated and detailed information, the layer of changes with the land uses of 2006 ('g100_ch00_06', V17 (12/2013)) was also integrated. For the remaining areas, the reported CLC2006 was considered. Subsequently, the CLC 2000 was also updated in order to make both maps, 2000 and 2006, comparable. With this aim, to the updated version of CLC2006 (described above) we integrated the changes with information on the land uses from 2000 ('g100_ch06_00', V17 (12/2013)). In this way, direct comparison of both land use maps will provide just changes in those areas reported by the EEA

To cover the entire study period, we used two additional data sets. MODIS (Moderate Resolution Imaging Spectroradiometer) has an interpretation of land cover and land use data for every year since 2001. For this study we downloaded the data for 2001, 2006 and 2012. Care should also be given when using the updated layers for inferring changes over time due to considerable data uncertainty. Finally we also used LUISA, the JRC's integrated assessment model which contains at its core a land use model. We used the refined CLC 2006 map and the 2010 projection based on the EU Reference Scenario 2014, the baseline scenario used in LUISA. A detailed description of the EU Reference Scenario 2014 is presented in *(11)*.

We aggregated the different land cover and land use types to the MAES ecosystem typology using the cross walk tables which are presented in the tables in Annex 1. Next, we calculated per method an annualized rate of change for every MAES ecosystem type as a percentage per year. Finally, we used the average rate of change (% per year or per decade) to analyse changes in the extent of ecosystems at the EU scale.

Table 1. Ecosystem types and data sources used to assess changes in the spatial extent of ecosystems in the EU.

MAES ecosystem types	Description
Urban	Urban ecosystems are areas where most of the human population lives and it is also a class significantly affecting other ecosystem types. Urban areas represent mainly human habitats but they usually include significant areas for synanthropic species, which are associated with urban habitats. This class includes urban, industrial, commercial, and transport areas, urban green areas, mines, dumping and construction sites.
Cropland	Cropland is the main food production area including both intensively managed ecosystems and multifunctional areas supporting many semi- and natural species along with food production (lower intensity management). It includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics).
Grassland	Grassland covers areas dominated by grassy vegetation (including tall forbs, mosses and lichens) of two kinds – managed pastures and (semi-)natural (extensively managed) grasslands.
Woodland and forest	Woodland and forest are areas dominated by woody vegetation of various age or they have succession climax vegetation types on most of the area supporting many ecosystem services.
Heathland and shrub	Heathland and shrub are areas with vegetation dominated by shrubs or dwarf shrubs. They are mostly secondary ecosystems with unfavourable (harsh) natural conditions. They include moors, heathland and sclerophyllous vegetation.
Sparsely vegetated land	Sparsely or unvegetated land are all unvegetated or sparsely vegetated habitats (naturally unvegetated areas). Often these ecosystems have extreme natural conditions that might support particular species. They include bare rocks, glaciers and dunes, beaches and sand plains.
Wetlands	Inland wetlands are predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites
Rivers and lakes	Rivers and lakes are the permanent freshwater inland surface waters. This class includes water courses and water bodies.

Table 2. Land cover land use data used in this study.

Data sources and description	Description
Corine Land Cover (CLC):	The CLC data is a map of the European environmental landscape based on interpretation of satellite images with land cover types in 44 standard classes. The map was created in GIS ARC/INFO format at an original scale of 1:100,000 and a minimum mapping unit of 25ha. Raster data are available for 1990, 2000 and 2006. The version of 2012 is in preparation. Vector maps with the changes between 1990 and 2000 and between 2000 and 2006 are available as well. The CLC data is maintained and made available by the European Environment Agency. This report used version 17. http://www.eea.europa.eu/data-and-maps http://www.eea.europa.eu/data-and-maps/figures/land-cover-2006-and-changes
LUCAS	LUCAS is the EU's land cover and land use survey whereby an observer goes to a predefined survey point in order to visually inspect the land cover and the land use. The LUCAS data are made available by Eurostat for 23 countries. http://epp.eurostat.ec.europa.eu/portal/page/portal/lucas/introduction
LUISA	LUISA is the Joint Research Center's land use model which downscales an aggregated amount of land use expected in the future (based on land claims of different economic sectors) to a fine resolution using suitability maps for different land uses and neighbourhood relationships between land uses. The suitability and neighbourhood parameters are statistically calibrated based on observed land-use patterns. It uses a refined version of the CLC 2006 raster data as a starting point (*8*). The CLC 2006 refined dataset has an improved minimum mapping unit of 1 hectare for all types of artificial surfaces and inland waters. In this report we used the LUISA 2006 and 2010 maps.
MODIS	The primary land cover scheme of MODIS identifies 17 land cover classes defined by the International Geosphere Biosphere Programme (IGBP), which includes 11 natural vegetation classes, 3 developed and mosaicked land classes, and three non-vegetated land classes. Annual updates for these raster maps are available since 2001 at 500 m resolution. The land cover product of MODIS copes with several uncertainties (personal communication MODIS team) so the rate of change based on these data was not calculated nor included to assess average trends per ecosystem. https://lpdaac.usgs.gov/products/modis_products_table/mcd12q1

2.2 Results

An estimate of the share of each ecosystem type, based on the refined CLC map 2006, is presented in Figure 1. In the EU cropland is the dominant land cover followed by woodlands and forest and grasslands. Artificial areas cover about 5.5% of the land while other ecosystem types account each for less than 5% of the land. Importantly, these numbers vary according to the dataset used.

Table 3 presents per data source and for the years when updates are available the land covered by the different ecosystem types. Land cover estimates based on MODIS differ significantly from all other methods assigning higher percentages to cropland and grassland and lower percentages to other ecosystem types. Smaller differences can be observed between estimates based on the CLC raster data, the CLC change map and the LUCAS surveys. These changes arise as a result of the usage of different mapping units, different resolution or in case of LUCAS a different objective.

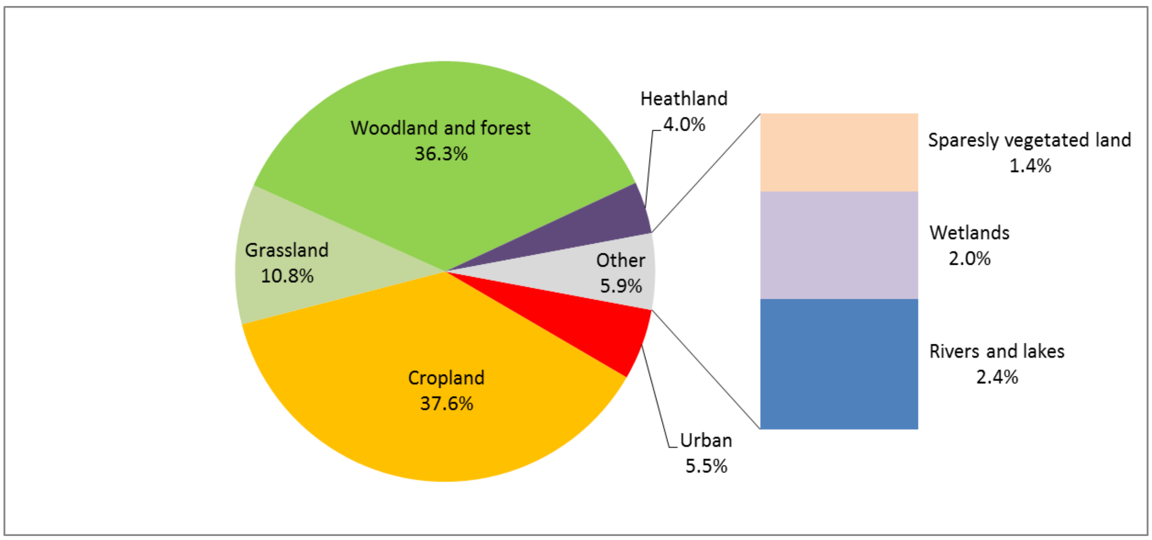


Figure 1. Relative surface area of ecosystems in the EU.

Table 3 also reports the observed changes in the total area of ecosystems in the EU as an annualized rate of change. Based on this analysis, Figure 2 presents an average decadal change per ecosystem type based.

In the EU forests are estimated to have grown with, on average, 2.8% between 2000 and 2010. Also the area covered by artificial land cover has increased with 0.35%. These changes happened at the cost of cropland (-2.1%), grassland which lost almost 1% of its surface area, and heath land and shrub exhibiting a smaller loss. The other ecosystem types including wetlands remained more or less stable in surface area.

The major trends are thus increasing built up and afforestation in combination with a loss of agricultural areas (cropland and pasture). Importantly, all datasets are in agreement about the direction of these trends but the annualized rate of change differs from method to method.

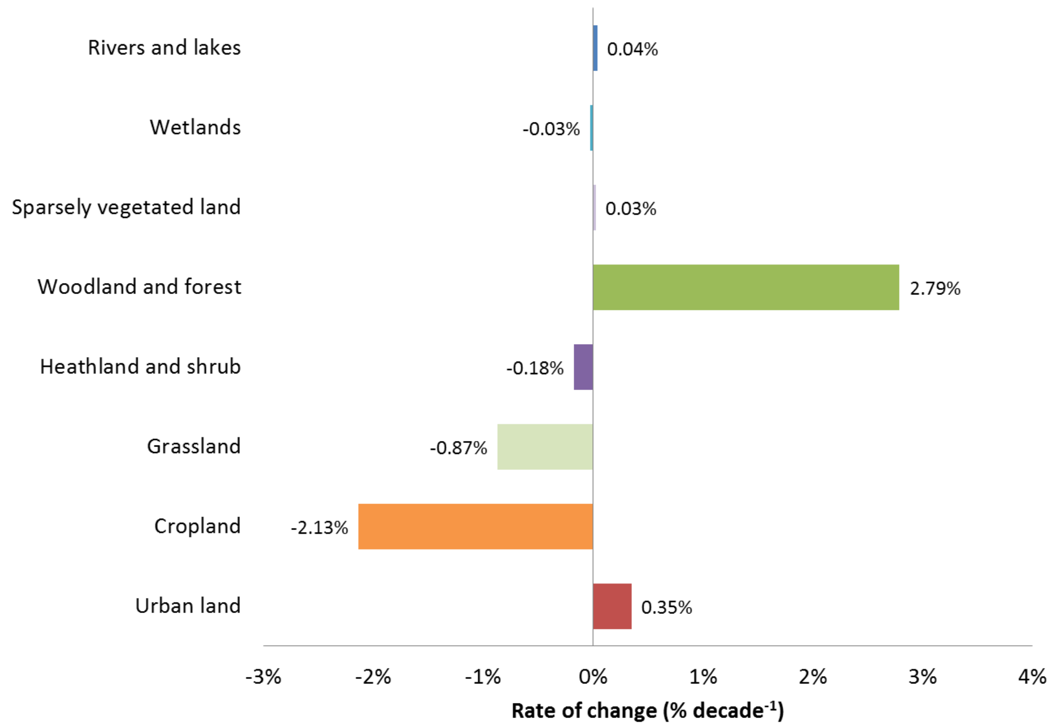


Figure 2. Average rate of change in the spatial extent of ecosystem types based on different land cover datasets (see Table 3).

Table 3. Land covered by different ecosystem types (% of the total land area) and changes in the extent of ecosystems based on land cover and land use datasets.

Ecosystem type	Data	2000	2001	2006	2009	2010	2012	Rate of change (% year^{-1})
Urban	CLC[1]	4.2%		4.5%				
	CLC change	5.1%		5.3%				0.021%
	CLC refined/LUISA			5.5%		5.6%		0.038%
	LUCAS[2]				5.1%		5.3%	0.048%
	LUCAS (Eurostat)[3]				4.3%		4.7%	
	MODIS[4]	2.4%		2.4%			2.4%	
Cropland	CLC	38.7%		38.4%				
	CLC change	37.9%		37.8%				-0.015%
	CLC refined/LUISA			37.6%		35.5%		-0.523%
	LUCAS				31.1%		30.8%	-0.101%
	MODIS		46.1%	46.1%			44.7%	
Grassland	CLC	11.0%		11.0%				
	CLC change	10.9%		10.8%				-0.006%
	CLC refined/LUISA			10.8%		9.8%		-0.231%
	LUCAS				22.9%		22.8%	-0.023%
	MODIS		19.0%	19.8%			18.2%	
Heathland and shrub	CLC	4.2%		3.6%				
	CLC change	4.0%		4.0%				-0.003%
	CLC refined/LUISA			4.0%		3.7%		
	LUCAS				4.8%		4.7%	-0.032%
	MODIS		4.8%	4.5%			3.2%	
Woodland and forest	CLC	36.1%		36.6%				
	CLC change	36.2%		36.2%				0.005%
	CLC refined/LUISA			36.3%		39.5%		0.780%
	LUCAS				31.1%		31.3%	0.053%
	MODIS		26.2%	25.6%			29.8%	0.302%
Sparsely vegetated land	CLC	1.5%		1.4%				-0.002%
	CLC change	1.5%		1.4%				
	CLC refined/LUISA			1.4%		1.4%		
	LUCAS				1.4%		1.6%	0.053%
	MODIS		0.2%	0.1%				
Wetlands	CLC	1.9%		2.1%				
	CLC change	2.0%		2.0%				-0.002%
	CLC refined/LUISA			2.0%		2.1%		
	LUCAS				1.0%		1.0%	-0.003%
	MODIS		0.2%	0.3%			0.3%	
Rivers and lakes	CLC	2.4%		2.5%				
	CLC change	2.4%		2.4%				0.002%
	CLC refined/LUISA			2.4%		2.5%		
	LUCAS				2.5%		2.5%	0.006%
	MODIS		1.1%	1.3%			1.3%	

[1]Percentages reported for CLC are based on the 2000 and 2006 raster data but were not used to compute rate of change; instead the vector layer with the changes per CLC type are used.

[2]Results based on overlapping sampling points only. The following countries are included: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom,.

[2]Reported in table lan_lcv_art (Eurostat). Eurostat discourages the use these statistics for comparing different years.

[4]Due to data uncertainty of the MODIS land cover product, no rate of change was calculated to determine the average rate of change as presented in Figure 2.

3 Trends in ecosystem services

The main question we address in this assessment is if the supply or the use of ecosystem services has changed in the EU between 2000 and 2010. We used a set of 30 indicators to assess the decadal trend of ecosystem services in the EU. The indicators are drawn from reported data, earth observation and models.

3.1 Ecosystem services typology and indicators

The assessment uses the CICES classification system which was proposed as common typology for assessments under Action 5 of the EU biodiversity strategy. CICES, the Common International Classification of Ecosystem Services (www.cices.eu) provides a framework for classifying ecosystem services that depend on living processes. It is hierarchical in structure, with each level providing a more detailed description of the ecosystem service being considered. The advantage of a hierarchical system is that some commonly used indicators for ecosystem services can be used at the most detailed level while others can represent higher hierarchical levels if no detailed data is available.

This assessment is focused on the supply side of ecosystem services. This means that mainly indicators are considered which measure either the supply of ecosystem services or the actual use of services. The MAES conceptual framework, which is rooted in the ecosystem service cascade model (*9*), portrays how ecosystem functions define a supply of ecosystem services which turn into a demand driven use of services. Synonyms for supply of ecosystem services used in the literature are stock, potential services or the capacity (or potential) of ecosystems to deliver services. Synonyms for use are intermediate services, actual services, or flow. We did not consider indicators that measure the benefits of ecosystem services but this exercise will follow in a later stage.

Indicators for either supply or use needed to comply with the following minimum requirements:

- The indicator is standardized across the EU
- The indicator has quantitative values at least at the country scale
- The indicator is available for at least two years.

Table 4 presents the indicators that are retained in our analysis assorted according to CICES. A total of 30 indicators is used for the trend analysis. For some ecosystem services, no indicators which comply with the criteria, could be found. Cultural ecosystem services remain a group with the most gaps in available data and indicators. We used only three indicators leaving one CICES division blank in Table 4. Also for regulating ecosystem services, several gaps are evident. At CICES group level mediation by biota, pest and disease control, and water conditions are left without indicators. At CICES class level, more indicators are lacking. Provisioning ecosystem services are, typically, better covered.

Table 4. Ecosystem service indicators used in this study assorted according to CICES.

CICES Division	CICES Group	CICES Class	Indicators (units)
Nutrition	Biomass	Cultivated crops	Surface area of organic crops (ha) Harvested production of food crops (ton $year^{-1}$)
		Reared animals and their outputs	Grazing livestock (heads)
	Water	Surface water for drinking Ground water for drinking	Total water abstraction for public use (m^3) Proportion of renewable water withdrawn for public use (%)
Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Harvested production of textile crops (ton $year^{-1}$) Total timber removal (m^3 $year^{-1}$) Timber growing stock (m^3)
		Materials from plants, algae and animals for agricultural use	Harvested production of fodder (ton $year^{-1}$)
	Water	Surface water for non-drinking purposes	Total water abstraction for industrial use (m^3) Proportion of renewable water withdrawn for industrial use (%)
		Ground water for non-drinking purposes	Total water abstraction for agricultural use (m^3) Proportion of renewable water withdrawn for agricultural use (%)
Energy	Biomass-based energy sources	Plant-based resources	Timber growing stock (m^3) Harvested production of energy crops (ton $year^{-1}$)
Mediation of waste, toxics and other nuisances	Mediation by biota		
	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	Proportion of green areas in the high density area of cities (%) Removal of NO_2 by urban vegetation (ton ha^{-1} $year^{-1}$)
		Dilution by atmosphere, freshwater and marine ecosystems	
		Mediation of smell/noise/visual impacts	
Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	Capacity of ecosystems to avoid soil erosion (dimensionless between 0-1) Soil retention (ton ha^{-1} $year^{-1}$)

CICES Division	CICES Group	CICES Class	Indicators (units)
		Buffering and attenuation of mass flows	Surface area of forest with a protective function (ha)
	Liquid flows	Hydrological cycle and water flow maintenance	Water Retention Index (dimensionless between 0-10)
	Gaseous / air flows		
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Pollination potential (dimensionless between 0-1) Crop production deficit (%)
		Maintaining nursery populations and habitats	Habitat quality based on common birds (dimensionless ratio)
	Pest and disease control		
	Soil formation and composition	Weathering processes	
		Decomposition and fixing processes	Gross nitrogen balance (ton year^{-1})
	Water conditions		
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	Net ecosystem productivity (normalised index between 0-1) Forest carbon potential (percent change, %)
		Micro and regional climate regulation	
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]			Share of high provision easily accessible land in the recreation opportunity spectrum (%) Surface area of special protection area (ha) Surface area of sites of community importance (ha)
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]			

3.2 General overview of the data sources

Hereafter, we present general information on the data sources used for the assessment. More detailed information per ecosystem service follows in the description of the trends per ecosystem service at the EU scale (section 3.3.1).

Table 5 lists again the indicators but adds a short group name which is used in this report to group ecosystem services and refers to the data sources. The short group name is only used in this document for reporting and style purposes and does not link to a classification system. Table 5 also assigns the indicators with the label supply or use. We consider a supply indicator as an indicator on the capacity of ecosystems to provide a service. Synonyms are stock or potential. Use indicators have always units per time and represent the actual or realized use of ecosystem services between two points in time.

3.2.1 Data sources for provisioning ecosystem services

In general, information on provisioning ecosystem services such as food, water, biomass based energy and materials is collected annually by Eurostat, at the EU level, and by other international organizations such as FAO or the World Bank at the global scale.

Eurostat represents a primary data source for statistics related to agricultural output, water and timber but we opted to extract the agricultural statistics from the CAPRI model (see next paragraph). CAPRI[6] stands for Common Agricultural Policy Regionalised Impact Modelling System. It maintains a database with consistent and gap-filled data based on Eurostat and FAOSTAT statistics. This database can be consulted through a graphical user interface which users need to install. In principle, there should be no differences between the statistics reported by Eurostat and CAPRI since the CAPRI uses Eurostat as a principal source for statistical data. Missing Eurostat data on water provision were gapfilled using Aquastat (the water data base from FAO).

3.2.2 Data sources for regulating and maintenance ecosystem services

Trends in regulating and maintenance ecosystem services are mostly based on ESTIMAP, a model developed and maintained by the Joint Research Centre. ESTIMAP stands for Ecosystem Services Mapping tool (*10*). It is a collection of spatially explicit models to support the mapping and modelling of ecosystem services at European scale. The main objective of ESTIMAP is to support EU policies with spatial information on where ecosystem services are provided (see also Box 1).

[6] http://www.capri-model.org/

Forest carbon potential is based on a Bayesian model which maps the probability of service provision based on a number of ecosystem functions which are modelled in the Community Land Model[7]. This indicator has no values for a start and end year but presents the percentage change between 2000 and 2010.

In addition to these modelled indicators, we also used the following indicators based on observations: the proportion of green areas in the high density area of cities (%) drawn from the urban atlas, the surface area of forest with a protective function (ha) and gross nitrogen balance reported by Eurostat, and the net ecosystem productivity (normalized between 0 and 1) based on Spot Vegetation (*34*).

Box 1. The ESTIMAP model.

The Ecosystem Services Mapping tool (ESTIMAP) is a collection of spatially explicit models to support the mapping and modelling of ecosystem services at European scale. The main objective of ESTIMAP is to support EU policies with spatial information on where ecosystem services are provided and consumed.
ESTIMAP is a model that operates at European continental scale. It runs a set of spatial operations in a Geographical Information System (GIS) environment to calculate the following indicators:

- removal of NO_2 by urban vegetation (ton ha^{-1} $year^{-1}$)
- capacity of ecosystems to avoid soil erosion (dimensionless indicator between 0 and 1)
- soil retention (ton ha^{-1} $year^{-1}$)
- water retention index (dimensionless indicator between 0 and 10)
- pollination potential (dimensionless indicator between 0 and 1)
- habitat quality based on common birds (dimensionless ratio)
- nature-based recreation opportunity spectrum (share of land pixels with varying recreation potential and proximity)
- coastal protection capacity and demand (dimensionless indicators between 0 and 1)
- forest carbon potential (percent change relative to 2000)

Land use is a key component for all models, which are designed to fit a scenario assessment approach using 2006 as a baseline. Hereto, ESTIMAP is dynamically integrated with a land use change model (*11, 12*).
References: (*10, 13*)

Annex 2 provides references or short descriptions of all indicators with reference to data sources and models used in this study.

[7] Community Land Model is available at: http://www.cgd.ucar.edu/tss/clm/

3.2.3 Data sources for cultural ecosystem services

Only limited information is available to assess cultural ecosystem services in a consistent manner across Europe. Several countries, regions or national parks collect visitor statistics but such information is not consistently available for all EU Member States. Other cultural ecosystem services are difficult to quantify. Therefore our analysis is restricted to three indicators.

The recreation opportunity spectrum is available as a module in ESTIMAP. In this report we used the relative occurrence of land pixels with a high potential to provide recreation and which are easily accessible to the public.

In addition to the information on recreation, we plotted two trends in surface area of sites of the Natura 2000 network using data provided by the directorate-general for the environment of the European Commission.

Table 5. Ecosystem service indicators and data sources

Short group name	Indicators	Supply or use	Data
Food and feed	Surface area of organic crops	Supply	Eurostat
	Harvested production of food	Use	CAPRI
	Harvested production of fodder	Use	CAPRI
	Grazing livestock	Supply	CAPRI
Water	Total water abstraction for public use Proportion of renewable water withdrawn for public use	Use	Eurostat FAO – Aquastat
	Total water abstraction for industrial use Proportion of renewable water withdrawn for industrial use	Use	Eurostat FAO – Aquastat
	Total water abstraction for industrial use Proportion of renewable water withdrawn for agricultural use	Use	Eurostat FAO – Aquastat
Materials, timber and energy	Harvested production of textile crops	Use	CAPRI
	Total timber removal	Use	Eurostat
	Timber growing stock	Supply	Eurostat
	Harvested production of energy crops	Use	CAPRI
Air quality regulation	Proportion of green areas in the high density area of cities	Supply	Urban Atlas
	Removal of NO_2 by urban vegetation	Use	ESTIMAP (model)
Erosion control and water regulation	Capacity of ecosystems to avoid soil erosion	Supply	ESTIMAP (model)
	Soil retention	Use	ESTIMAP (model)
	Surface area of forest with a protective function	Supply	Eurostat
	Water Retention Index	Supply	ESTIMAP (model)
Pollination	Pollination potential	Supply	ESTIMAP (model)
	Crop production deficit	Use	CAPRI
Maintenance of habitat	Habitat quality based on common birds	Supply	ESTIMAP (model)
Soil fertility	Gross nitrogen balance	Use	Eurostat
Climate regulation	Net ecosystem productivity	Use	SPOT VEGETATION (with the PHENOLO algorithm)
	Forest carbon potential	Use	ESTIMAP (model) - Community Land Model (CLM 4.0)
Recreation	Share of easily accessible high quality nature in the recreation opportunity spectrum	Supply	ESTIMAP (model)
	Surface area of special protection areas Surface area of sites of community importance	Supply	Natura 2000 data

3.3 EU wide assessment.

3.3.1 Trends in the status of ecosystem services

This section presents the time trends of ecosystem services we observed during the first decade of the 21st century for the different indicators. First we discuss the general results based on all indicators. Table 6 contains values for the start and end years of the assessment period as well as two rates of change (one for the period between two years for which data were collected and one adjusted to a 10 year time interval). In this sense Table 6 can be considered as an account with an opening and a closing stock containing supply or use values for ecosystem services in the EU.

Note that hereafter every indicator is briefly explained and graphed showing where possible also inter-annual variability.

Generally we see the following trends at the EU scale:

For provisioning ecosystem services:

- More crops for food, feed and energy are produced in the EU on less arable land. More organic food is grown. Textile crop production and the total number of grazing livestock have decreased.
- The EU has used water in a slightly more resource-efficient way. Reported water abstractions decreased in both absolute and relative terms (relative to the naturally available water).
- Timber removals have increased but so, too, did the total timber stock.

For regulating ecosystem services:

- There is a substantial increase in net ecosystem productivity.
- Several regulating services, but in particular those which are related to the presence of trees, woodland or forests, increased slightly. This is the case for water retention, forest carbon potential, erosion control, and air quality regulation.
- Pollination potential and habitat quality show a negative trend.

For cultural ecosystem services:

- More land is protected and there is a positive trend in the opportunity for citizens to have access to land with a high recreation potential.

Table 6. Accounts and percent change of ecosystem services in the EU.

	Indicator	Years of the assessment		Change (%)	Change(% 10 year^{-1})
Provisioning services		2000	2011		
	Agricultural area (10^6 ha)	189.4	185.4	–2.1	–1.9
	Harvested production food crops (10^6ton)	701.1	712.8	+1.7	+1.5
	Harvested production fodder crops (10^6 ton)	1464.1	1661.6	+13.5	+12.3
	Harvested production energy crops (10^6 ton)	313.5	345.4	+10.2	+9.2
	Harvested production textile crops (10^6 ton)	1.42	0.89	–39.1	–35.5
		2000	2010		
	Total organic crop area (10^6 ha) (EU-15)	3.9	7.2	+82.1	+82.1
		2005	2012		
	Total organic crop area (10^6 ha) (EU-27)	6.5	10.0	+54.9	+78.4
		2000	2012		
	Total timber removal (10^6 m^3)	411.7	423.3	+2.8	+2.3
		2000	2011		
	Grazing livestock (10^6 heads)	207.3	175.6	–15.3	–13.9
		2000	2010		
	Growing stock in forests and other wooded land (10^9 m^3)	223.7	246.9	+10.3	+10.3
		2000	2011		
	Average total industry water abstraction (10^9 m^3)	104.9	102.7	–2.1	–1.8
	Average total agricultural water abstraction (10^9 m^3)	43.2	37.4	–13.3	–11.1
	Average total public water abstraction (10^9 m^3)	46.7	44.1	–5.7	–4.7
	Proportion of renewable water withdrawn for industrial use (%)	6.98	6.83	–0.1	–0.1
	Proportion of renewable water withdrawn for agricultural use (%)	2.87	2.49	–0.4	–0.3
	Proportion of renewable water withdrawn for public use (%)	3.11	2.93	–0.2	–0.1
Regulating and maintenance services		2000	2010		
	Forest area with protective function (10^6 ha)	25.2	32.6	+29.4	+29.4
	Pollination potential (0-1)	0.0517	0.0496	–4.2	–4.2
	Water Retention Index (0-10)	4.039	4.046	+0.2	+0.2
	Capacity of ecosystems to avoid soil erosion (0-1)	0.9429	0.9445	+0.2	+0.2
	Average soil retention (1000 ton ha^{-1} $year^{-1}$)	32.1	33.6	+4.6	+4.6
	Removal of NO_2 by urban green areas (1000 ton $year^{-1}$)	635.5	640.3	+0.8	+0.8

	Indicator	2000	2010	Change (%)	Change(% 10 year^{-1})
Regulating and maintenance services	Habitat quality (dimensionless ratio)	0.9944	0.9861	–0.9	–0.9
	Forest carbon potential (% change)			+1.7	+1.7
		2000	2011		
	Proportion of green areas in the high density area of cities (%)	12.64	13.73	+1.1	+1.2
	Net ecosystem productivity (0-1)	0.559	0.612	+9.5	+10.5
		2000	2011		
	Pollination crop production deficit (%)	25.89	26.39	+0.5	+0.5
		2000	2011		
	Gross nutrient balance (10^6 ton year^{-1})	10.7	8.5	–20.2	–25.2
Cultural services		2000	2010		
	Proportion of high provision easily accessible areas in the recreation opportunity spectrum (%)	12.0	15.6	+3.5	+3.5
		2000	2010		
	Special Protection Areas (10^6 ha) (EU-27)	41.3	59.3	+43.9	+87.7
	Sites of Community Importance (10^6 ha) (EU-27)	54.6	71.9	+31.7	+63.4
		2000	2011		
	Special Protection Areas (10^6 ha) (EU-15)	16.9	44.7	+163.9	+163.9
	Sites of Community Importance (10^6 ha) (EU-15)	33.8	55.1	+63.2	+63.2

Important remark: Eurostat and FAO/Aquastat data were downloaded in June 2014. Eurostat data are regularly updated and reported values may undergo slight changes which explains why values reported in this report may not represent the most actual values available on the Eurostat website.

Provisioning ecosystem services: Food and feed

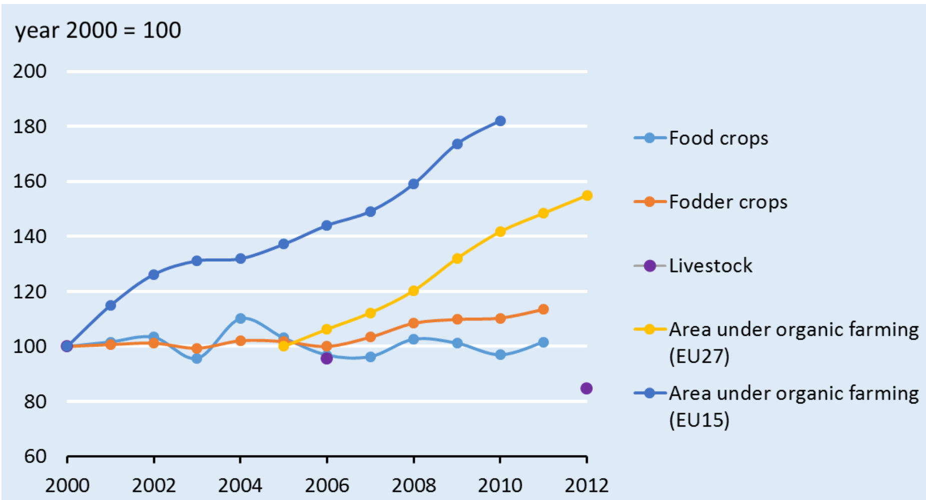
Four different indicators are used to report trends of food and feed (or fodder) provision: the surface area of organic crops (ha), the total harvested production of food crops (ton year^{-1}) as well as of fodder (ton year^{-1}), and the numbers of grazing livestock (heads of cattle, goats and sheep) (Figure 3).

Statistical information on the surface area of cropland including of organic crops and the production of food and feed in the EU is readily available and reported by Eurostat. Crop production data reported here are, however, taken from the CoCo database which is coupled to the CAPRI model. CoCo stands for complete and consistent.

The most noticeable trend is the increase in area under organic farming. According to Eurostat data, the EU-27 had in 2011 a total area of 9.6 million hectares cultivated as organic, up from 6.5 million in 2005. Considering only the EU-15, almost 4 million ha was under organic farming in 2000. This increased to 7.4 million in 2010

The production of food crops fluctuated between 2000 and 2012 while fodder production increased. These trends coincide with a loss of cropland in the EU with an estimated 2% between 2000 and 2010.

The number of grazing livestock decreased. In 2001 Eurostat counted 207 million heads, a number which decreased to 175 million in 2012.



Data sources:

Food and fodder production: CoCo database from CAPRI based on Eurostat table [agr_r_crops];

Livestock: Eurostat table [agr_r_animal];

Area under organic farming: Eurostat table [tsdpc440]

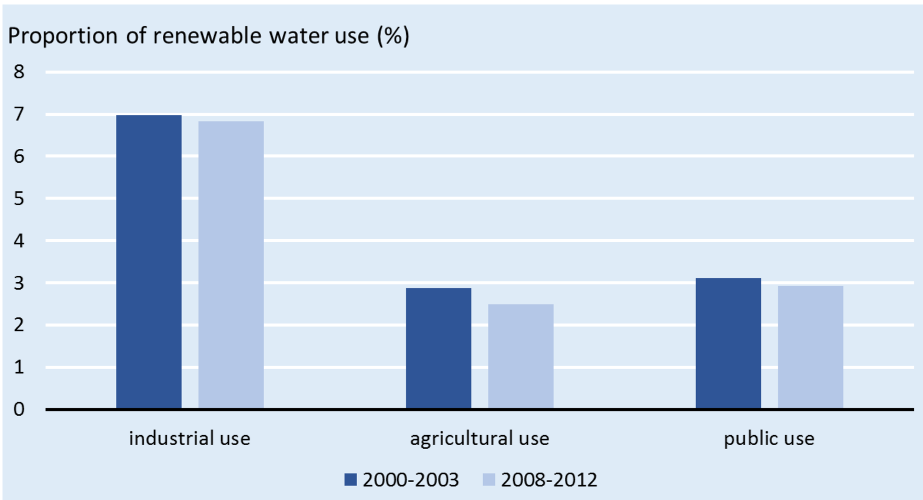
Figure 3. Provisioning ecosystem services: food and feed. Data for each indicator are relative to the year 2000.

Provisioning ecosystem services: Water

Water is extracted by households to be used as drinking water, and by industry and agriculture to support production. We used data on water abstraction by the public sector, industry and agriculture as indicators for water provision. In addition, a ratio between water withdrawals and the total renewable freshwater reserves per country is calculated to provide a context of total water supply.

Water related data are made available by Eurostat. Data are not available for all years or for all countries so we used averaged water statistics based on three periods: [2000-2003], [2004-2007], and [2008-2012]. We also relied on Aquastat, a service from the FAO. This database provides gapfilled data for areas where Eurostat has insufficient information. Water abstraction data for the UK are limited to England. For the purpose of this report, we estimated the data for Scotland, Wales and Northern Island by assuming that water abstractions for public, industrial and agricultural use are proportionate to the share of population, industrial land use and agricultural land use, respectively, of these regions relative to the reported data for England.

At the start of the assessment period, the aggregated industrial, agricultural and public water abstraction mounted to almost 195 billion m^3 per year. Ten years later the EU withdrew annually around 184 billion m^3, a decrease with 5.6%. In Figure 4 these data are presented per sector and relative to the total available volume of renewable freshwater resources. In the period 2008-2012, 6.8% of renewable freshwater was used for industrial applications. Agriculture accounted for 2.5% while public withdrawals equaled 3% of the renewable water resources.



Data source:

Aquastat (FAO).
Data for 3 regions in the UK are estimated

Figure 4. Provisioning ecosystem services: Water. Proportion of renewable water use per sector.

Provisioning ecosystem services: Materials, timber and energy

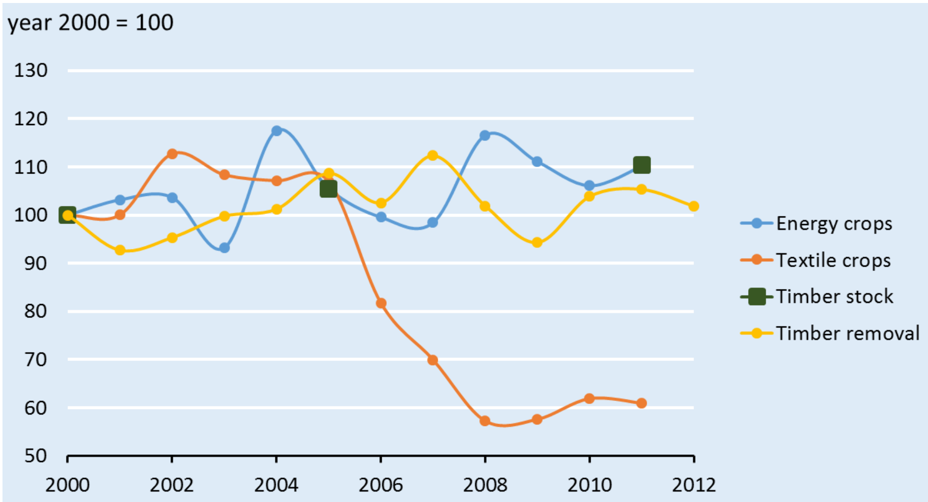
Four indicators are used to assess the trends in the provision of raw materials and energy: the harvested production of textile crops (ton year^{-1}) and of energy crops (ton year^{-1}), the total timber growing stock (m^3) and timber removal from forests (m^3 year^{-1}) (Figure 5).

We used Eurostat based agriculture and forestry statistics. Similar as for food and feed, statistics for textile and energy crops were taken from the CoCo database of the CAPRI model. Timber data are directly downloaded from the Eurostat database.

The production of energy crops which are used to produce biofuels varied annually but increased since 2000 and was ten years later 10% higher. The production of textile crops such as cotton declined sharply after 2005.

The growing stock of timber in the EU is expanding. Eurostat reported in 2000 a stock of 22 billion m^3 which increased with about 10% in 2010 (Table 6).

Less than 2% of the timber growing stock is annually harvested as timber: 411 million m^3 in 2000 and 423 million m^3 in 2010.



Data sources:

Energy and textile crops: CoCo database from CAPRI based on Eurostat table [agr_r_crops];

Timber stock: Eurostat table wood volume [for_vol];

Timber removal: Eurostat table roundwood removals [for_remov]

Figure 5. Provisioning ecosystem services: Materials, timber and energy. Data for each indicator are relative to the year 2000.

Regulating and maintenance ecosystem services: Air quality regulation

A considerable share of air pollutants, such as NO_2 and particular matter, end up on soils through deposition processes. Trees enhance the deposition of air pollutants through their leaves air and capture pollutants which are stored in tissue or flushed down when it rains. In forests and protected areas, deposition of nitrogen and other pollutants causes acidification and eutrophication if critical thresholds are exceeded. In turn, biodiversity is negatively impacted as species sensitive to nutrient enriched soil disappear. In cities, the same physical processes take place and urban trees can decrease the concentration of certain pollutants by capturing fine dust particles or chemical pollutants. In contrast to rural areas, pollutant removal by trees is considered beneficial, presumably because urban parks and their soils are given other priorities than conservation and are therefore not considered when assessing critical loads.

Our assessment includes two main indicators addressing air quality regulation: the share of green urban area and the total amount of NO_2 removed by urban vegetation. The spatial extent of the assessment for these two indicators is limited to the large urban zones (*14*). The share of green urban area in the EU is based on a sample of 30 cities for which data was available for 1997 and 2006 (Moland/Urban Atlas, see also (*15*)).

Based on a sample, the high-density core of cities contained in 1996, on average, 12.6% of green areas (Table 7). This share rose to 13.7% in 2006, an increase with 1.1%.

Using the ESTIMAP model, we assessed for the EU's large urban zones how much air pollutants can be captured by urban forests. NO_2 is used as indicator substance. The calculation of NO_2 removal is based on Novak et al. (*16*). The calculation requires mapped data of NO_2 concentration (often expressed in $\mu g\ m^{-3}$) and dry deposition rates (often expressed in $cm\ s^{-1}$). The product between concentration and deposition rate results in the removal which has units of mass per surface area. Dry deposition rates depend on, among others, land cover and land use with trees (but also high buildings) capturing more pollutants than flat surfaces such as grassland. Based on this method, we assessed annual removal of NO_2 for all the large urban zones in Europe. Annex 2 provides a more detailed description of this indicator.

We estimated that a total of 635×10^3 ton of NO_2 was removed by urban forests inside the large urban zones during 2000 (Table 6). This figure increased to an estimated 640×10^3 ton for 2010. To provide a context, the total emission of NO_2 in the EU during 2010 was estimated at 9139×10^3 ton (EMEP emission inventory; http://www.ceip.at/).

Higher NO_2 concentrations result also in higher NO_2 removals keeping everything else constant. However, the increment of NO_2 removal in 2010 relative to 2000 is not caused by higher NO_2 concentrations. In almost all countries, urban NO_2 concentration decreased during the assessment period. So the higher removal, although limited to 0.8%, can effectively be attributed to the growth of green urban areas.

Table 7. Green urban areas in cities.

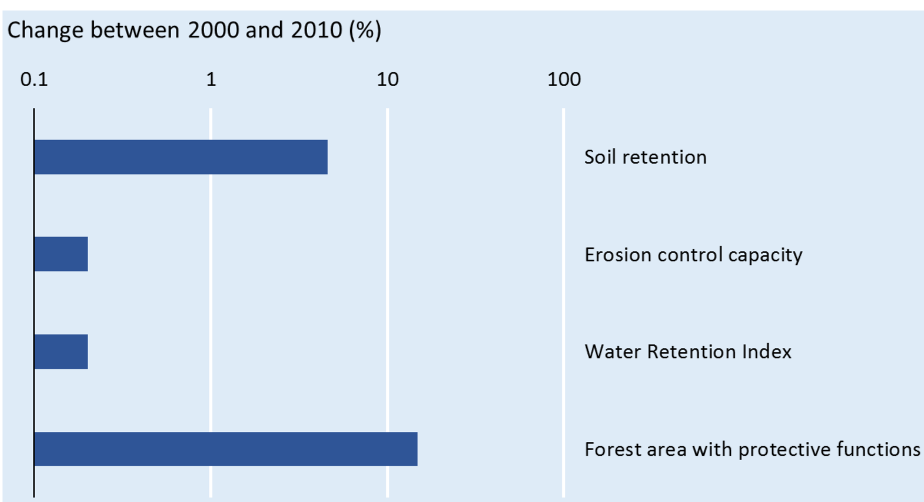
City	1997	2006	Change
Bilbao	11.3%	17.6%	6.3%
Bratislava	25.5%	27.9%	2.5%
Brussels	19.6%	20.6%	1.0%
Copenhagen	7.0%	7.9%	0.9%
Dresden	28.4%	26.2%	-2.1%
Dublin	16.6%	15.8%	-0.8%
Duisburg	8.4%	14.1%	5.7%
Essen	9.7%	16.0%	6.3%
Faro	3.5%	0.8%	-2.7%
Gothenburg	26.8%	23.6%	-3.2%
Grenoble	30.0%	30.9%	0.9%
Helsinki	36.4%	35.0%	-1.3%
Heraklion	0.9%	0.9%	0.0%
Lyon	10.8%	10.2%	-0.6%
Marseille	10.1%	9.4%	-0.7%
Milano	6.1%	7.0%	0.9%
Mulheim	6.1%	8.9%	2.8%
Munich	12.6%	12.9%	0.3%
Nicosia	3.3%	4.2%	0.9%
Oberhausen	7.1%	11.7%	4.6%
Olhão	0.5%	0.3%	-0.3%
Padova	3.6%	2.0%	-1.6%
Palermo	12.4%	10.8%	-1.6%
Porto	9.2%	8.7%	-0.5%
Prague	14.0%	18.5%	4.6%
Setubal	4.2%	10.1%	5.9%
Sunderland	1.3%	1.6%	0.3%
Tallinn	28.6%	28.3%	-0.3%
Venice	2.4%	3.8%	1.3%
Vienna	22.7%	26.0%	3.2%
Average	12.6%	13.7%	1.1%

Regulating and maintenance ecosystem services: Erosion control and water regulation

Both erosion control and water regulation are important services provided by vegetation. Grasslands and forest reduce the speed of runoff water and thus regulate water flows and avoid soil erosion. Here we used four indicators, all but one are modelled using ESTIMAP.

The module on soil erosion control is based on the Revised Universal Soil Loss Equation and essentially compares modelled soil erosion with and without the presence of vegetation (*17*). The difference between both outcomes, referred to as soil retention in ton ha^{-1} $year^{-1}$, is considered as a suitable indicator to quantify soil erosion control. An additional dimensionless indicator measures the capacity of ecosystems to avoid soil erosion and gives scores to land pixels between 0 and 1. The model results for 2000 and 2010 suggest that, on average, the capacity of ecosystems to avoid soil erosion increased slightly (Figure 6). Total soil retention was almost 5% higher in 2010 relative to 2000, although this is partially explained by a comparable increase of precipitation in the same period.

Water regulation was recently added to ESTIMAP using the Water Retention Index (WRI, Vandecasteele et al. submitted). This composite indicator assesses the capacity of the landscape to regulate and retain water passing through it. The Water Retention Index takes into account the role of interception by vegetation, the water-holding capacity of the soil, and the relative capacity of both the soil and the bedrock to allow percolation of water. The influence of soil sealing and slope gradient is additionally considered in calculating the final index. Similar to the capacity to avoid soil erosion, we conclude a slight increase of the water retention index during the assessment period (Figure 6)



Data sources:

Soil retention, Erosion control capacity and Water Retention Index: ESTIMAP

Forest area with protective functions: Eurostat table protective functions of forests [for_profnc]

Figure 6. Regulating and maintenance ecosystem services: water regulation and erosion control

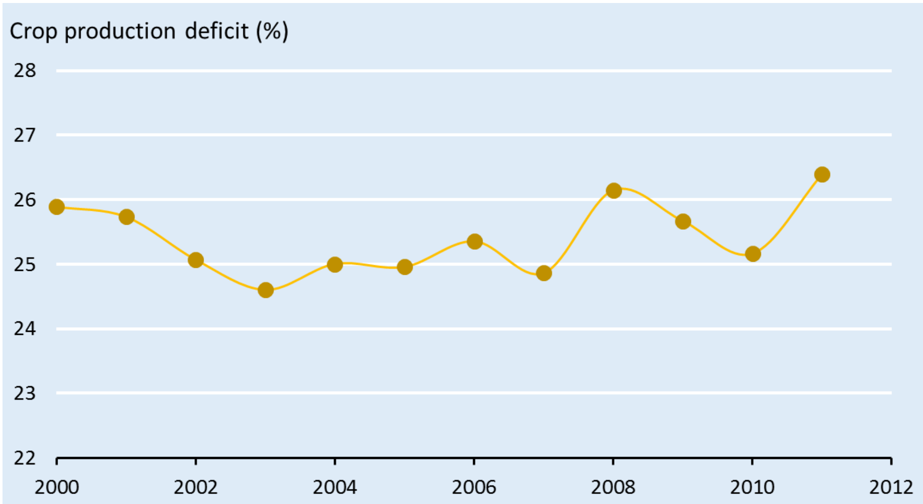
Finally, we also included the forest area with a protective function which is reported by Eurostat. However, not all member states report this data. Eurostat reports a total of 25.2 million ha and 32.6 million ha for 2000 and 2010, respectively, corresponding to an increase with almost 30% over 10 years (Figure 6, Table 6).

Regulating and maintenance ecosystem services: Pollination

The trend in pollination services provided by pollinating insects was estimated using relative pollination potential. This indicator assesses the capacity of ecosystems to provide pollination to adjacent crops which are dependent on insects for transferring pollen. The model generates a map showing the relative pollination potential based on a single ecological guild of pollinators with a relatively short flight distance, using solitary bees as model. Particularly fruit and several vegetable species such as pumpkin and cucumber need pollinators to produce the parts we consume.

The modelling results for 2000 and 2010 suggest a drop in relative pollination potential with almost 5% (Table 6). Afforestation in combination with the loss of grassland nearby cropland are the main responsible causes for this drop. Semi-natural grasslands are given high scores for nesting suitability and flower availability, two variables which drive pollination potential of ecosystems in the model. The loss of grassland results therefore in a loss of pollination potential. In addition, pollinator species do not frequent forest cores but tend to use forest edges as habitat from which they can forage on adjacent croplands and pollinate crops. This behavior is included in the model giving more weight to forest edges while decreasing the suitability scores towards the forest core. Increasing forest area and the associated, decreasing ratio of forest edge to forest core has in the model a negative impact on pollination potential.

While pollination potential has fallen, the total production of crops which depend on insect pollination has increased to some extent. This is expressed by the crop production deficit, which is the theoretical percentage of production that would be lost in absence of insect pollination (*33*). In the EU, crop production deficit due to pollination increased with half a percent point from 25.8% in 2000 to 26.4% in 2010. However, annual variation is large so no clear trend is apparent (Figure 7).



Data sources:

Eurostat data on crop production:

Relative dependency on pollination per crop

See also (*33*)

Figure 7. Regulating and maintenance ecosystem services: Pollination. Crop production deficit resulting from a loss of insect pollination (%)

Regulating and maintenance ecosystem services: Maintenance of habitat

The maintenance of nursery populations and habitats is by the CICES classification considered as a separate ecosystem service. It recognizes the role ecosystems play in support of provisioning services. The Millennium Ecosystem Assessment (*1*) considered such services indeed as supporting services.

ESTIMAP contains an indicator on habitat quality based on the modelled distribution of common birds, including the species listed in the European Common Birds indicator (see Annex 2).

Data on bird species occurrences were obtained from the EBCC Atlas of European Breeding Birds[8]. ESTIMAP uses species distribution models (SDM) and downscales species distributions to a 10 km^2 resolution.

We defined the species richness in relative terms as the ratio between the local species richness and the average species richness in the neighbourhood (i.e. within a 500 km diameter). As a result, the relative species richness is indicative of the capacity of ecosystems to provide suitable habitat for common bird communities and is interpreted as a 'habitat quality indicator' (HQI). The HQI, as expressed in relative terms, allows making direct comparisons between regions. Those areas showing large values of the HQI are indicative of places with high relative species richness, becoming of special concern for the maintenance of nursery habitats for common birds.

On average, HQI slightly decreased with about 1% between 2000 and 2010 (Table 6).

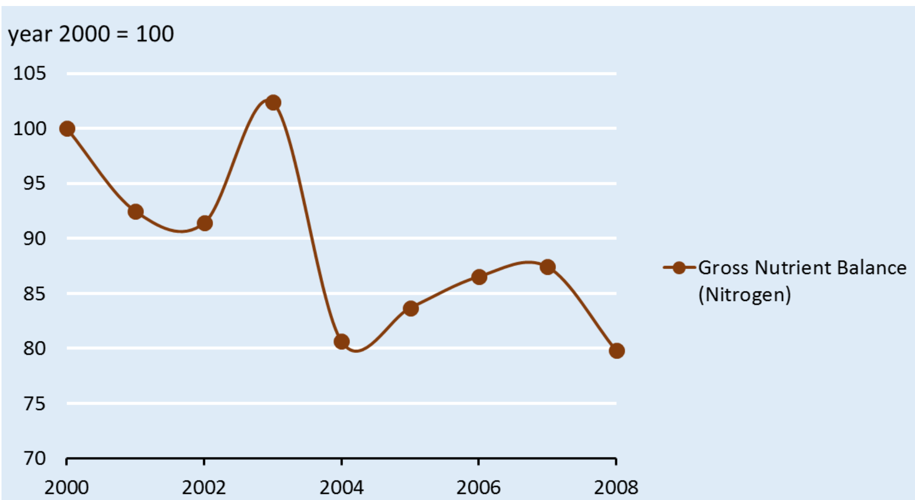
[8] http://www.ebcc.info/

Regulating and maintenance ecosystem services: Soil formation and composition

In absence of a better indicator which can assess trends in soil formation and composition, we used gross nitrogen balance which is also suggested in the 2nd MAES report on indicators for services delivered by agro-ecosystems (*5*). Gross nitrogen balance is an agri-environment indicator and provides an indication of the potential surplus of nitrogen (N) on agricultural land (kg N ha^{-1} $year^{-1}$).

Although annual variations of this indicator are evident, the generally declining trend is positive news as it corresponds to a decreased nitrogen surplus on cropland.

Nonetheless gross nitrogen balance remains positive which means that nitrogen inputs to farmland are still exceeding the outputs resulting in further enrichment of the soil and ground water.



Data sources:

Eurostat table on gross nutrient balance [aei_pr_gnb].

Figure 8. Regulating and maintenance ecosystem services: Gross nutrient balance as indicator for soil composition.

Regulating and maintenance ecosystem services: Climate regulation

Climate regulation refers to the role ecosystems have in maintaining a livable climate. At global scale, this role refers essentially to maintain the chemical composition of the atmosphere while at more local scale, ecosystems regulate the microclimate, for instance in cities.

In the literature climate regulation as an ecosystem service is often indicated by carbon sequestration or by net primary productivity, probably as a result of global attention to climate change. In this report, we used net ecosystem productivity (NEP) [9] and forest carbon potential as indicators for climate regulation.

It is important to stress that the indicator used (NEP) is an approximation and should not be used to make conclusions on carbon fixation. Synonyms or other potential names for this indicator are "standing biomass" or "growing season biomass".

NEP may act as a surrogate for many ecosystem services given the crucial role of photosynthesis for many, if not all, services. Primary production data is readily available from different remote sensing programs. Our indicator is based on NDVI measurements by Spot Vegetation[10]. NDVI data were taken for three sets of three years: 1999, 2000, 2001; 2004, 2005, 2006 and 2009, 2010 and 2011. The Phenelo algorithm was used to calculate productivity based on seasonal vs. non seasonal vegetation, which involves a calculation of growing season biomass for those vegetated surfaces which exhibited seasonal variations (*34*). For each map, the upper and lower 90 percentile were set as maximum and minimum to avoid outliers due to e.g. satellite sensor acquisition error and subsequently the data were scaled between 0 (lower 90 percentile) and 1 (upper 90 percentile) to give a more apprehensive measure of standing biomass. Next, for each set of three years an annual average was calculated to reduce the effect of annual variation on primary production.

In the EU, there is an upward trend in net ecosystem productivity (+10.5% over 10 year) (Figure 9).

Remote sensing data suggest that there are substantial increases in photosynthetic activity in the Northern Hemisphere ((*18-20*)) with one report indicating an increase of 6% in net primary production between 1982 and 1999 (*18*). Cited reasons are elevated atmospheric CO_2 concentrations, (ii) increased atmospheric N deposition, and (iii) longer growing seasons (*19*).

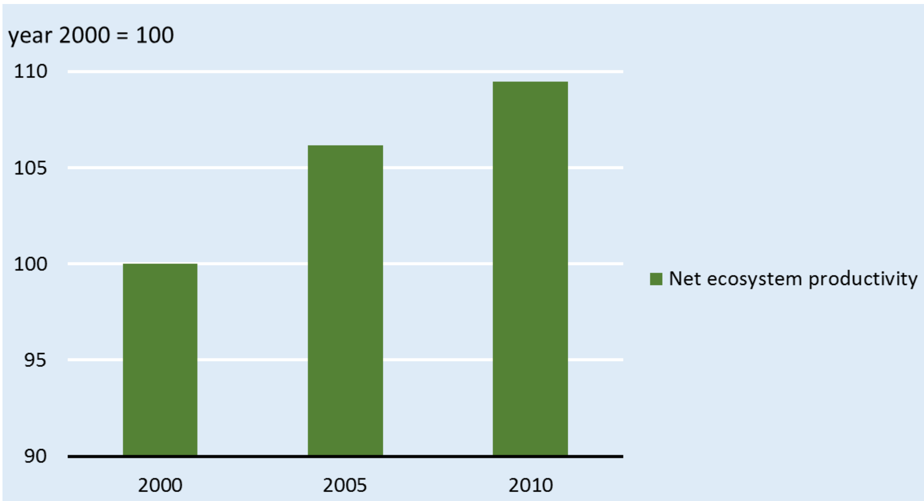
In contrast to NEP and despite global focus on climate change research, surprisingly little consistent data at global or continental scale is available to map and assess trends in the quantities of carbon which are annually sequestered by different ecosystems. Mostly, data is available for above ground vegetation or for particular ecosystems but there are no consistent time records per country. Therefore, we used a newly developed indicator, forest carbon potential, which is consistent with the developments of ESTIMAP and LUISA. The objective of this indicator is to assess relative changes in carbon stock and flows and to compute its variation between 2010 and 2000, in relation to the extent of forests within the European Union. A more detailed description of the indicator is included in Annex 2. Table 6 reports an increase of about 1.7% for forest carbon potential.

The increase in both Net Ecosystem Productivity and Forest carbon potential correspond with increases in forest stock, the extent of forests in the EU, and in case of NEP also the higher

[9] Net primary production of productivity (NPP) is defined as the net flux of carbon from the atmosphere into green plants per unit time. It equals the gross primary production minus the respiration by plants. Net ecosystem production or productivity denotes the net accumulation of organic matter or carbon by an ecosystem; NEP is the difference between NPP and the decomposition rate of dead organic matter (heterotrophic respiration).

[10] http://www.spot-vegetation.com/

agricultural production. However, a correlation analysis at country scale did not reveal significant correlations so further study a finer spatial resolution is needed to determine if and how these different production-related indicators correlate.



Data sources:

Spot Vegetation Normalized Difference Vegetation Index Phenolo approach (*34*)

Figure 9. Regulating and maintenance ecosystem services: Net ecosystem productivity

Cultural ecosystem services: Recreation

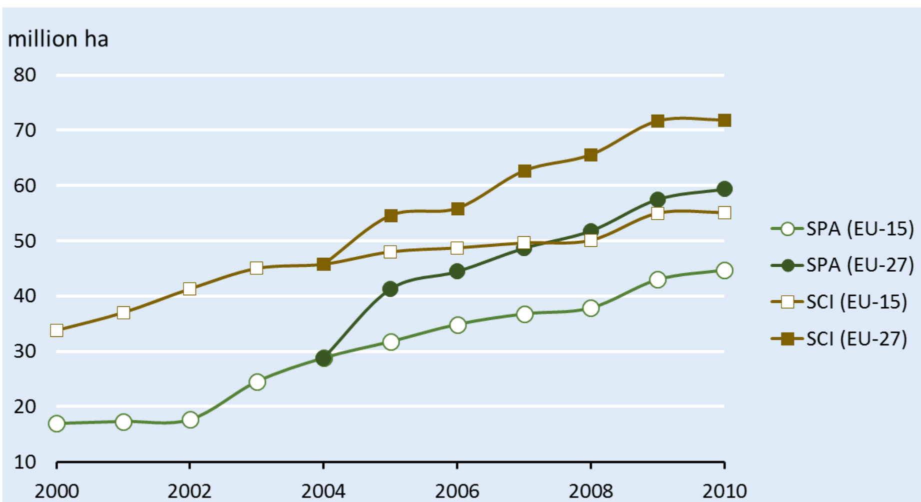
Only one cultural ecosystem service is considered in this analysis: recreation in nature. We used the Recreational Opportunity Spectrum (ROS), an indicator modelled in ESTIMAP, as source of information (*21*). In particular, we calculated the trend between 2000 and 2010 in the share of high provision, easily accessible land pixels in the ROS. In addition, we used indicators based on the spatial extent of Natura 2000 sites, assuming that this network of protected areas is an important source of recreation for people.

The Recreation Opportunity Spectrum represents the degree of service available according to proximity to roads and residential areas. It combines the potential opportunities offered by nature and a proximity map to derive nine categories: three levels of provision (low, medium and high provision) and three degrees of proximity (from proximal to remote).

Here we used the most interesting ROS category for citizens to recreate: land with a high potential provision of recreation and which is easily accessible for day recreation. The results suggest an important increase of this category. Based on the model, 12% of all land pixels in the EU are expected to be covered by the high recreation potential/easily accessible ROS class. In 2010, this percentage increased to 15.6%.

There is no consistent database which can be used for the evolution of the total area of Natura 2000 sites since the start of the network. However, the Natura 2000 newsletter reports annual recordings for special protection areas (SPA's), established under the Birds Directive, and for the sites of community importance (SCI's), established under the Habitats Directive. Once designated, SCI's are called special areas of conservation (SAC's). SPA's often overlap with SCI's and spatially separating the two datasets for every year since the establishment of the network is rather time consuming. For this report, we used the tables published in the Natura 2000 newsletters (Eurobarometer). In particular, we copied the surface area (km^2 or ha) for SCI's and SPA's per country and summed these statistics to obtain results for the EU-15 and EU-28[11].

Another data source on protected areas (CDDA data on nationally designated sites) has a similar issue (spatial overlap in the designations which requires a spatial analysis to assess the trend in the total area of protected sites per country). In 2000, 17 million ha was protected as SPA and 33.8 million ha was assigned under the Habitats Directive. The surface area of protected areas grew substantially to 59.3 million had and 71.9 million ha, respectively, in 2010. In 2004, 10 new member states joined the EU which has had an impact on the growth of the network. Figure 10 thus plots the surface area of both SPA's and SCI's separately for the EU-15 and for the EU-27.



Data sources:

Natura 2000 barometer reported in the Natura 2000 newsletters

Figure 10. Trend in the area of protected areas under the Birds and Habitats directive. SPA are special protection areas; SCI are sites of community importance.

[11] We observed that the total sum of the national area of SCI and SPA decreased after 2010. The numbers reported here are therefore under revision but we still prefer to include indicators on protected areas in this assessment as they are important sites for nature based recreation and as Natura 2000 contributes significantly to the supply of many ecosystem services.

3.3.2 Trends in the status of ecosystem service per ecosystem

Table 8 presents the trends which were reported in the previous sections but this time per ecosystem (using the MAES typology). In particular, we present the change per indicator as a percentage per decade (10 years). So for indicators for which the start and end dates do not correspond to 2000 and 2010, respectively, rates of change were converted to represent a 10 year time step.

All provisioning ecosystem services, for which data were in general derived from reported statistics per country, were assigned to particular ecosystems. Evidently, all crop and timber statistics were assigned to cropland, and woodland and forest, respectively. Note that all crop services (crops for food, feed, textile and energy) are combined into total crop production. Water was expected to be abstracted from rivers and lakes but this clearly ignores the role of ground water. Grazing livestock (sheep, goats and cattle) was attributed to grassland.

Several indicators for regulating ecosystem services such as pollination potential, erosion control and soil retention, and water retention are modelled in ESTIMAP across all ecosystems so ecosystem-specific values for change are reported. Indicators based on observed data or taken from databases were, similarly to provisioning services, assigned to the supplying ecosystems: urban green areas and NO_2 removal to urban systems, forest area with protective functions to woodland and forest, and gross nitrogen balance and crop production deficit related to pollination to cropland. Net ecosystem productivity was also assessed per ecosystem by intersecting the Corine Land Cover based ecosystem map with the different productivity maps.

The cultural ecosystem services, the share high provision easily accessible in the recreation opportunity spectrum (in Table 8 abbreviated to recreation potential) as well as the Natura 2000 statistics on special protection areas and sites of community importance, were not assigned to a particular system. They are assumed to cover all ecosystems. Similarly, habitat quality for birds is influenced by the presence of different ecosystem types so that an assessment per ecosystem is not really appropriate.

The breakdown of indicators which are assigned to single ecosystems does not reveal additional information. However, where indicators cover multiple ecosystems, additional trends can be observed. Pollination potential, the supporting role ecosystems have to sustain crop production, differs markedly across ecosystems with a considerable fall of pollination potential for grassland, forest and heathland. Erosion control and water retention, both indicators which refer to the capacity of ecosystems to provide these regulating services, hardly changed and resulted values of less than 1% per 10 years. Soil retention varied per ecosystem but this is mainly a consequence of an increased structural impact of soil erosion on agricultural land. A better indicator is available which takes the structural impact into account (*17*).

Increasing values of ecosystem services use (or flow) under increasing pressure can result in counter-intuitive interpretations. Ecosystems regulate the stocks of pollutants such as nitrogen in water, particulate matter (PM) in the atmosphere, or fertile soil on cropland. Service flows are therefore a function of the total size of the ecosystems (as well as their condition) but also of the stock which is regulated. Keeping nitrogen concentration constant, increasing the size of a wetland will result in higher nitrogen retention. Keeping the size of the wetland constant, a higher nitrogen load will also increase the total nitrogen retention (at least until a threshold is reached after which the wetland is too contaminated and denitrification rates may fall). In sum, increased stock quantity (increased nitrogen concentration, more atmospheric PM or more soil on sensitive slopes) almost invariantly yield higher service flows (more nitrogen is denitrified, more PM is captured, and more soil is retained). Therefore, indicators which measure actual flows or uses of regulating ecosystem services must be interpreted carefully.

Guerra et al (*17*) provide an elegant solution to this problem and propose the rate of effective service provision which is the change in the total amount of actual ecosystem service provision corrected by the structural impact fluctuations for a given region. They define structural impact as the impact that would take place in absence of regulating ecosystem services. For example, the structural impact related to soil erosion is the total erosion that would theoretically occur if in absence of protective cover and vegetation.

Consider for example an area which is very sensitive to erosion and one that is not. Vegetation on sensitive soils situated in the first region helps control erosion, while vegetation in the second region contribute only little or not to erosion mitigation. Guerra *et al.* refer to the first region as one with high structural impact, while the second one has low structural impact. This difference is considered in the rate of effective service provision, which corrects the flow or use of a regulating ecosystem service given the structural impact.

Table 8. Decadal change in ecosystem services per ecosystem.

	Indicator	Urban	Crop land	Grass land	Wood land and forest	Heath land and shrub	Bare land	Wet lands	Rivers and lakes
Provisioning	Harvested production		+7.7%						
	Agricultural Area		–1.9%						
	Total Organic Crop Area		+78.5%						
	Total timber Removal				+2.3%				
	Grazing Livestock			–13.9%					
	Timber growing stock				+10.3%				
	Industrial water abstraction								–1.8%
	Agricultural water abstraction								–11.1%
	Public water abstraction								–4.7%
Regulating and maintenance	Forest area with protective function				+29.4%				
	Pollination Potential		–4.1%	–26.8%	–27.7%	–40.6%			
	Water Retention		+0.4%	–0.04%	–0.1%	–0.2%	+0.05%		
	Erosion control		+0.2%	+0.2%	–0.1%	+1.6%			
	Soil retention		+17.8%	–8.3%	+9.6%	–4.0%			
	NO_2 Removal	+0.8%							
	Urban Green	+1.2%							
	Net ecosystem productivity		+9.2%	+9.2%	+9.6%	+10.3%	+11.0%	+10.3%	
	Crop production deficit		+0.5%						
	Habitat Quality	–0.9%							
Cultural	Recreation opportunity	+3.5							
	Special protection area	+87.7							
	Site of community importance	+63.4							

3.3.3 Trends in the status of ecosystem service per country

In Annex 3 of this report, we present 28 country profiles based on the same data that were used to report at the EU level. The percent change for ecosystem extent and for most ecosystem service indicators between 2000 and 2010 is given for each country as well as a synthesis of the main trends. Due to some potential errors with the area of SPA's and SCI's these two indicators are not reported but in principle all EU countries are expected to have an increasing area of sites covered by the Natura 2000 network.

Table 9 summarizes per country the main trends for ecosystems and ecosystem services. The following general trends are observed between 2000 and 2010 in almost all EU Member states:

- Urban areas are expanding.
- There is an increase of biomass in forests and cropland. Consistently, net ecosystem productivity is increasing.
- Organic farming gains in importance.
- The total number of livestock (cattle, goat and sheep) is decreasing.
- The use of water did not increase but stabilized or slightly decreased.
- Gross nutrient balance for nitrogen is decreasing but despite this positive trend, there remains a surplus in all EU countries which means that input of nitrogen is higher than output.

The country profiles reveal sometimes conflicting results: The direction of change of land cover (forest and cropland) is not always consistent with reported data on timber stock or used agricultural area, which are reported to Eurostat. Likewise, fodder crops increased everywhere whereas livestock which typically uses pastures in summer were decreasing. These trends are difficult to interpret and at several occasions mixed patterns emerge. They require discussion with national experts who have much better insights for explaining (or rejecting) the trends we report here.

A more in depth assessment of what underlying factors and processes cause the differences between countries was not possible when preparing this report. A visual inspection of the different country profiles published in Annex 3 suggests that countries can be grouped based on the direction of change of the different indicators. A clear divide seems to exist between countries with increasing farmland and decreasing forest versus countries with decreasing agricultural areas but increasing forest. Changes in these ecosystem types provoke corresponding changes in ecosystem services which are delivered by these ecosystems but the direction of change is not always as expected. Croatia, in particular, exhibits an interesting profile. According to our results, Croatia, member of the EU since 1 July 2013, lost cropland and grassland while forests and heathland underwent strong growth between 2000 and 2010. As for ecosystem services, our results suggest increasing use of provisioning services while also trends of regulating and cultural services increased. Other countries with similar changes in land cover (increasing forest and decreasing farmland) typically result in tradeoffs among different services. One hypothesis is that that these differences among countries are related to the differences in current performance of ecosystems relative to the maximum sustainable level of total ecosystem service provision. To put differently, in countries where ecosystems are exploited at levels which are unsustainable, trade-offs between services would come to the surface whereas in countries where ecosystems are used at levels well under the maximum sustainable level of total ecosystem service provision such trade-offs remain under the surface and are not observed. Such assessment would need to define sustainable levels of ecosystem service provision. But, alternatively, analyzing the data on ecosystem services which are collected for the purpose of this report against a gradient of human appropriation of ecosystems could help understand different patterns observed among countries.

In any case, it appears that the picture at EU level is somewhat clearer which may be related to the use of aggregated data (Eurostat, FAO) as well as the continental modelling approach to assess several regulating services, which delivers comparable and consistent results for the different countries.

Some contradicting results warrant further research including also a better knowledge on import and export of ecosystem services to and from the EU including imports and exports of food and timber.

We thus stress the importance of the ongoing MAES assessments at national scale which should be based on better and more reliable data. We invite Member States to report potential errors in our analysis and to confront our assessment with nationally based data and models.

Table 9. Summary of the country profiles (Figures with changes are included in Annex 3).

Country	Trends in ecosystems	Trends in ecosystem services
Austria	Austrian forest area grew by almost 3% at the cost of grassland, heathlands and cropland. Urban areas increased steadily.	Enhanced net ecosystem productivity and general increase in biomass of crops and forests while several regulating ecosystem services decreased. Pollination potential dropped considerably.
Belgium	Increments in cropland and urban areas and negative trends in forests and semi-natural areas.	Increased production of several provisioning services. Strong growth of area under organic farming. Notable increment for pollination potential and net ecosystem productivity.
Bulgaria	Cropland area decreased with almost 3%. Growth of heathland, shrubs and forest. Urban area expanded as well.	Increased agricultural output and strong growth of land under organic farming. Notable increment of soil retention values. Enhanced net ecosystem productivity but losses in NO_2 removal and pollination.
Cyprus	Expansion of urban areas and forests. Losses of cropland, grassland and heathland.	Outspoken trends in ecosystem services. Strong growth or organic farming and pollination potential but losses habitat quality and soil retention.
Czech Republic	Expansion of urban land, grassland and heathland. Negative trends for forest and cropland.	Positive evolution of area under organic farming and soil retention. Decreased pollination potential

Country	Trends in ecosystems	Trends in ecosystem services
Germany	Expansion of cropland, forests, heathland and sparsely vegetated land.	Important growth of net ecosystem productivity and forest carbon potential. Increment of area under organic farming and forest area with protective functions. Status quo, slight decrease or notable increase for many ecosystem services.
Denmark	Substantial loss of agricultural area in favor of forests and woodland	Positive trends for many ecosystem services.
Estonia	Moderated urban growth. Losses in farmland in favor of forests and semi-natural areas.	Conflicting trends between land cover land use and reported statistics on provisioning services. Moderated growth in a number of regulating and cultural services.
Spain	Expansion of urban areas lower than expected. Substantial increase in forest and woodland but losses in cropland and heathland	Loss in pollination potential but growth of several other regulating services. Increment in recreation opportunity.
Finland	Growth of woodland and forest at the cost of cropland. Slow growth of urban areas.	Built up of biomass (timber, crops, ecosystem productivity) but lower area reported as forest with protective functions. Significant increase in recreation opportunity
France	Conflicting trends between land cover changes and reported indicators. Important increment of urban area.	Slight decreases or status quo for many indicators but higher area under organic farming, increasing timber stock, and more area of forest with protective functions.
Greece	Increasing heathland and forest areas while cropland and grassland decreased.	Drop in different crop production categories and timber removal. Reported increases in organic farming.
Croatia	Strong growth of forest and semi-natural area and losses for cropland and grassland	A very particular profile emerges. Higher production of crops and timber; increased water use and positive trends for most regulating and cultural ecosystem services.
Hungary	Cropland loss and afforestation. Moderate growth of urban areas.	Increased provisioning services including higher water use and mixed trends in regulating services.
Ireland	Increasing cropland and forest area and a significant loss of grassland. But the positive trend in cropland is not reported by Eurostat.	Outspoken positive and negative trends in ecosystem services. Higher pollination potential is likely coupled to increased crops which supply foraging resources.
Italy	Losses in cropland and grassland while increases in forests. Growth of urban areas.	Shifts in crop categories under constant total production. Decreases in water usage. Both positive and negative trends in regulating services but the decrease in air quality regulation suggests loss of urban green areas.
Lithuania	Important gains of woodland and forest in balance with losses of grassland and to a lesser extent cropland. Slow urban growth.	Biomass built up in agriculture and in forests. More sustainable water use. Positive trends for several ecosystem services.

Country	Trends in ecosystems	Trends in ecosystem services
Luxembourg	Important growth of urban area and strong loss of cropland.	Status quo or increases for several services but notable loss of habitat quality
Latvia	Notable afforestation.	Strong growth of area under organic farming. Increment of several regulating and cultural ecosystem services.
Malta	High rate of urban area increment. Forest and cropland grew. Heathlands are taken.	Production increments for forest and agricultural products and for several ecosystem services. Some values are uncertain due to errors that arise from using models with an inappropriate spatial resolution relative to the size of the island.
Netherlands	Increments of urban land and forest, loss of grassland.	Improvements for several services relative to 2000.
Poland	Relatively small changes.	Increasing biomass built up and slightly negative trends several services.
Portugal	Substantial loss of cropland but strong growth of forest	Agricultural intensification with higher yields on less area. Reported data suggest more sustainable water use in agriculture and industry. Varying trends for regulating services.
Romania	Cropland and grassland show positive trends but forest area decreased. Contradiction with the trend in agricultural area.	Strongly increased agricultural production which trades off with several regulating ecosystem services.
Sweden	Gains in forest and woodland but losses in cropland.	Doubling of area under organic crop production. Increasing harvests of crops and round wood. Higher ecosystem productivity but losses of pollination potential and habitat quality.
Slovenia	Succession from heathland to forest but no trends in cropland	Varying trends but in general a positive profile with increasing regulating services.
Slovakia	Considerable growth of urban area and loss in forest and woodland which contradicts the direction of other forest indicators.	Increased production of crops on less area suggestion more intensive use. Negative trends for pollination and habitat quality.
United Kingdom	Notable loss of grassland and increasing heathland and shrub.	Varying trends in ecosystem services with a notable increase of crops which require pollination.

3.4 Mapping ecosystem services

This report also acts as a reference for a set of maps of ecosystem services, in particular for those ecosystem services which were modelled using the spatially explicit ESTIMAP model.

Other indicators that were available at national scale were downscaled to the 10 km grid using the refined Corine Land Cover layer 2006 (*8*). Downscaling was area based. For example, total national timber removal was downscaled to every 10 km grid cell by taking the ratio between the total area of forest in the cell and the total area of forest in the country. The national timber removal was then multiplied with this ratio to derive a removal estimate for the cell. Table 10 identifies the land cover classes that were used to assess the surface area per cell and per country for every indicator which was downscaled.

Thumbnails of the all the maps are presented in Figure 11 and Figure 12. Larger versions are printed in Annex 4.

Clearly downscaling nationally aggregated statistics is subject to uncertainty about the actual cell values. Dick *et al.* (*22*) present a cross-scale analysis of ecosystem services identified and assessed at local and European level based on a previous set of ecosystem service maps (*23*). Importantly, the analysis showed that the different sites form similar type of clusters when subject to multivariate ordination. Regression analysis of selected locally derived versus European based indicators for ecosystem services suggested that after downscaling between 20% and 30% of the variance is maintained. Despite the low explained variance, this research still provides an encouraging result. As more effort and research is focused on these areas it seems likely that data sets generated at different spatial scales and using different types of data will complement one another and converge on a coherent message regarding the health of global ecosystems and the benefits they confer upon society.

In some cases, e.g. for area of forest with protective functions, the maps based on downscaled statistical data reveals large differences between countries. These differences effectively originate at country level and are reported as such in the Eurostat database. Here we can, however, not provide a justification for large differences among countries.

For local to regional assessments of ecosystem services, users of these downscaled maps are therefore advised to investigate if more accurate information is available.

For indicators based on the ESTIMAP model (pollination potential, water retention, recreation, erosion control, habitat quality) we are more confident about the mapped cell values and we argue they can be used for regional to national assessments if no other spatial information is available.

Yet, we contributed to a recent study (*24*) who made a systematic review and quantitative comparison of ecosystem service maps on the European scale to generate insights in the uncertainty of ecosystem service maps and discuss the possibilities for quantitative validation. One conclusion was that different approaches diverge on mapping hotspots of ecosystem services. Maps of climate regulation and recreation were reasonably similar while large uncertainties among maps of erosion protection and flood regulation were observed. Pollination maps had a moderate similarity. Differences among the maps were caused by differences in indicator definition, level of process understanding, mapping aim, data sources and methodology. Caution is therefore needed when applying ecosystem service maps for decision-making.

The maps which are published in this report can be requested to the authors and will also be made available on the Ecosystem Services Partnership Visualiation tool (*25*) where they can be downloaded as either raster (geotiff) or vector (shapefile). The authors are interested in comparisons with other studies across spatial scales so as to improve the present maps and reduce uncertainty.

Table 10. Surrogates for downscaling aggregated statistical data.

Surrogates	Land cover classes used for downscaling (CLC label 3)	Downscaled indicators
Industry	Industrial or commercial units Road and rail networks and associated land Port areas Airports	Water abstraction for industrial use
Crops	Non-irrigated arable land Permanently irrigated land Rice fields Vineyards Fruit trees and berry plantations Olive groves Pastures Annual crops associated with permanent crops Complex cultivation patterns Land principally occupied by agriculture, with significant areas of natural vegetation	All crop related statistics (food crops, fodder crops, textile crops, energy crops, pollination dependent crops, and the area under organic farming) Water abstraction for agricultural use
Timber	Agro-forestry areas Broad-leaved forest Coniferous forest Mixed forest	Timber related statistic (Timber standing stock and Timber removals)
Population	CLC population map aggregated at 1 km	Water abstraction for public use
Nitrogen	Non-irrigated arable land Permanently irrigated land Rice fields Pastures Complex cultivation patterns	Gross nitrogen balance
Livestock	Pastures	Grazing livestock

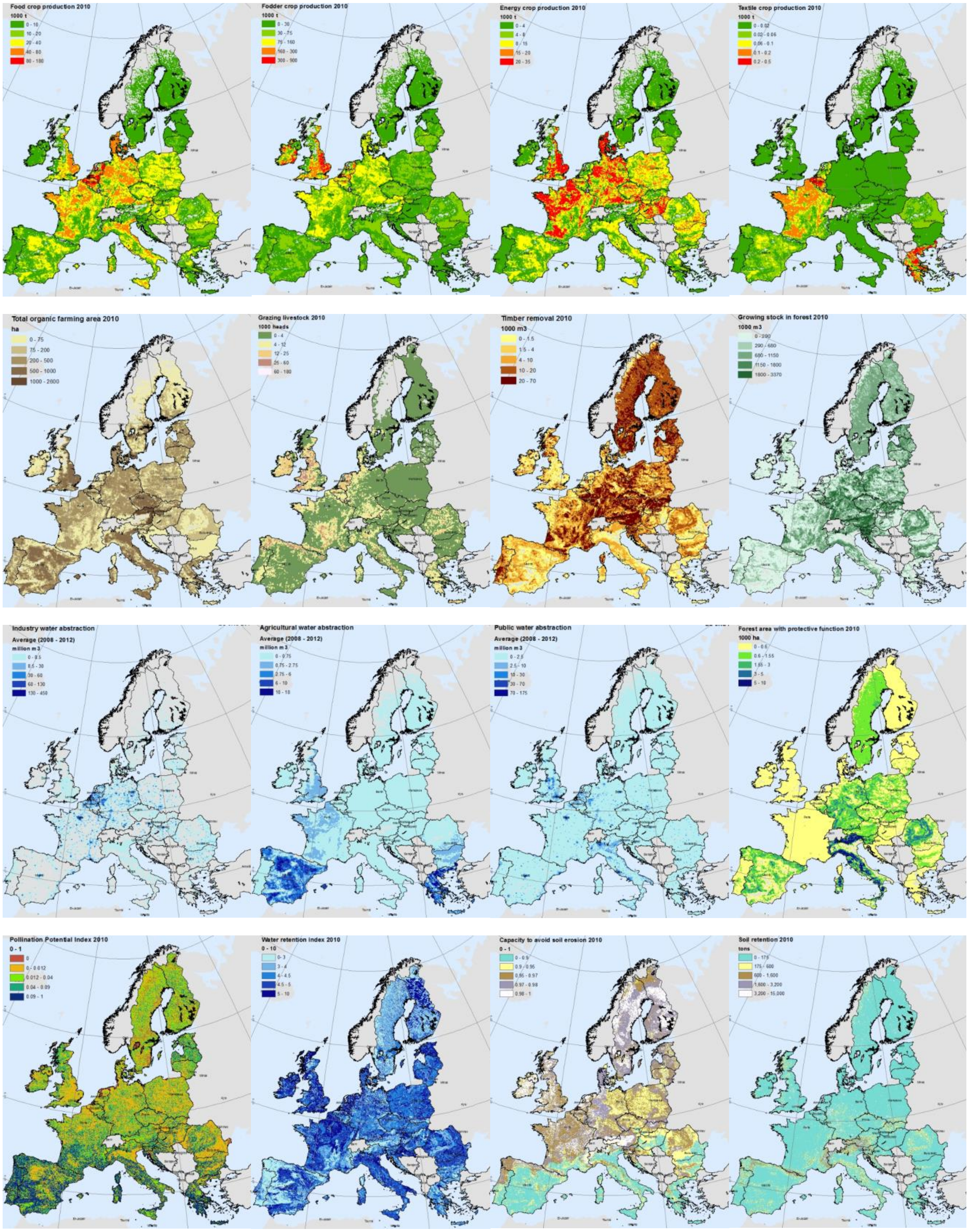


Figure 11. Mapped ecosystem service indicators (Large maps in Annex 4)

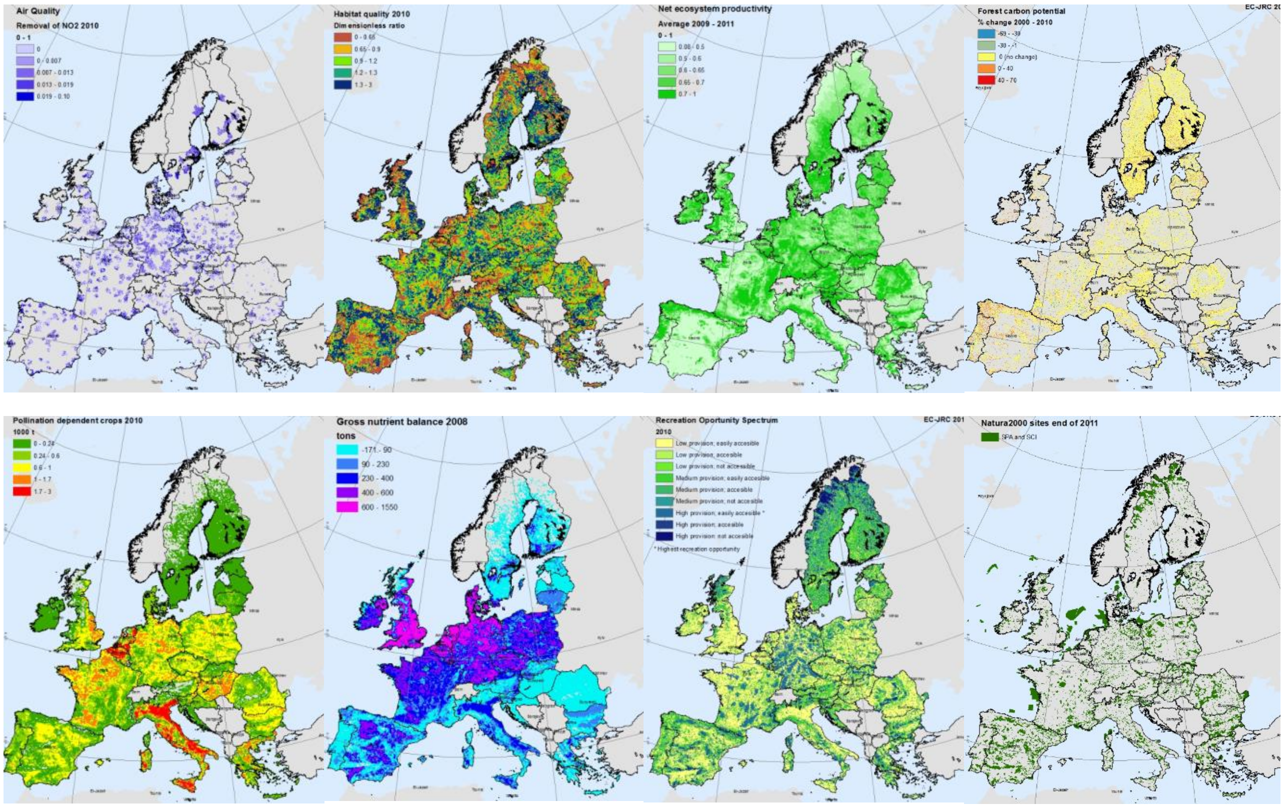


Figure 12. Mapped ecosystem service indicators (Large maps in Annex 4)

4 Discussion

A recent assessment of biodiversity and ecosystem services at the global scale (*26, 27*) revealed that based on current trends, pressures on biodiversity will continue to increase at least until 2020, and that the status of biodiversity will continue to decline. Habitats important for ecosystem services, for example wetlands and forests, continue to be lost and degraded. Analysis of the major primary sectors indicates that drivers linked to agriculture account for 70 per cent of the projected loss of terrestrial biodiversity.

Still there is room for a positive message as well. Of the 55 indicators used in the global biodiversity outlook to assess progress to the 20 Aichi biodiversity targets, the large majority (38) shows a positive trend, although reaching the targets would require increasing efforts. Five indicators show a trend which moves away from the target; 10 do not show a trend while 2 were not evaluated. In general, indicators which measure the societal response to biodiversity loss show positive trends but several indicators which assess the pressures and state on biodiversity continue to decrease. One reason for this difference could be that it takes several years, if not decades, before increased responses translate in positive changes to the state of biodiversity and ecosystems.

Global targets 14 and 15 on ecosystem services and restoration show a varied picture. The GBO4 report recognizes that there is high variation across ecosystems and services with no clear progress at the global scale. Yet this conclusion is based on scattered evidence, not on a systematic assessment of ecosystems and their services.

Global targets 14 and 15 are equivalent to target 2 of the EU Biodiversity Strategy to 2020 which aims to maintain and enhance ecosystems and their services by establishing green infrastructure and restoring at least 15 % of degraded ecosystems. This assessment can be used as a first piece of evidence to measure the trends of ecosystems and their services. We believe that it is the first, systematic assessment of ecosystem services performed at this scale using quantitative data.

Based on the available data we found positive trends in several ecosystem services which are presumably driven by a complex interaction of changes in agricultural production, afforestation, higher ecosystem productivity and increased protection of nature.

Many provisioning services show increasing trends. More crops are produced on less arable land which suggests that cropland is used more intensively. Also organic farming gains importance but the area under organic farming represents only about 5% of all utilized agricultural land in the EU. More timber is removed from forests with increasing timber stocks. The built up in biomass from crops and timber seems to be detectable from earth observation sensors. Net ecosystem productivity (and thus also net primary production) is rising.

The increasing extent of forests, driven by land abandonment and the demand for biofuels, has, evidently, positive influences on ecosystem services which are delivered by trees, woodland and forest. Trees in cities, patches of forest in agricultural land or forests help control erosion, store carbon, regulate water flows, improve air quality and are important to sustain recreation. Indicators for these services remained stable or showed upward trends with higher values in 2010 than in 2000.

From our assessment, it is not clear what the role of nature protection is to explain the increases in the aggregated supply of ecosystem services at EU scale. In the EU 17% of the land is reserved for nature protection and the Natura 2000 network is estimated to provide economic benefits worth hundreds of billions of euro annually (*28*). Yet, it is also significant to observe that the trends of two ecosystem services indicators which are directly related to biodiversity, pollination and habitat quality, are worsening.

A recent review of the scientific literature (*29*) concluded that most reported relationships between biodiversity attributes (such as species richness, diversity and abundance) and ecosystem services were positive. Yet, these relationships are usually not included in ecosystem services models or they cannot be inferred from statistical data. The absence of indicators which link biodiversity to ecosystem services in our study remains a weakness and justifies more research efforts. Therefore this report has published a series of maps which come at different spatial resolution and which can be used for a more in depth analysis of spatial relations between biodiversity, ecosystem condition and ecosystem services. Such an analysis is necessary to help define priorities for the restoration of ecosystems in the EU.

In addition, there remain a number of alternative assumptions to explain the trends revealed in this report.

Shifting baseline: The increase of several ecosystem services in the EU is only relative (Figure 13). In absolute terms, the EU has gradually lost many important ecosystems such as wetlands, grasslands and semi-natural vegetation which are essential service providers. In particular regulating and maintenance services have decreased while provisioning services such as crops and timber continue to increase.

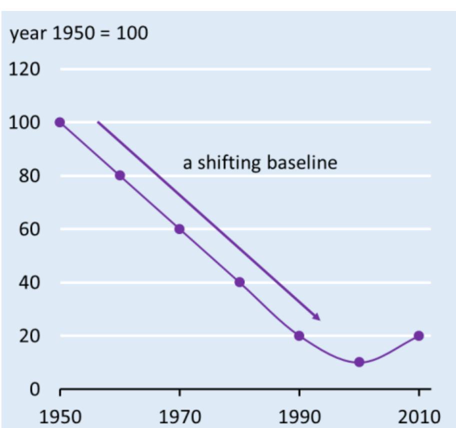


Figure 13. Truly increasing ecosystem services?

Historical data on land cover and land use changes may be a valuable source to assess whether or not ecosystem services have undergone significant change over the last 6 decades (Figure 13). Reconstruction of historic land cover and land use does suggest indeed that Europe is much greener today than it was 100 years ago (*30*). The same patterns emerge as reported here: afforestation, urbanization (in combination with land abandonment) and decreasing cropland area which is more intensively used. Caution must be paid, however, when using ecosystem service models (including matrix approaches) to assess historic trends. Such models are often based on land use and land cover and tend to give high scores to the relative role of forest in supplying ecosystem services and would thus reinforce the trend that we report here.

Biased indicators. Despite of the recent advancements in ecosystem services research, the selection of indicators to map and assess trends of ecosystem services is biased towards provisioning services delivered by forest and cropland or towards available information which results in a partial picture of the state of ecosystems and the trends of, in particular, regulating and cultural services. Table 4 reveals too many services for which no suitable indicator is found. Wetlands, for example, were largely ignored in this study while these ecosystems deliver many services at high quantities. For now, we have to assume that trends in serviced delivered by wetlands can be assessed using changes in their extent, which, in turn, are likely underestimated in this report due to a lack of high resolution land cover data.

Similarly, urban systems and soil ecosystem services are somewhat overlooked but they will be subject of collaborative research in the framework of the MAES working group activities planned for 2015. Whereas substantial improvements on urban systems (e.g. (*31*)) and soil services (e.g. (*32*)) can be reported, it remains challenging to find data that can indicate changes of time.

Clearly, a more complete analysis including more indicators which report over a longer time period and which also capture the demand site of ecosystem services will be needed to see if the conclusions of this first assessment of ecosystems and their services at EU scale will be confirmed or rejected. An important role is foreseen for the IPBES regional assessment of biodiversity and ecosystem services which will start in 2015. Both this report but also the continued efforts of the MAES working group as well as the contributions of EU funded research on ecosystem services will serve as crucial inputs to the IPBES assessment.

This report is an important step towards a more comprehensive assessment of ecosystem services at European scale. Several questions remain unanswered which require a more in-depth assessment of the data that were used in this study in combination with additional data on biodiversity and the condition of ecosystems. The indicators used in this study report the supply or use of ecosystem services. A subsequent analysis needs to compare the results of this study with indicators which measure the demand for ecosystem services to test whether or not ecosystem services are used at sustainable levels. This sustainability perspective needs to be incorporated to avoid a simplistic use of the different indicators. Importantly, there is an urgent need to identify the synergies and trade-offs that exist between ecosystem services and ecosystem condition to support biodiversity policy and to prioritize restoration efforts.

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Annex 1. Cross walk tables between the MAES ecosystem typology and different land cover land use datasets.

Table A1.1. Cross walk table between the MODIS derived IGBP Type 1 classes and the MAES ecosystem types.

IGBP (Type 1)	MAES ecosystem types
Water	**Rivers and lakes**
Evergreen Needleleaf forest	**Woodland and forest**
Evergreen Broadleaf forest	**Woodland and forest**
Deciduous Needleleaf forest	**Woodland and forest**
Deciduous Broadleaf forest	**Woodland and forest**
Mixed forest	**Woodland and forest**
Closed shrublands	**Woodland and forest**
Open shrublands	**Heathland and shrub**
Woody savannas	**Grassland**
Savannas	**Grassland**
Grasslands	**Grassland**
Permanent wetlands	**Wetlands**
Croplands	**Cropland**
Urban and built–up	**Urban**
Cropland/Natural vegetation mosaic	**Cropland**
Snow and ice	**Sparsely vegetated land**
Barren or sparsely vegetated	**Sparsely vegetated land**

Table A1.2. Cross walk table between the LUCAS land cover classes and the MAES ecosystem types.

LUCAS land cover types	MAES ecosystem types
Artificial Land	Urban
Cropland	Cropland
Woodland	Woodland and forest
Shrubland	Heathland and shrub
Grassland	Grassland
Bare land and lichens/moss	Sparsely vegetated land
Water areas	Rivers and lakes
Wetlands	Wetlands

Table A1.3. Cross walk table between the Corine Land Cover, the LUISA land use model and the MAES ecosystem types.

Corine Land Cover classes (Label 3)	LUISA classes	MAES ecosystem types
Continuous urban fabric	Urban fabric	Urban
Discontinuous urban fabric	Urban fabric	Urban
Built–up Low Density (*)	Urban fabric	Urban
Touristic and leisure built–up (*)	Urban fabric	Urban
Industrial or commercial units	Industry and related uses	Urban
Road and rail networks and associated land	Infrastructure	Urban
Port areas	Infrastructure	Urban
Airports	Infrastructure	Urban
Mineral extraction sites	Infrastructure	Urban
Dump sites	Infrastructure	Urban
Construction sites	Infrastructure	Urban
Green urban areas	Urban green leisure	Urban
Sport and leisure facilities	Urban green leisure	Urban
Non–irrigated arable land	Arable	Cropland
Permanently irrigated land	Arable	Cropland
Rice fields	Arable	Cropland
Vineyards	Permanent crops	Cropland
Fruit trees and berry plantations	Permanent crops	Cropland
Olive groves	Permanent crops	Cropland
Pastures	Pastures	Grassland and heathland
Annual crops associated with permanent crops	Arable	Cropland
Complex cultivation patterns	Arable	Cropland
Land principally occupied by agriculture, with significant areas of natural vegetation	Arable	Cropland
Agro–forestry areas	Permanent crops	Cropland
Broad–leaved forest	Forests	Woodland and forest
Coniferous forest	Forests	Woodland and forest
Mixed forest	Forests	Woodland and forest
Natural grasslands	Natural land	Grassland and heathland
Moors and heathland	Natural land	Grassland and heathland
Sclerophyllous vegetation	Natural land	Grassland and heathland
Transitional woodland–shrub	Transitional woodland–shrub	Woodland and forest
Beaches, dunes, sands	Other nature	Sparsely vegetated land
Bare rocks	Other nature	Sparsely vegetated land
Sparsely vegetated areas	Other nature	Sparsely vegetated land
Burnt areas	Other nature	Sparsely vegetated land
Glaciers and perpetual snow	Other nature	Sparsely vegetated land
Inland marshes	Wetlands	Wetland
Peat bogs	Wetlands	Wetland
Salt marshes	Wetlands	Marine
Salines	Wetlands	Marine
Intertidal flats	Wetlands	Marine
Water courses	Water bodies	Rivers and lakes
Water bodies	Water bodies	Rivers and lakes
Coastal lagoons	Water bodies	Marine
Estuaries	Water bodies	Marine
Sea and ocean	Water bodies	Marine

(*) only in Corine Land Cover 2006 refined

Annex 2. Descriptions of the indicators based on the ESTIMAP model

Eight ecosystem services indicators were modelled using ESTIMAP, the JRC's model for mapping ecosystem services: removal of NO_2 by urban forest, water retention, pollination potential, capacity for erosion control, soil retention, habitat quality, forest carbon potential, and recreation opportunity. ESTIMAP contains also a module on coastal protection but this model was not used in this study.

This annex contains for every indicator the reference where more detailed information can be found. Some indicators are recently developed for the purpose of this report and for application in impact assessment studies which JRC has undertaken in 2014. Some work is submitted while for other indicators separate reports will be produced. We cannot provide all technical details in this report but we provide a limited description of each model.

An application of ESTIMAP with a brief description of the different indicators can be found in Maes et al. (2014).

Reference:

Maes, J., Barbosa, A., Baranzelli, C., Zulian, G., Batista e Silva, F., Vandecasteele, I., Hiederer, R., Liquete, C., Paracchini, M., Mubareka, S., Jacobs-Crisioni, C., Castillo, C., Lavalle, C., 2014. More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe. Landscape Ecology, 1-18.

Pollination potential

The relative pollination potential index is fully documented in a technical JRC report by Zulian et al (2013) and in an article by Zulian et al. (2014).

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Share of easily accessible high quality nature in the recreation opportunity spectrum

Zulian et al (2013) describe in detail the recreational opportunity spectrum. Furthermore, the indicators is also presented in an article by Paracchini et al. (2014).

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Capacity of ecosystems to avoid soil erosion and soil retention

1. Identification (title; code) and classification (DPSIR; typology)

Erosion control service in ecosystems is determined in the framework of ESTIMAP project by means of two indicators (Guerra et al. 2014):

- Capacity of ecosystems to avoid soil erosion
- Soil retention

DPSIR: indicator of state

2. Rationale — justification for indicator selection; scientific references

Soil erosion is one of the major and most widespread forms of soil degradation in Europe. Despite the fact that erosion is a natural process, it can however be significantly accelerated by human activities such as agricultural practices, deforestation, overgrazing and construction activities. The major impacts are on the topsoil layer destroying the capability of the soil to provide economic or environmental services (EC, 1995). Moreover, future variations in the rainfall patterns due to climate change will also have an influence on soil erosion processes (IPCC, 2007).

In this context, soil erosion control is a key service supply by terrestrial ecosystems, mainly provided by vegetation cover. Erosion control is referred to the capacity of ecosystems to provide these regulating services and is quantify by means of the two indicators: soil retention and the capacity of ecosystems to avoid soil erosion.

3. Indicator definition — definition; units

Erosion control assessment is performed under the conceptual framework of the Revised Universal Soil Loss Equation aiming at quantifying this regulating service mainly addressed by two indicators.

The first dimensionless indicator measures the capacity of ecosystems to avoid soil erosion assigning values ranging from 0 to 1 at pixel level, covering the EU-28 territory for 2000 and 2010. This indicator is related to the capacity of a given land cover type to provide soil protection.

The second indicator, soil retention, is calculated as soil loss without vegetation cover minus soil loss including the current land use/cover pattern. In other words, soil retention (actual ecosystem service provision) is the difference between the structural impact and the mitigated impact, measured in ton ha^{-1} $year^{-1}$. Specifically, this indicator takes into account climate data (observed measurements for rainfall and modelled for snow), topographic aspects, soil properties and the presence or not of the vegetation cover.

4. Methodology (indicator calculation; gap filling; references)

Pan-European data sources, spatial analysis technics and LUISA (Land Use Integrated Sustainability Assessment) modelling platform have been used to model the soil retention and the capacity of ecosystems to avoid soil erosion at European scale in 2000 and 2010. The base map in LUISA for the simulation is the Corine Land Cover 2006 (refined version). Arable lands, permanent crops, pastures, natural vegetation and forest are the land uses/covers that are considered to have a major influence when assessing erosion control service of ecosystems.

Both indicators were implemented in LUISA according to the Revised Universal Soil Loss Equation (USLE/RUSLE) (Wischmeier, 1978; Renard, 1997). The parameters included in the USLE equation combine data on precipitation, soil properties, topography and land use/cover. USLE equation provides the conceptual framework for the estimation of soil losses and soil retention by applying the following equation:

$$A = R * K * L S * C * P$$

where A is the amount of soil loss ((t ha^{-1} yr^{-1}); R stands for rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}); K is the soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}; L is the slope length factor and S stands for slope factor (dimensionless); C is dimensionless vegetation cover factor; and dimensionless P refers to the soil conservation and management practice aimed at erosion control.

C and R factor are considered dynamic factors in LUISA since they will be projected to future time. However, P, LS and the K factors will keep static, as the studied period is not temporarily long enough to detect changes on the erodibility parameters and topography (driven by geological erosion). The lack of information of P factor leads us to keep this factor as static as well (assigned a constant value equal to 1).

To estimate the rainfall erosivity parameter we used observed precipitation values from the European Climate Assessment and Dataset (E-OBS) for 2000 and 2010 (ECA&D, 2014). The R-factor was estimated based on the MedREM model proposed by Diodato and Bellocchi (2010) for Mediterranean conditions. For each time slice, the rainfall erosivity factor was calculated using the following expression:

$$R_y = b_0 * P_y * \sqrt{d_{ymax}} * (\alpha + b_1 * L)$$

where, Ry (MJ mm ha^{-1} h^{-1} y^{-1}) corresponds to the yearly rainfall erosivity for the year y (2000 and 2010), b_0 (MJ ha^{-1} h^{-1}) is a constant equal to 0.117, b_1 ($d^{0.5}$ $mm^{-0.50-1}$) is a constant equal to 2, α ($d^{0.5}$ $mm^{-0.50}$) is a constant equal to -0.015, L corresponds to the site longitude, P_y (mm y^{-1}) to the total amount of precipitation in a given year, and d_{ymax} (mm d^{-1}) to the annual maximum daily precipitation for year y averaged over a multi-year period of 10 years.

For the C factor, the procedure has certain complexity. To estimate the vegetation cover per land cover class, Corine Land Cover Map for 2006 was used (EEA, 2013) as a reference year .This was reclassified to a smaller number of land cover classes to be combined with the outputs from LUISA (Table A1.3). Then, vegetation cover was monthly estimated using the relation between the Normalized Difference Vegetation Index (NDVI; calculated from 2009 MODIS 16 days NDVI composites with a 250 meters pixel resolution) and the USLE C Factor (Wischmeier and Smith, 1978) proposed by Van der Knijff *et al.* (1999, 2000). Afterwards, using the environmental zones from Metzger et al. (2005) to stratify the original *C* Factor data, zonal statistics were calculated to obtain the average monthly value of *C* present in each land cover class. Then, a monthly snow cover data set (Dosio, 2011; Dosio,2012) was included to mask the obtained C factor. Finally, a yearly average of C factor was obtained for each reference year, 2000 and 2010, by averaging for each pixel the results obtained for every month, obtaining a composite spatial representation of vegetation cover for Europe.

In order to assess erosion control service of ecosystems it is needed an adaptation of the empirical USLE equation to provide four outputs under a conceptual ecosystem services framework (Guerra et al., 2014). Specifically, these four concepts are:

- Structural Impact is defined as the total soil erosion impact when any ecosystem service is provided. In soil erosion context, it is referred to the potential soil erosion including rainfall erosivity, soil erodibility and topography.
- Capacity for Ecosystem service provision is the fraction of the structural impact that is mitigated by the ecosystem service and it correspond to a dimensionless gradient varying from 0 to 1. In the ESTIMAP context, it is called as **capacity of ecosystems to avoid soil erosion**.
- Ecosystem service mitigated impact is referred to the remaining soil erosion after the ecosystem service provision, that is, the ecosystem capacity to provide a specific service (soil protection).
- Actual ecosystem service provision corresponds to the total amount of ecosystem service provided measured in ton ha^{-1} $year^{-1}$ (tons of soil not eroded). In the ESTIMAP context, it is called as **soil retention** understood as the modelled soil erosion with and without the presence of vegetation.

Methodology references:

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5. Data specifications - data references; external data references; data sources in latest figures

In order to carry out the erosion control assessment the following data sources were used:

- LUISA outputs (land use map): year 2010

- Corine Land Cover 2006 refined and Corine Land Cover 2000

- Observed climate data (precipitation for 2000 and 2010): ENSEMBLES project, E-OBS gridded dataset.

- Projections of snow data (from 1990 to 2050): JRC

- K erodibility factor: JRC

- LS factor: JRC

- Environmental Zones: Metzger et al., 2005

- NDVI index calculated from MODIS 250 m pixel images

6. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

This indicator is implemented in the LUISA modelling platform and this poses a certain degree of uncertainty not only due to the temporal simulation (from 2006 up to 2050) itself, but also to the limitations and uncertainties of the sectorial models used as inputs (e.g. to assess land demand) in the platform. Modelling land use/cover changes require a set of spatial explicit data and statistical data whose availability and resolution are limited. Data harmonization is required to make consistent the inputs and outputs in the model.

The methodology is based on an empirical equation (USLE/RUSLE) in order to quantify the soil erosion control service. This model contains different factors, which individually incorporate high uncertainties to the model outputs, especially at local level. One of the most influent factors in the equation is the rainfall erosivity factor (R-factor) whose spatial and temporal resolution may not be adequated to represent the impact of extreme rainfall. Other complex factor is the land cover factor (C-factor) due to two main reasons. Firstly, land use/cover maps are outputs modelled from LUISA and, secondly, the C-factor has been calculated using spatial data (e.g. snow cover projections) that might increase its degree of uncertainty.

Though there is a certain degree of uncertainty of the modelled indicators, soil retention and capacity indicator, due to the limitations of the applied methodology and data used, the assessment can offer valuable information at the European scale about the areas where erosion mitigation and prevention measures should be implemented.

7. Further work (short-term work; long-term work)

The limited availability of high-resolution data related to the different biophysical phenomena that are considered within the soil erosion model is furthermore hampering the calculation of its indicators at higher resolution. Improvements in the R and LS factors are expected in the near future.

Furthermore, the management practices factor (P-factor) needs further investigation due to the difficulty to find data on sustainable agriculture and soils conservation practices that are suitable to be modelled at local scale.

Water Retention Index

1. Identification (title; code) and classification (DPSIR; typology)

WRI

DPSIR: indicator of state

2. Rationale — justification for indicator selection; scientific references

In order to assess the potential amount of water retained in the landscape a complex soil-plant-atmosphere system model is needed. A composite indicator was developed to assess the capacity of the landscape to regulate and retain water passing through it. This indicator shows where there could be a deficit in the capacity of the landscape to retain water which, combined with rainfall extremes, could lead to higher flood risk or water scarcity.

Reference

Vandecasteele I., Mari Rivero I., Dreoni I., Becker W., Vizcaino P., Maes J., Lavalle C., Batelaan O., 2014: Potential Landscape Water Retention as an indicator for Water Quantity Regulation in Europe, submitted to Ecosystem Services Journal.

3. Indicator definition — definition; units

The indicator shows the spatial and temporal distribution of the landscape's capacity to capture water, reducing runoff. The Water Retention Index is a composite indicator, dimensionless, which takes into account the role of interception by vegetation, the water-holding capacity of the soil, and the relative capacity of both the soil and the bedrock to allow percolation of water. The influence of soil sealing and slope gradient are additionally considered.

4. Methodology (indicator calculation; gap filling; references)

The Water Retention Index (WRI) is a composite indicator which takes into account the retention (or storage) of water throughout the landscape. We assume the total landscape potential for water retention to be a function of the retention in vegetation (Rv), soil (Rs) and groundwater (Rg). We in addition take into account the impact of slope on the capacity to retain water, and correct the overall indicator for the share of sealed area (assumed to be impermeable). Both slope and soil sealing are limiting factors of the natural retention capacity, as actual retention should decrease with increasing share of sealed area and with increasing slope gradient. The WRI is computed as shown in figure 1, where grey boxes indicate the dynamic components. All parameters are given scores and combined in the composite indicator according to the available literature.

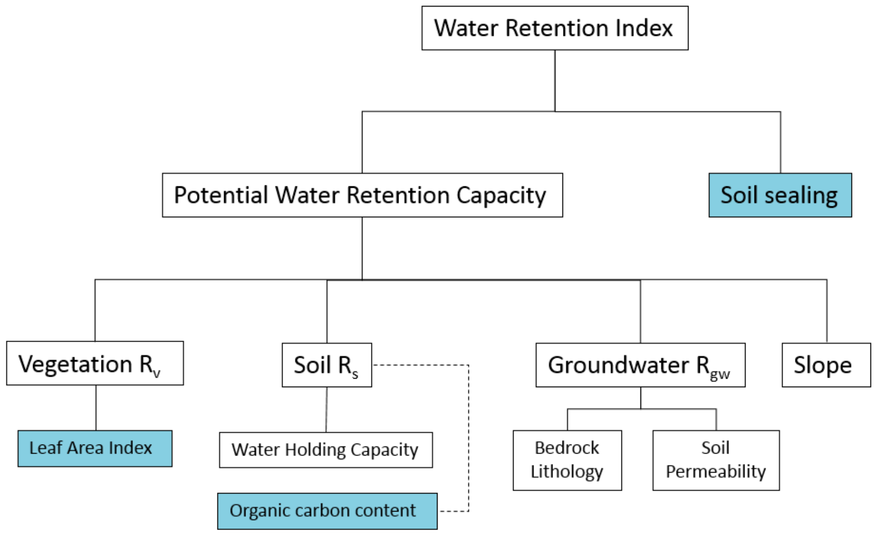

Figure 1. Schematic overview of the structure of the composite indicator. Parameters in grey are dynamic and updated based on land use.

All parameters are standardized and combined in the composite indicator. We performed a sensitivity analysis using an approach similar to that in Paruolo et al, 2013. We further adopted an optimisation procedure which iteratively adjusted the weights until the desired importance of each parameter was reached. The influence of each parameter on water retention capacity was taken to be equal, except for the slope factor, which was assumed to have a relatively lower impact. For this reason, the desired impact was assigned as half that of the other parameters. The structure of the WRI is:

$$WRI = (w1.Rv + w2.Rgw + w3.Rs + w4.Rslope).w5.(1- SS/100)$$

With w1 = 1.81; w2 = 0.22; w3 = 1.51; w4 = 0.2; w5 = 1.16

Processing is carried out at 100 m resolution and then aggregated to 1 km resolution, according to the lowest resolution of the input data.

To forecast the index from the base year 2006 to 2050, the Leaf Area index, the organic carbon content and the sealed areas are updated each 5 years. As in Van Dijk and Bruinzeel (2001), we assume that the canopy capacity, and therefore the potential amount of water intercepted, is linearly related to the leaf area index (LAI). The forecasted LAI (Rv), is re-computed directly from the average LAI values per land use class and per climatic zone (Metzger et al., 2005).

Both the soil organic carbon content and bulk density are influenced by changing land use typology over time (Bormann, 2007). We estimated the average expected changes in both parameters with land use conversions between cropland - grassland, and forests based on an extensive review of available literature (Bauer & Black, 1981; Bewket & Stroosnijder 2003; Breuer et al. 2006; Bronson et al. 2004; etc.). The resulting assumed changes are given in table 1. We therefore only used the changes in organic carbon content over time to update the Rs parameter, assuming a soil with a higher organic carbon content to have a proportionally higher water retention capacity.

Table 1. Estimated changes in soil bulk density and organic carbon content each 20 years.

Land use conversion	Assumed change in bulk density	Assumed change in OC
Crops to grassland	↓ 6.5%	↑ *5%*
Crops to forest	↓ 15%	↑ 15%
Grassland to crops	↑ 7%	↓ 20%
Grassland to forest	↓ 9%	↑ *10%*
Forest to crops	↑ 17%	↓ 35%
Forest to grassland	↑ 10%	↓ 15%

The soil sealing layer used is computed based on the average percentage soil sealing per land use class and per country. This means that the parameter can be calculated directly based on the simulated land use. The WRI can therefore be calculated for any year up to 2050 based on the updated land use map.

The relative permeability (Rgw) and the slope are static parameters. The first is based on the type of lithology present and its relative permeability. We assign estimated permeability scores for each major lithology based on the average of the range of permeabilities given by Domenico and Schwartz (1990), Gleeson et al. (2011), and Lewis et al. (2006). The European slope map we use is consistent with that used in the EUClueScanner model, as derived from the Global Digital Elevation Model (SRTM, NASA) (http://srtm.csi.cgiar.org/).

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5. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios: years 2010, 2020 and 2050
- Corine Land Cover 2006 refined
- Leaf Area Index: H08 IES-JRC
- Environmental Zones: Metzger et al., 2005
- Total Available Water Capacity: European Soil database (ESDB)
- Parent Material: ESDB
- Hydrological Class: ESDB
- One Geology dataset
- Cyprus and Austria geological surveys
- Slope: SRTM, NASA (used as DEM for the Land Use Model)
- Soil sealing: European Soil Sealing Map (EEA).

6. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty: The main limitation of the indicator is the lack of measured data to validate it. The methodology implies a certain degree of uncertainty. A composite indicator is a statistical representation of the studied phenomena and all data sets used will add errors to the final result. The forecasting methodology adds the uncertainties coming from the EUClueScanner model (LU maps), the assumptions taken to forecast the Rv and the soil sealing and the errors and limitations to forecast the total available water capacity in soil.

Dataset uncertainty: Each data set brings uncertainty. The land use scenarios, leaf area index and soil sealing lookup tables are at 100 m resolution, and are based on the outputs of the EUClueScanner model. The data sets used from the ESDB contain high uncertainty. These maps are computed by interpolating the measured points (LUCAS project) at 1km resolution. The One Geology project data sets used are also highly uncertain. However, it is the most complete lithology data available to date at European scale.

7. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

Removal of NO2 by urban vegetation

The calculation of the air purification model is based on the calculation of three different indicators: average concentrations of NO2, deposition velocity, and removal capacity. Those indicators are evaluated at European scale by using simple GIS map algebra operations. Each indicator is calculated as follows:

1. NO2 concentrations in 2000 and 2010:

Concentrations of NO2 were calculated using Land Use Regression (LUR) models. The LUR model was built using NO2 concentration for the monitoring sites located all along Europe used in the model as dependent variable, and several predictor parameters (independent variables) defined within a Geographic Information System (GIS). Either the input parameters as the output concentration maps were calculated and evaluated at 100m resolution.

A total of 1769 and 3035 monitoring sites for the year 2000 and 2010 respectively from the AirBase database (1) , were considered for the analysis. Those sites were meant to be representative of different type of areas (urban, suburban and rural sites) and different types of impact (or absence) of near-by emissions (industrial, traffic and background stations) according to the Guidance for the Implementing Decision on Air Quality Reporting (6) (2011/850/EU).

Regarding the predictor variables, some of them reflect sources or sinks for air pollution such as the road network, different types of land use and population density. Population density was also considered a proxy for traffic flow levels since no complete information on this is currently available. In addition, factors such as elevation, topographical exposure, distance to sea, annual mean temperature and annual mean wind speed, also influence the spatial concentration of pollutants and were included for the modelling. Table 1 includes the complete list of the parameters considered for the modelling and the source from where they were computed. Within all this predictor variables, only those related to land use and population density were variable along the years.

Because several of the independent variables influence at diverse spatial scales, by evaluating the correlation between each of the parameters at different scales (radius or buffer around the monitoring station evaluated from 50 to 1500 m every 50 m), and the measured NO2 concentrations, we selected the most relevant spatial radius as the one reporting the highest R2. Within this optimal radius, values of the original parameter were aggregated and resulting values were used as parameters for the LUR model.

Two different LUR modelling methods were compared: regression mapping and Random Forest (3) (RF). RF performed better than regression mapping (R^2 = 0,52 vs. 0.4) and also presents some advantages specific of the statistical method, among others; the possibility to rank variables based on their relative importance, the ability of RF to cope with highly correlated variables and the auto validation of the model by leaving some stations out of the analysis. For all these reasons RF was chosen for the final mapping of concentrations.

Table 1. List of the parameters.

Parameter type		Parameter name	Source 2010	Source 2000
Land Use		Urban	LUISA model [11]	CLC 2000: Based on Corine Land Cover [Vallecillo, S. 'Workflow_CLC2000_CLC2006_updates.docx'];(as described in this report under '2.1 Ecosystem typology and data sources')
		Infrastructures		
		Industry		
		Green Urban Areas (GUA)		
		Forest Agriculture		
		Main Roads	Teleatlas http://www.mapsharetool.com/external-iframe/external.jsp	Teleatlas http://www.mapsharetool.com/external-iframe/external.jsp
		Medium Roads		
		Minor Roads		
Physico-geomorpho-logical		Topographical exposure	Global digital elevation data based on the NASA Shuttle Radar Topographic Mission (SRTM) of 3 arc-second resolution [13]. Digital topographic maps for Scandinavian countries at different resolutions, [14]	
		Elevation		
		Coast distance	CLC 2000	
Climatological		Temperature	The European Commission Joint Research Centre (JRC). MARS daily data http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST/Data-distribution/AGRI4CAST-Interpolated-Meteorological-Data	
		Wind speed		
Population		Population density	LUISA model [11]	

2. Mapping Dry Deposition Velocity

In many studies (4, 9, 10) deposition velocities of the gaseous pollutants for the in-leaf season are estimated using a series of resistance formulas (11) that require specific information regarding the structure and composition of species of urban vegetation. Since this information was not available, the air pollution deposition velocity indicator was calculated following the approach proposed by Pistocchi (13), where deposition velocity depends on the wind speed at 10m and the land cover type, either forest or bare soil or water.

3. Mapping Air Pollution Removal

Annual removal capacity was estimated as the total pollution removal flux in the áreas covered by vegetation, where the removal flux is estimated as:

F= Vd x C where Vd is the deposition velocity of the pollutant to the leaf surface and C is pollutant concentration (ug m-3).

From the results obtained in previous paragraphs, total pollution removal flux was calculated for NO_2.

Areas covered by vegetation were calculated by combination of detailed maps of urban vegetation and forest, aggregated to 100 meter resolution. For urban vegetation, the green layers of the Global Human Settlement Layer (7, 7, 12) were used. For forests, the High Resolution Global Forest map developed by (8) was used. In overlapping areas, the maximum value of both maps was applied. Final map of vegetation had values between zero (no vegetation) and one (totally covered by vegetation). The final map of annual removal capacity was obtained multiplying this map and the estimated removal flux map.

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Forest carbon potential

Objective: To derive and compute an indicator for carbon stock and flows and to compute its variation between 2010 and 2000, in relation to the extent of forests within the European Union.

Input data

- Land-use / Land-cover:
  - 2000: Based on Corine Land Cover (as described in this report under '2.1 Ecosystem typology and data sources')
  - 2010: Simulated extent of 'forest' for 2010, obtained from the Land Use Modelling Integrated Sustainability Assessment Platform (LUISA).
- Bio-physical variables obtained for the 30-year period 1991-2020, from the Community Land Model (CLM) [1]. These data were produced during the EU-funded FP6 Integrated Project ENSEMBLES (Contract number 505539) using different regional climate models (RCM) applied to the SRES A1B IPCC scenario projections, with a spatial resolution of ca. 25 by 25 km.

Method

Carbon indicator: The indicator for Carbon stock and flow was generated using Bayesian Networks (BN), which allow modeling under uncertainty and integrating different types of probabilistic information. The nodes (i.e. 'variables') of the BN were represented by a selection of CLM outputs representing bio-physical structures and processes related to ecosystem functions. Figure 1 shows the network; table 1 describes the variables. The original CLM variables ('FROOTC', "ABOVEVEG", "TOTSOMC") were reclassified between 0 and 1 (0, 0.2, 0.4, …, 1), using Fisher intervals [2]. Nodes derived from 'FIRE_RISK' and 'C_Veg_Soil' were scored between 0 and 3. The final output was scored between -3 and + 3, with negative values indicating Carbon release.

Forest extent: Forest areas were the merged outputs of 3 Corine land cover classes (namely broad-leaved forest, coniferous forest and mixed forest). They were generated with a spatial resolution of

100 x 100 m for the extent of the European Union (EU) in 2014, therefore for 28 Member States (MS). We refer to this extent as 'EU28'.

Data processing: The main differences between the spatial definition of the BN inputs (from CLM) and the forest extent are:

Spatial resolution: 25 x 25 km for BN, vs. 100 x 100 m for forest;

Coordinate reference system: geographic coordinate system 'Latitude and Longitude' with Geodetic Datum WGS 1984 for BN, projected coordinate system 'Lambert Azimuthal Equal Area' (LAEA) with Geodetic Datum ETRS 1989 for forest.

The coordinate pairs from the CLM outputs were projected to the LAEA. Voronoi polygons were computed over the extent of the EU28, to establish a spatial relation between the two datasets. All computations were carried out at the spatial resolution of the forest layers (100 x 100 m). Since the CLM variables were based on one period (1991-2020), any difference in the outcome of the model is a consequence of changes in forest extent between 2010 and 2000.

Change detection: For each cell of a region of interest (i.e. a MS or the entire EU28) the change in CSS between 2010 and 2000 was defined as:

(CSS2010 – CSS2000)/3*100

Where:

- CSS2010 - CSS2000 is the difference between the scores of the indicator for 2010 and 2000, based on the extent of forest;
- 3 is the upper limit of the indicator.

Summary statistics were derived at the MS and EU28 scale:

- MS scale was the average of the change in each grid cell where in one or both periods (2010 and 2000) there was forest;
- EU28 was computed after applying the same procedure to the whole extent of EU28.

Table 1: Definitions and sources of the variables for the Bayesian Network (BN). 'ABOVEVEG', 'FROOTC' and 'TOTSOMC' were directly derived from the Community Land Model (CLM). 'FIRE_RISK' was generated after multiplying by 3 the CLM variable 'Probability of fire', to account for the importance of fire in relation to the other nodes. 'C_Veg_Soil' was an intermediate output of the BN.

Name	Definition	Source
ABOVEVEG	Above ground Carbon	CLM
FROOTC	Fine root Carbon	CLM
TOTSOMC	Total soil organic matter Carbon	CLM
C_Veg_Soil	Carbon in vegetation and soil	Generated from 3 parent nodes
FIRE_RISK	Risk of fire	Modified from CLM 'Probability of fire'
Carbon forest potential	Carbon storage and sequestration[12]	Output of the BN

[12] We do not differentiate between stock and flow; although three of the CLM variables are measured as gC/m^2 and therefore indicate a stock, they are computed over a defined time (month), subsequently averaged over 30-year simulations, and ultimately reclassified between 0 and 1 to allow the computation of the indicator. These transformations and the ones that follow from them move the indicator away from the original units of its input variables.

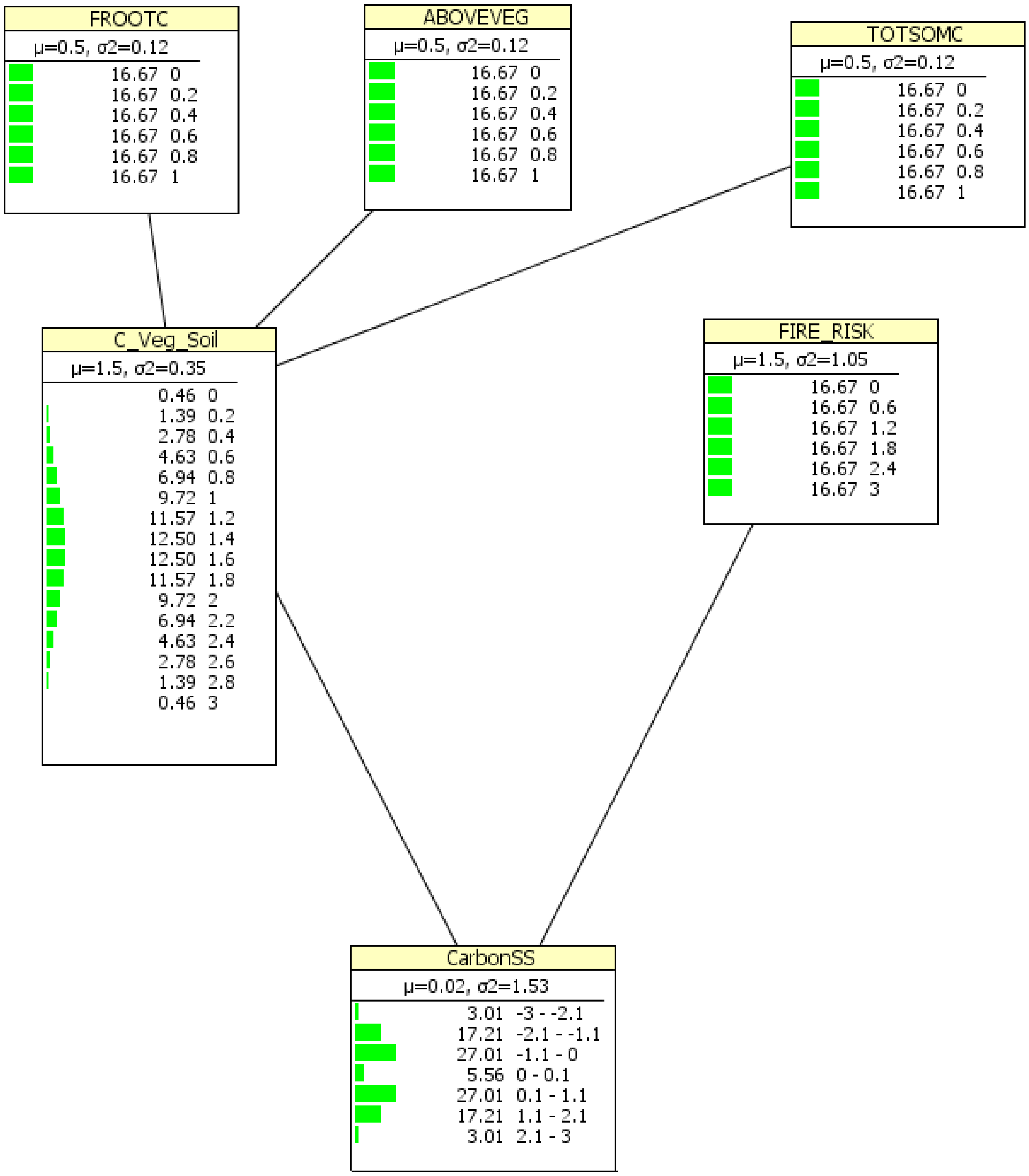

Figure 1: Representation of the Bayesian Network to estimate stock and flow of Carbon potential. Variables are defined in Table 1. Within each monitor window, bar charts and second columns represent initial conditions of the different scores. When the network is applied to a specific area (i.e. a grid cell of forest), these conditions reflect the probability of one or more scores for that particular area.

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Habitat quality based on common birds

Introduction

Common species are determinant of the structure, function and service provision by ecosystems, playing a key role in the regulation and maintenance of biological processes (Gaston, 2010). Common birds in particular are considered good proxies to measure the diversity and integrity of ecosystems as they tend to be near the top of the food chain, have large ranges and the ability to move elsewhere when their environment becomes unsuitable (Sekercioglu, 2006). Therefore, they are responsive to changes in their habitats and ecosystems at different spatial scales. In this context, the landscape shaped by the coexistence of different land uses and their changes through time at large spatial scales (i.e. European level) may significantly affect the suitability of habitats in a given region to maintain communities of common birds. Therefore, there is a need to develop a habitat quality indicator for this group of species to spatially explicitly assess the changes in habitat suitability at large spatial and temporal scales.

Methods

To develop the habitat quality indicator, we modelled species distribution of common birds, including the species listed in the European Common birds' indicator (Gregory et al., 2005; Eurostat, 2013). Data on bird species occurrences were obtained from the EBCC Atlas of European Breeding Birds (Hagemeijer & Blair, 1997). Species distribution models (SDM) were built by means of the maximum entropy method implemented in Maxent (Phillips et al. 2006) and downscaled at 10 km^2 resolution relying on an ecological basis. Within each polygon of the species range defined by the EBCC Atlas, we refined the species occurrence at grid cells of 10 km^2 resolution based on the species preferences for breeding habitats. It will allow a more detailed assessment of the land uses as drivers of species distribution changes. The methodology used is part of an unpublished work (Vallecillo et al. manuscript in preparation)

Since species richness maps, obtained from the overlay of SDM, show inherent spatial patterns due to the biogeography of the species considered in the analysis, we defined the species richness in relative terms as the ratio between the local species richness and the average species richness in the neighbourhood (i.e. in a 500 km diameter). This will allow overcoming the influence of the naturally heterogeneous patterns of species distributions at large spatial scales. Therefore, the relative species richness will be indicative of the capacity of ecosystems to provide suitable habitat for common bird communities and may be interpreted as a 'habitat quality indicator' (HQI). The HQI, as expressed in relative terms, allows making direct comparisons between regions. Those areas showing large values of the HQI are indicative of places with high relative species richness, becoming of special concern for the maintenance of nursery habitats for common birds.

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Gregory, R. D., A. J. van Strien, P. Vorisek, A. W. Gmelig Meyling, D. G. Noble, R. P. B. Foppen, and D. W. Gibbons. 2005. Developing indicators for European birds. Phil. Trans. R. Soc. Lond. B. 360:269-288.

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Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190:231-259.

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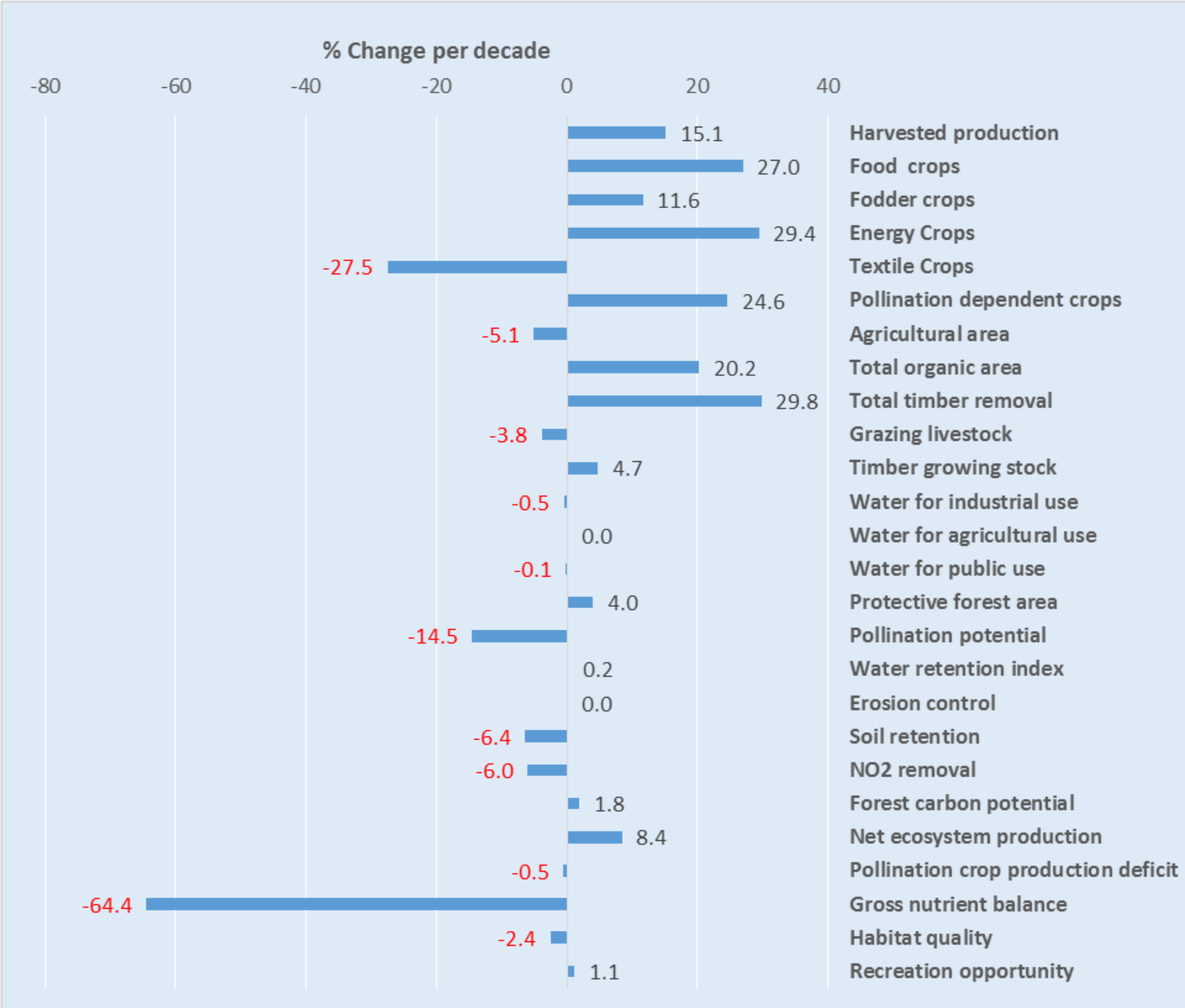
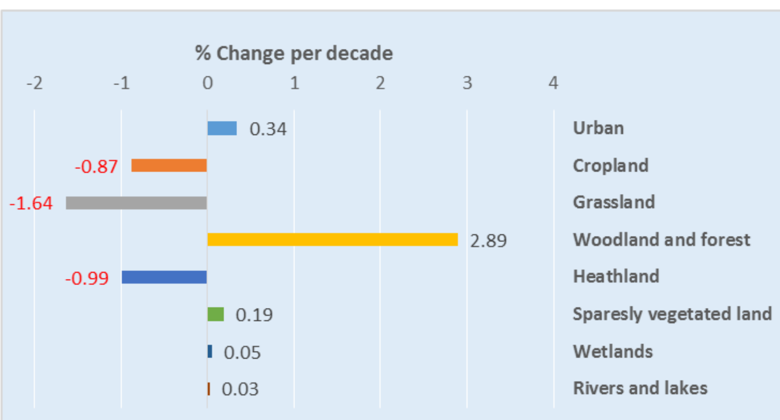
Vallecillo, S., Maes, J. Polce, C. Development of a habitat quality indicator based on species distribution models for common birds. Manuscript in preparation.

Annex 3. Country profiles

This annex present the country profiles. For each Member State of the EU the change in ecosystem extent and ecosystem services is presented.

AUSTRIA

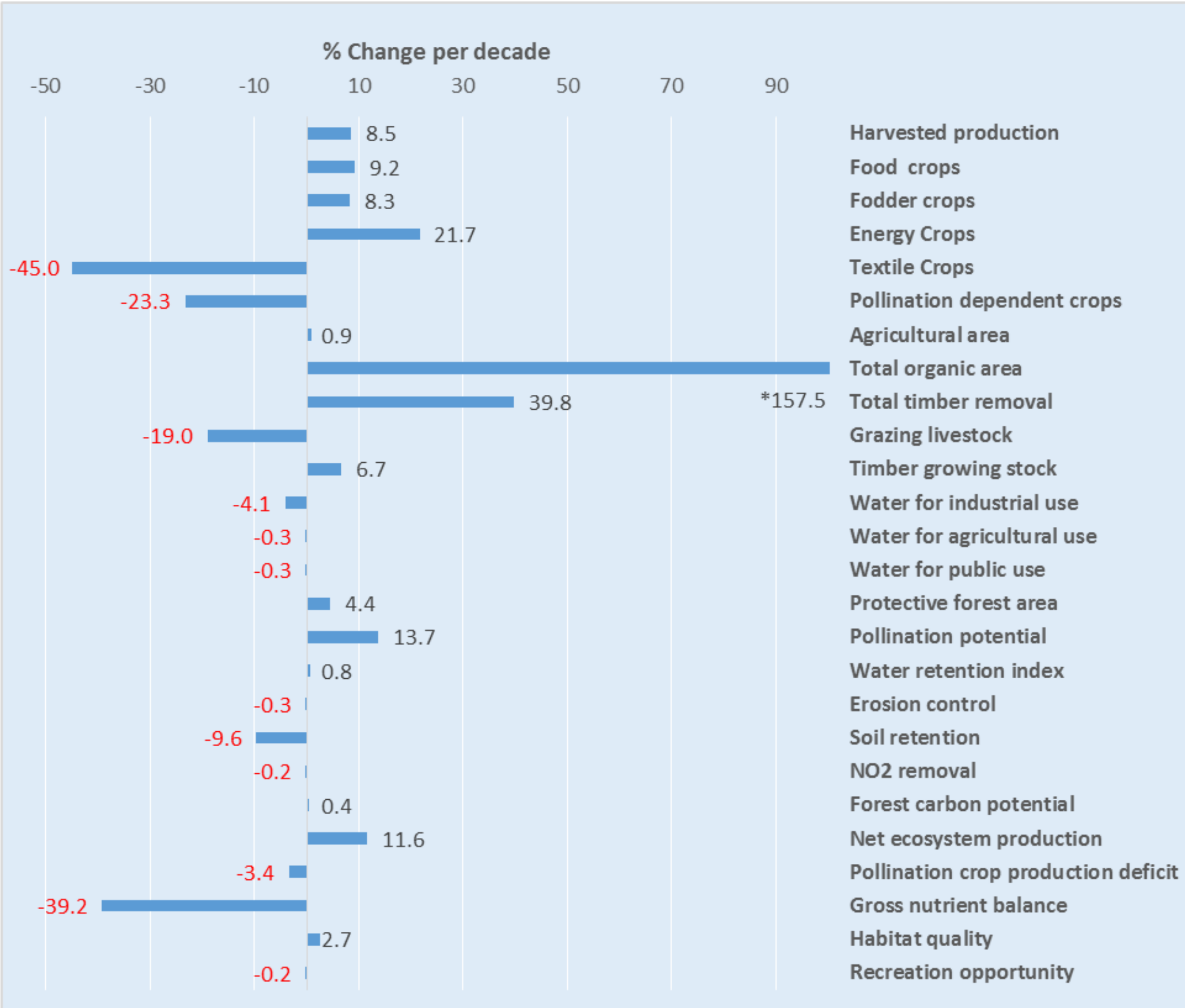


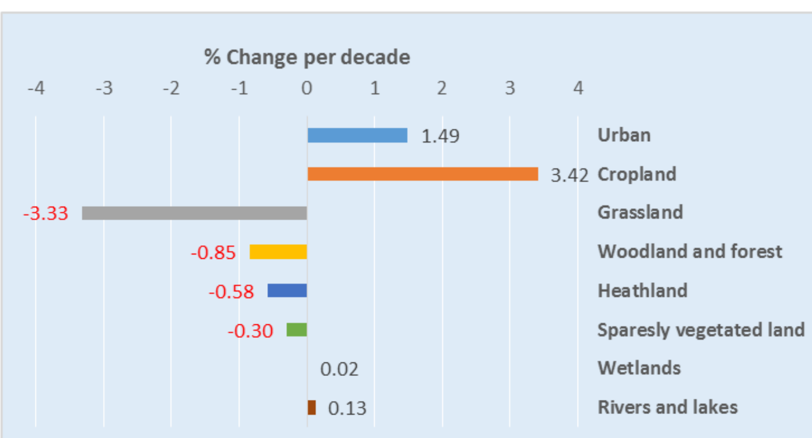


Trends in ecosystems:
Austrian forest area grew by almost 3% at the cost of grassland, heathlands and cropland. Urban areas grow steadily.

Trends in ecosystem services:
Enhance net ecosystem productivity and general increase in biomass from crops and forests while several regulating ecosystem services decreased. Pollination potential dropped considerably.

BELGIUM

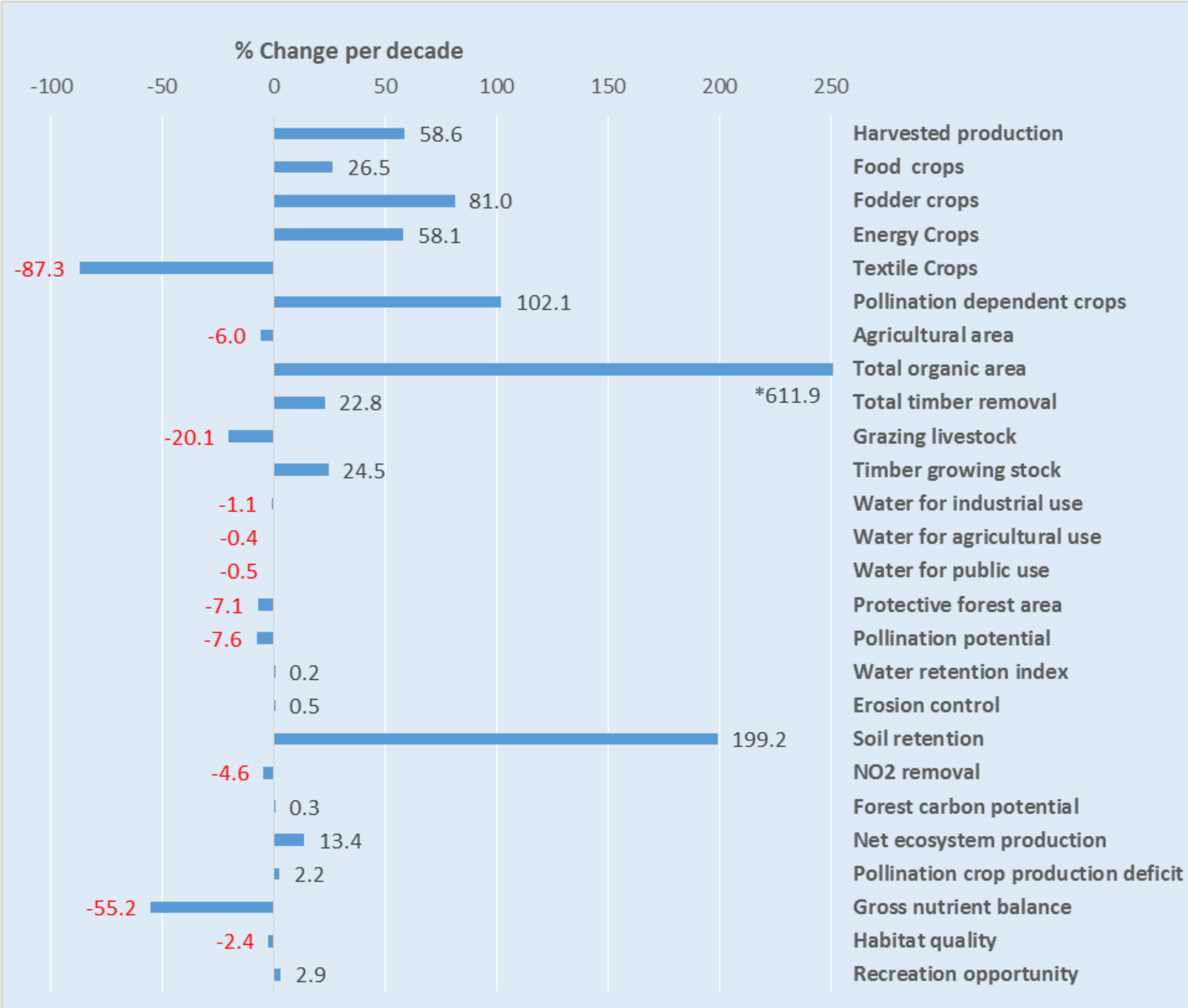


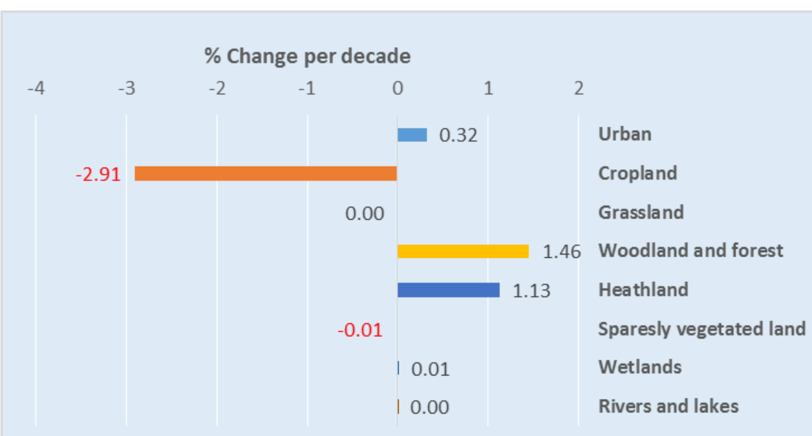


Trends in ecosystems:
Increments in cropland and urban areas cause negative trends in forests and semi-natural areas.

Trends in ecosystem services:
Increased production of several provisioning services. Strong growth of area under organic farming. Notable increment for pollination potential and net ecosystem productivity.

BULGARIA

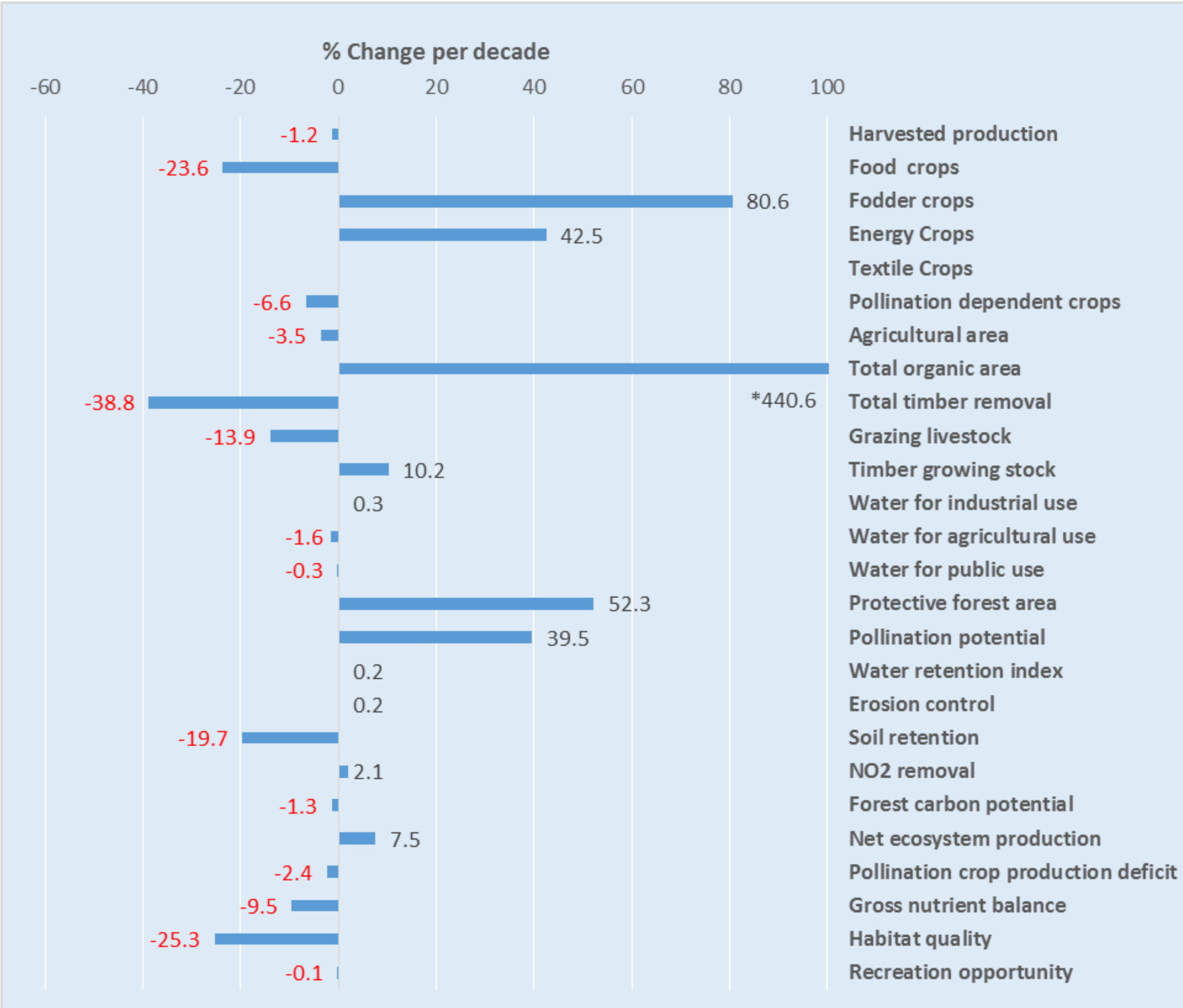


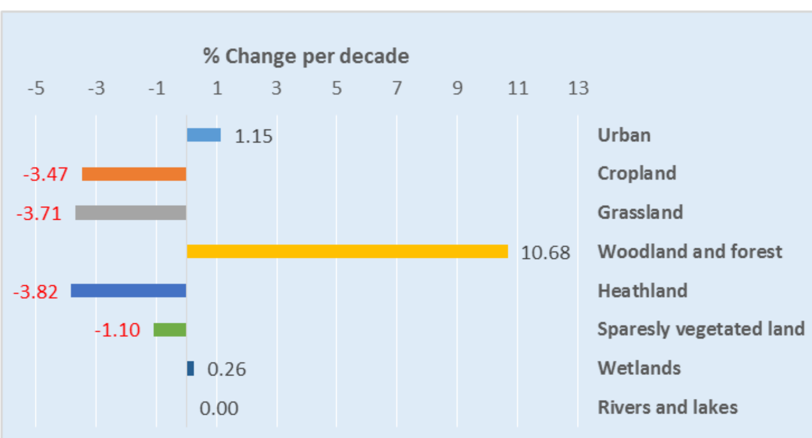


Trends in ecosystems: Cropland area decreased with almost 3%. Growth of heathland, shrubs and forest. Urban area expanded as well.

Trends in ecosystem services:
Increased agricultural output and strong growth of land under organic farming. Notable increment of soil retention values. Enhanced net ecosystem productivity but losses in NO_2 removal and pollination.

CYPRUS

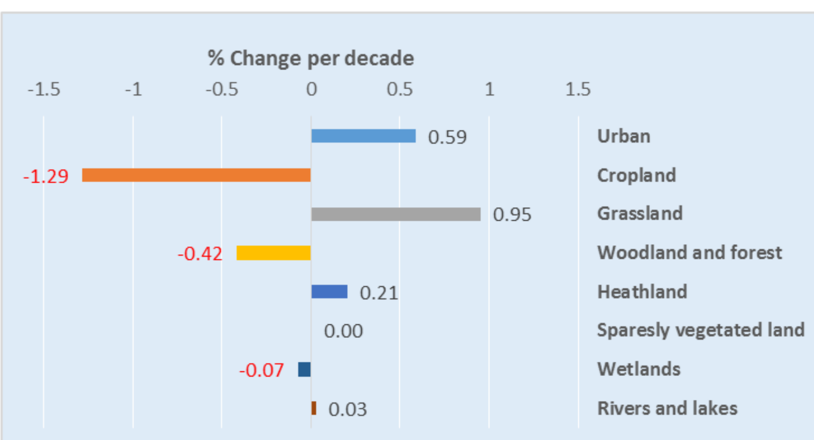




Trends in ecosystems:
Expansion of urban areas and forests. Losses of cropland, grassland and heathland.

Trends in ecosystem services:
Outspoken trends in ecosystem services. Strong growth or organic farming and pollination potential but losses habitat quality and soil retention.

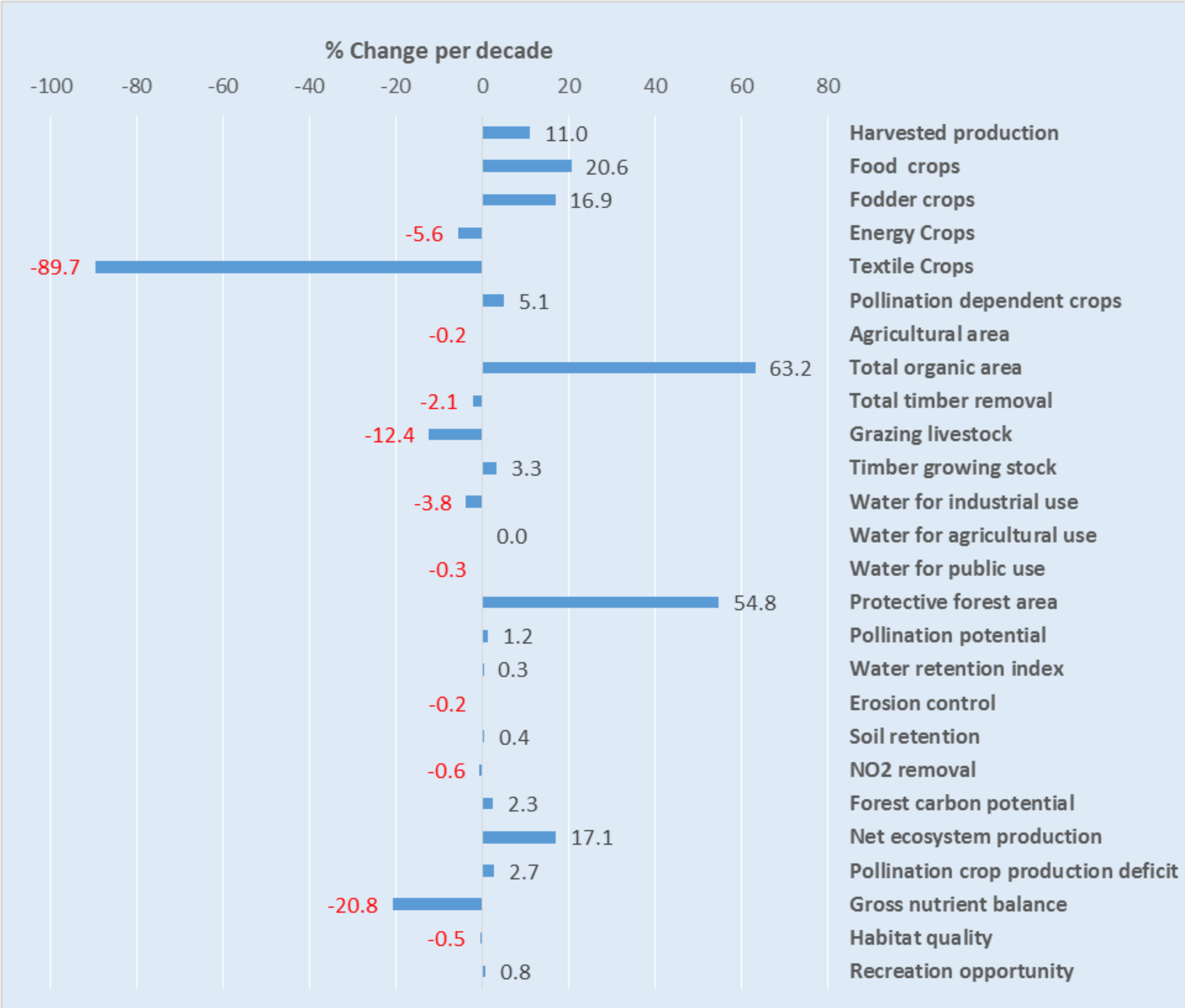
CZECH REPUBLIC

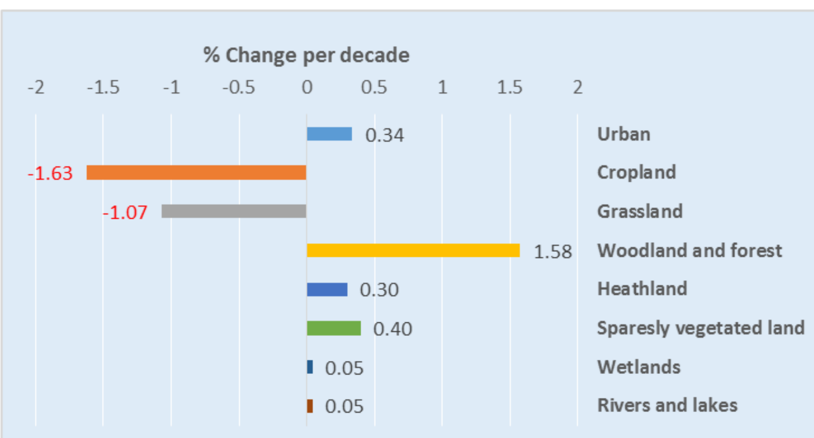


Trends in ecosystems:
Expansion of urban land, grassland and heathland. Negative trends for forest and cropland.

Trends in ecosystem services:
Positive evolution of area under organic farming and soil retention. Decreased pollination potential

GERMANY

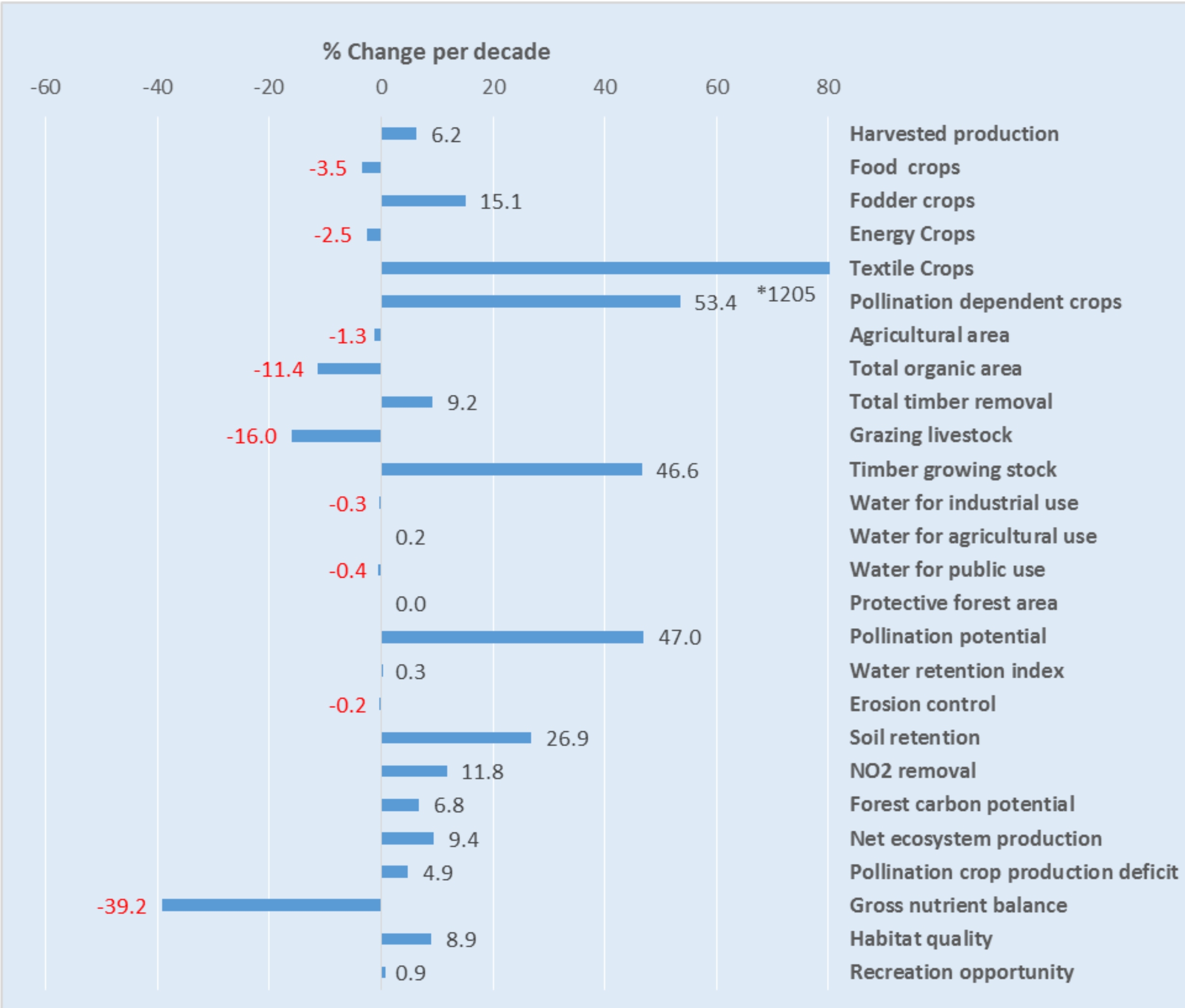


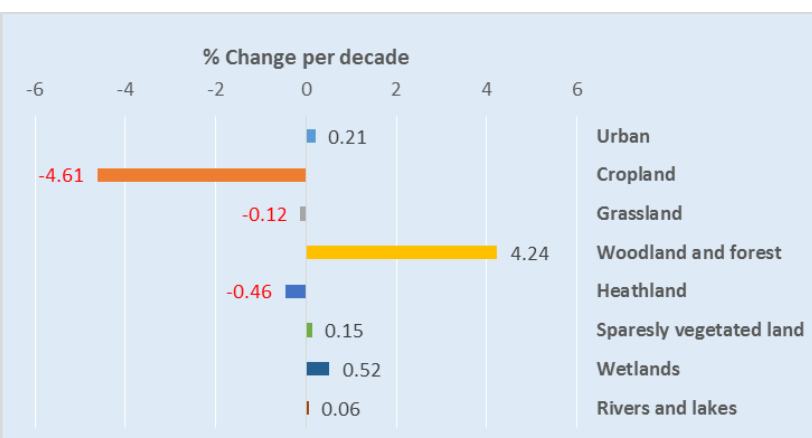


Trends in ecosystems:
Expansion of cropland, forests, heathland and sparsely vegetated land. Contraction of farmland.

Trends in ecosystem services:
Important growth of net ecosystem productivity and forest carbon potential. Increment of area under organic farming and forest area with protective functions. Status quo, slight decrease or notable increase for many ecosystem services.

DENMARK

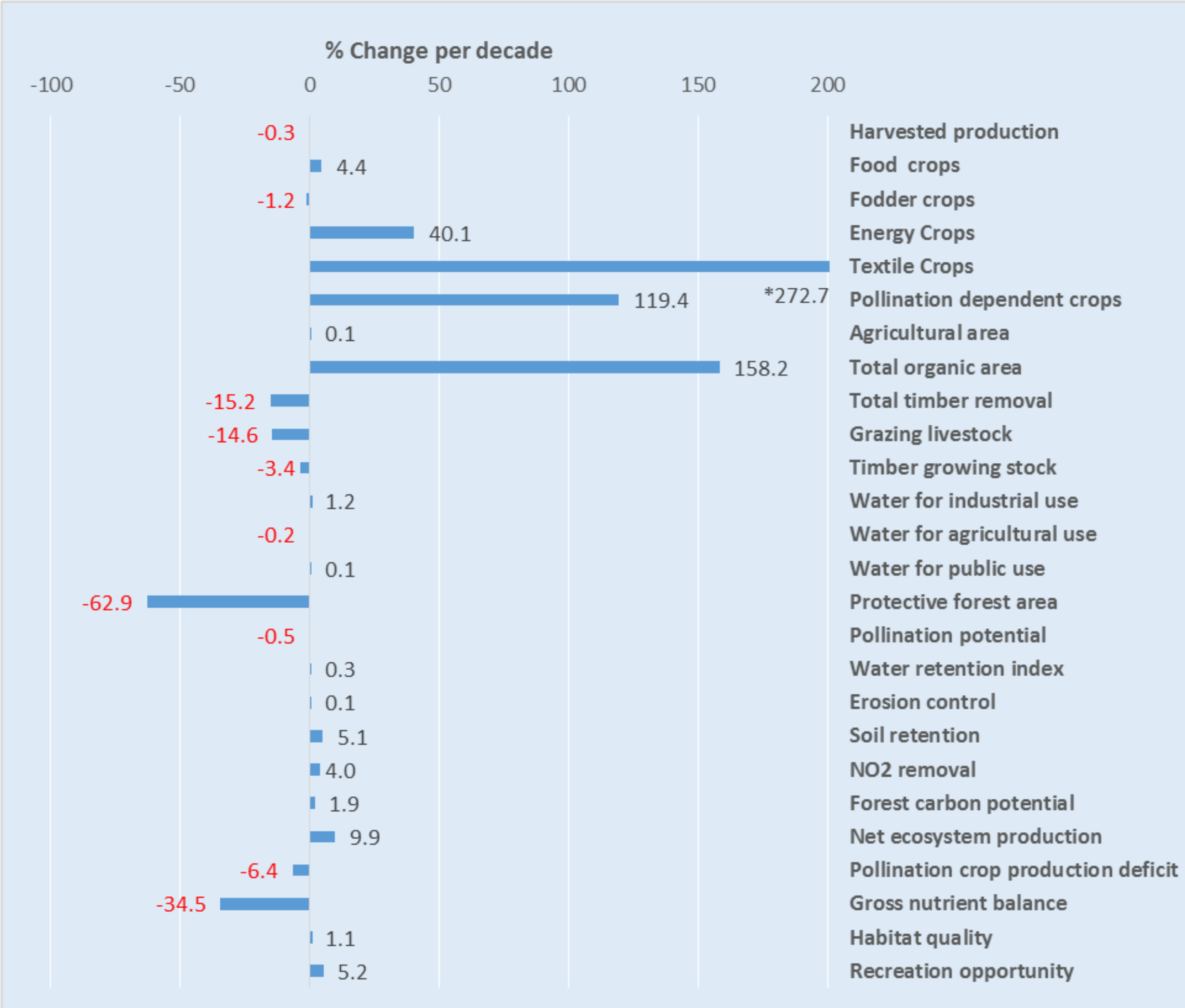


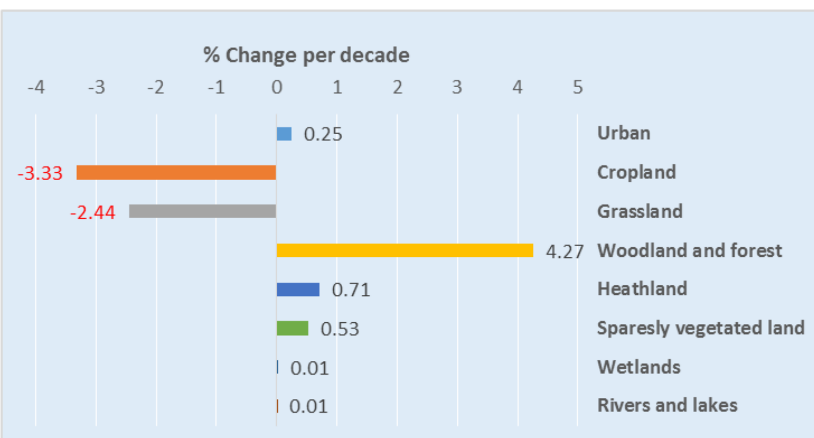


Trends in ecosystems:
Substantial loss of agricultural area in favor of forests and woodland

Trends in ecosystem services:
Positive trends for many ecosystem services.

ESTONIA

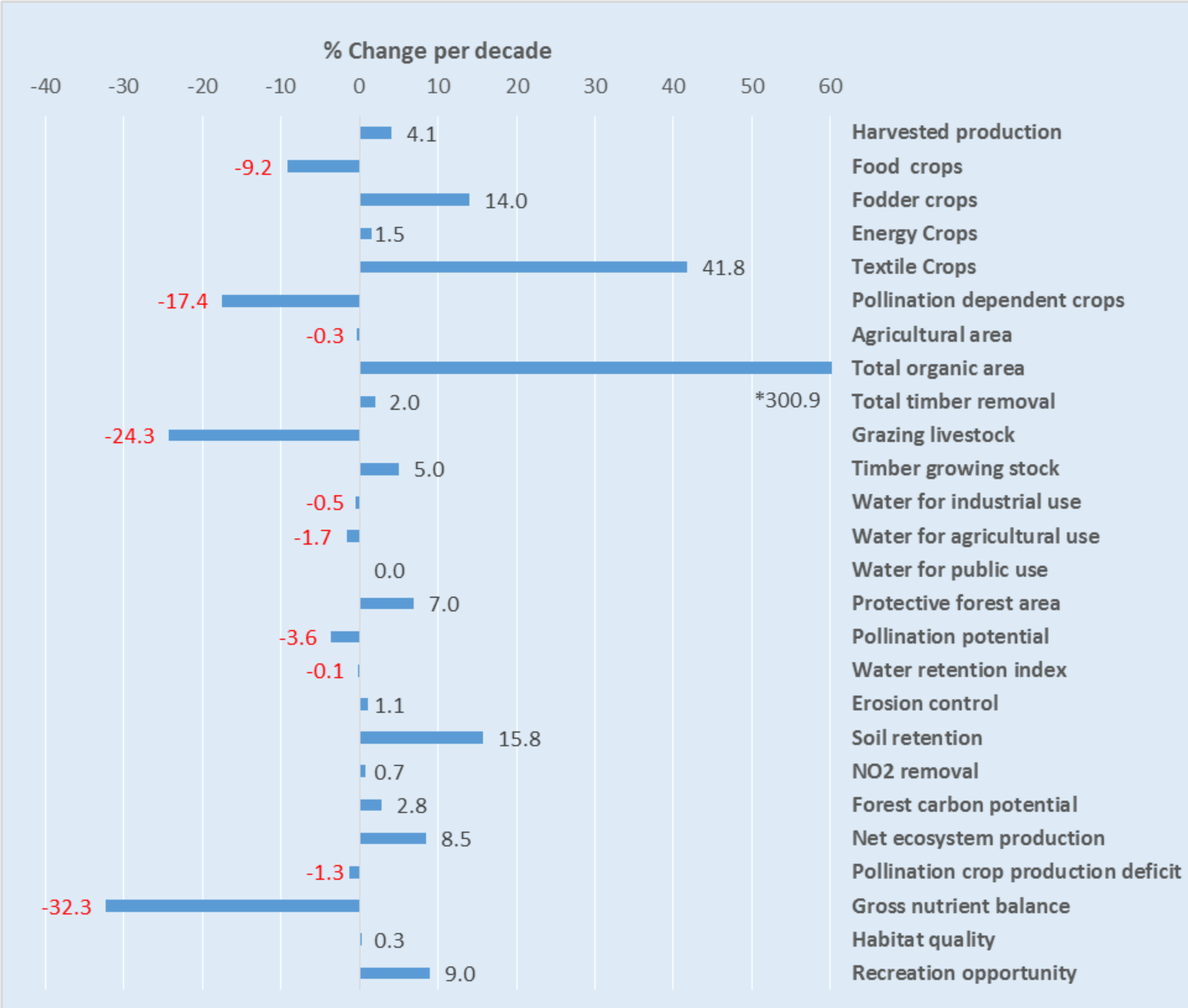


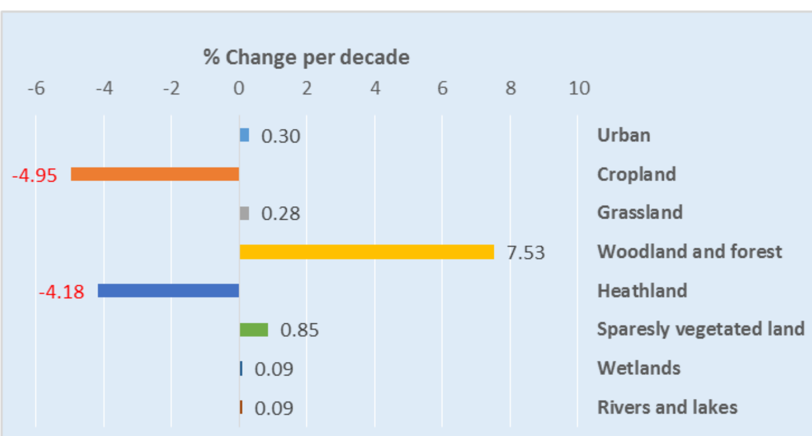


Trends in ecosystems:
Moderated urban growth. Losses in farmland in favor of forests and semi-natural areas.

Trends in ecosystem services:
Conflicting trends between land cover, land use, and reported statistics on provisioning services. Moderated growth in a number of regulating and cultural services.

SPAIN

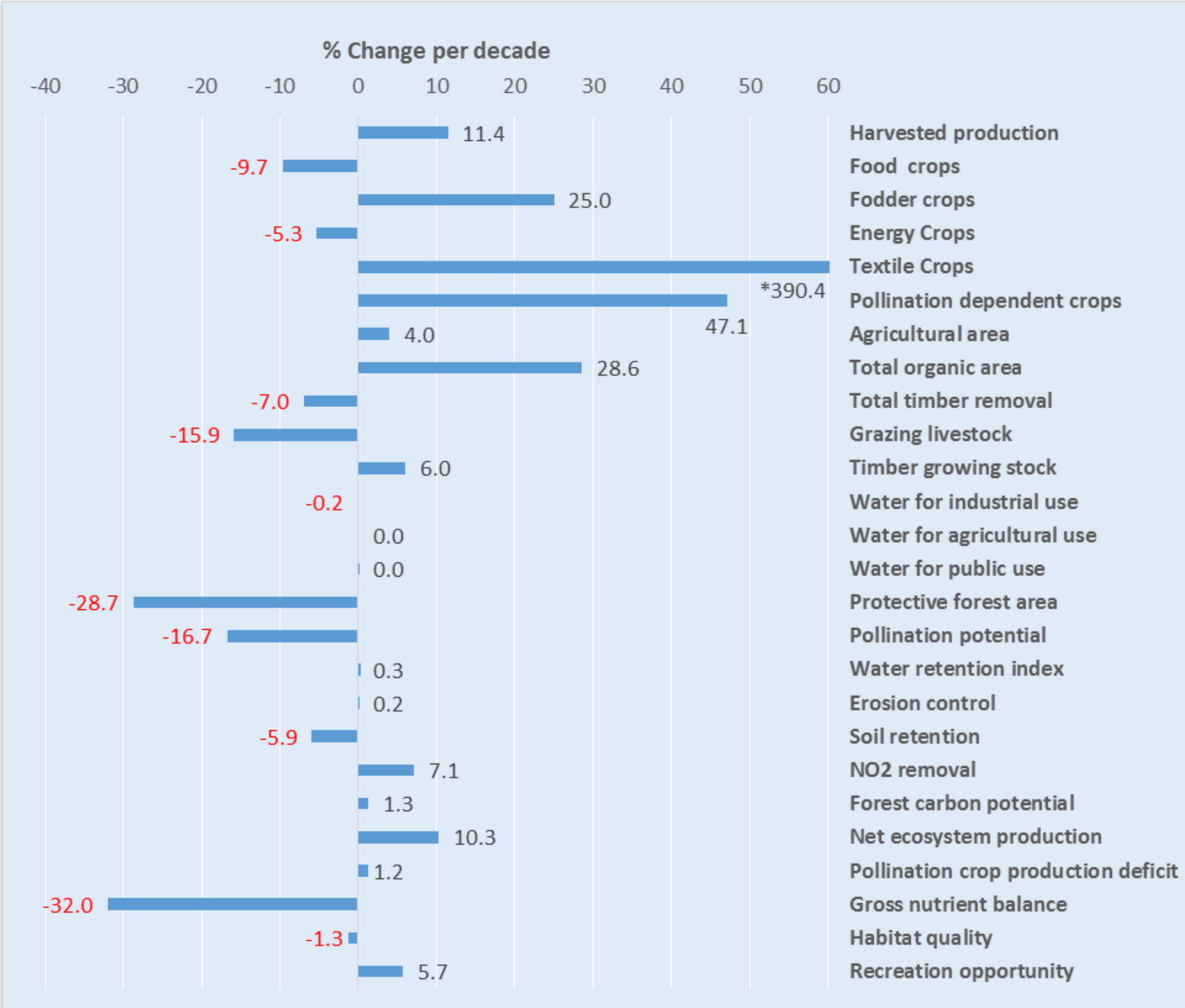


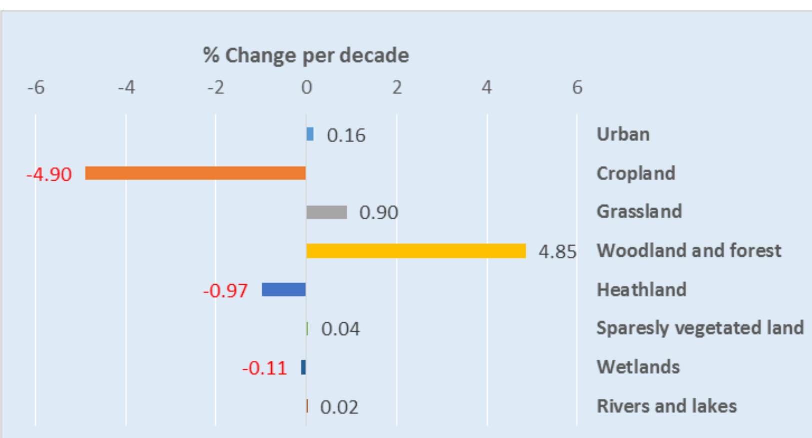


Trends in ecosystems:
Expansion of urban areas lower than expected. Substantial increase in forest and woodland but losses in cropland and heathland

Trends in ecosystem services:
Loss in pollination potential but growth of several other regulating services. Increment in recreation opportunity.

FINLAND

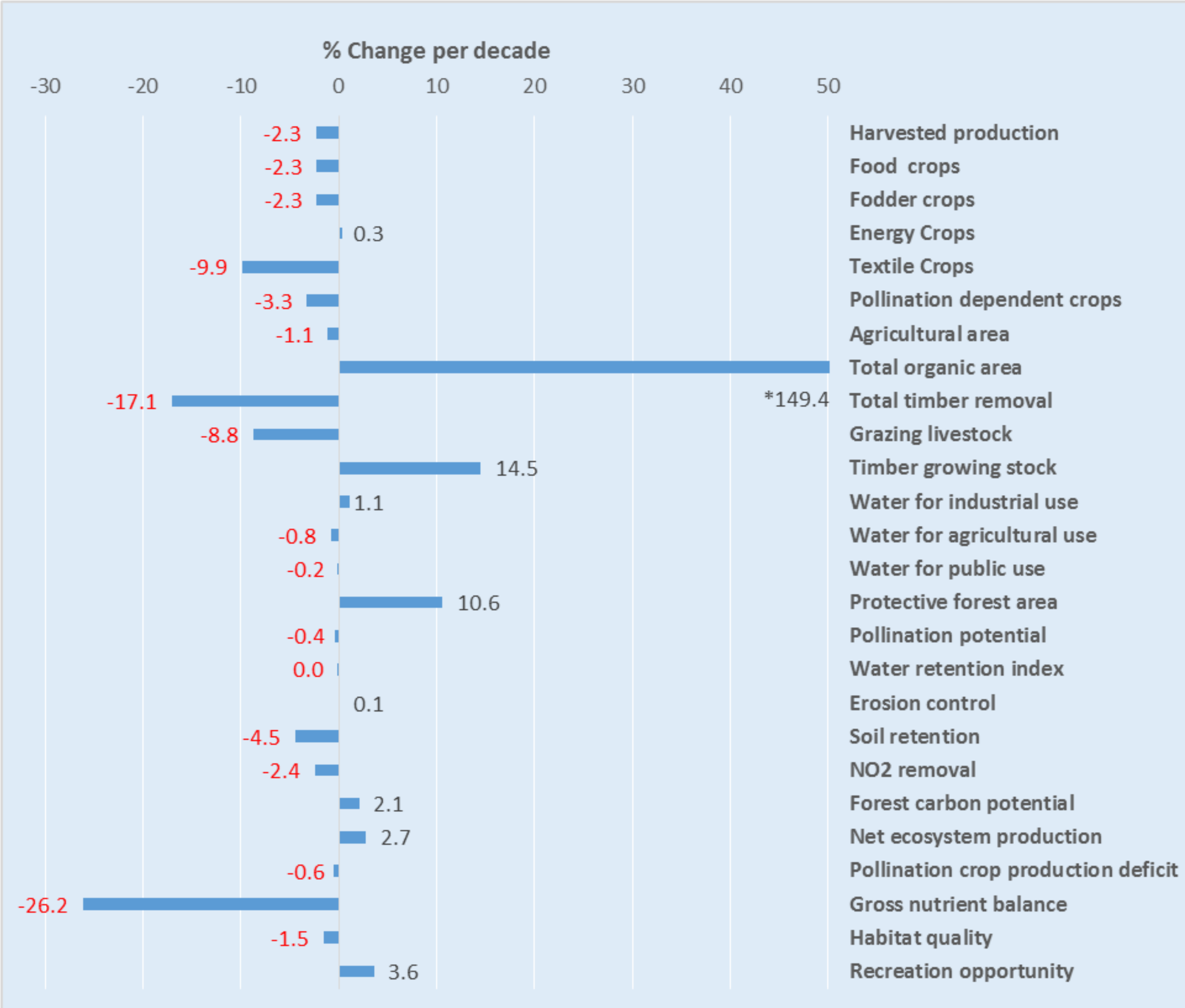


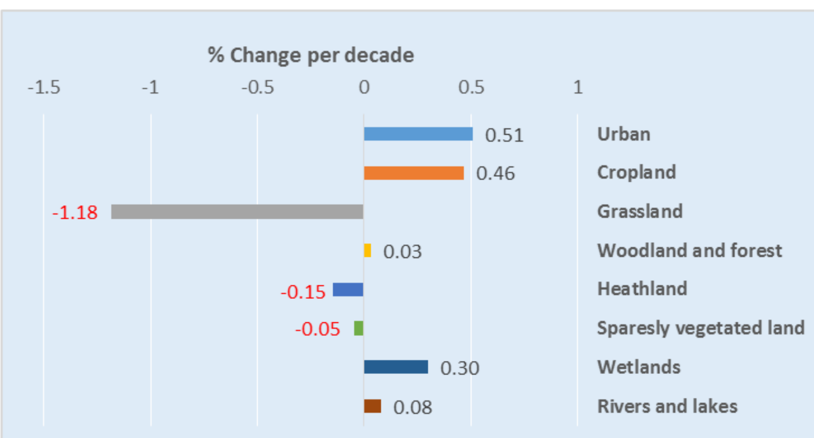


Trends in ecosystems: Growth of woodland and forest at the cost of cropland. Slow growth of urban areas.

Trends in ecosystem services: Built up of biomass (timber, crops, ecosystem productivity) but lower area reported as forest with protective functions. Significant increase in recreation opportunity.

FRANCE

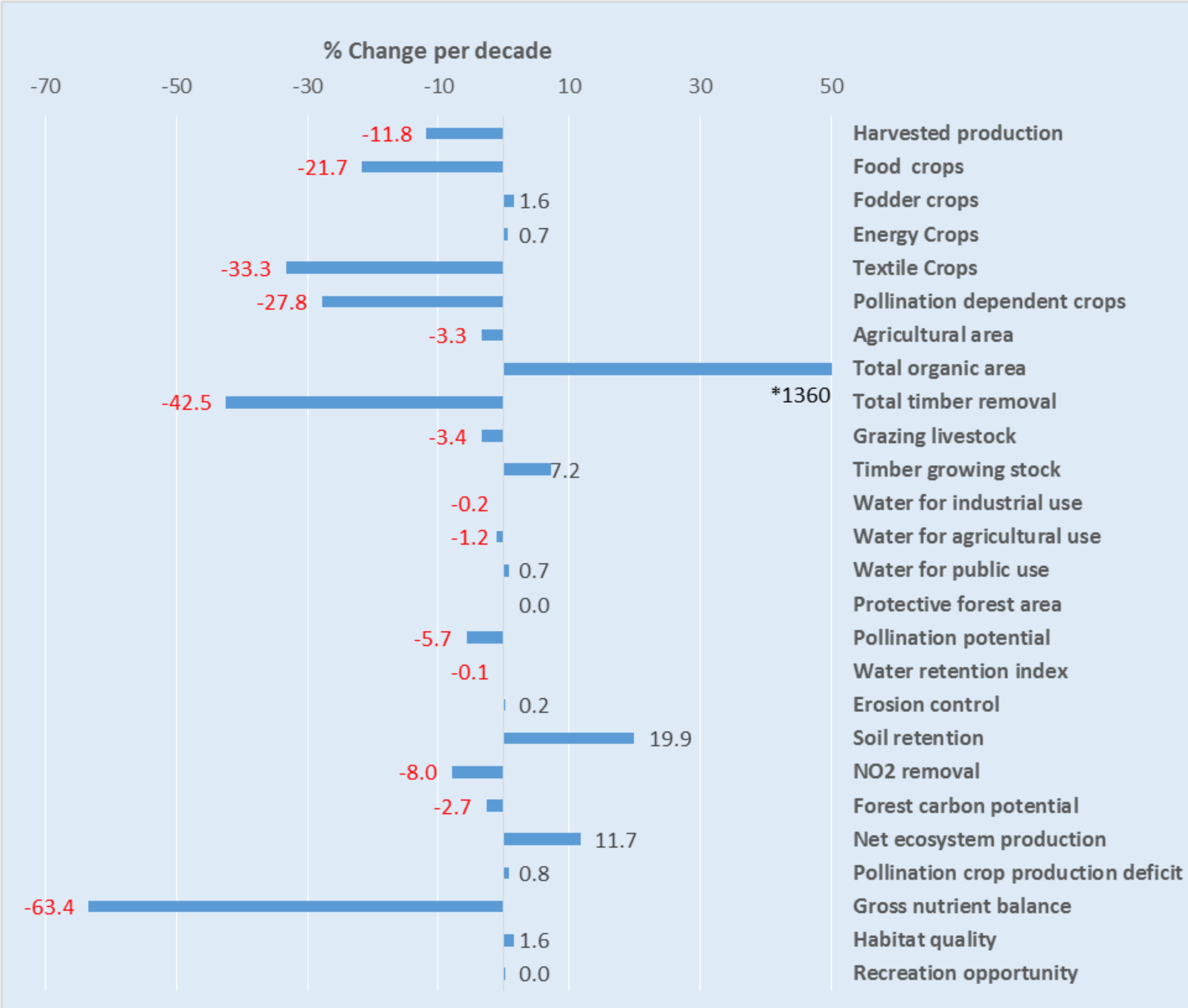


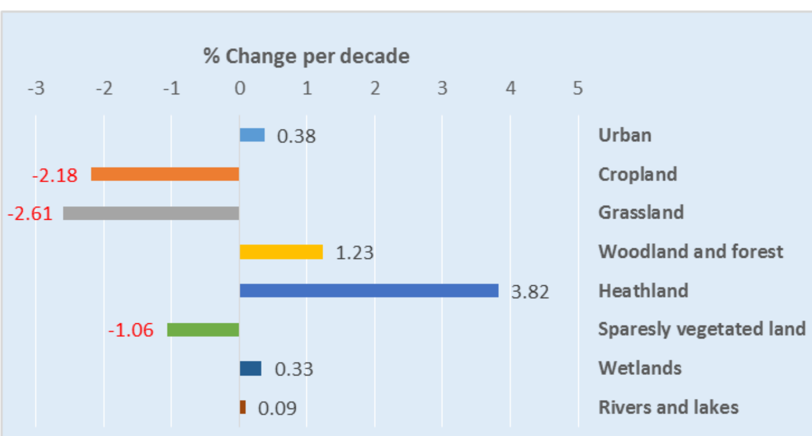


Trends in ecosystems: Conflicting trends in between land cover changes and reported indicators. Important increment of urban area.

Trends in ecosystem services: Slight decreases or status quo for many indicators but higher area under organic farming, increasing timber stock, and more area of forest with protective functions.

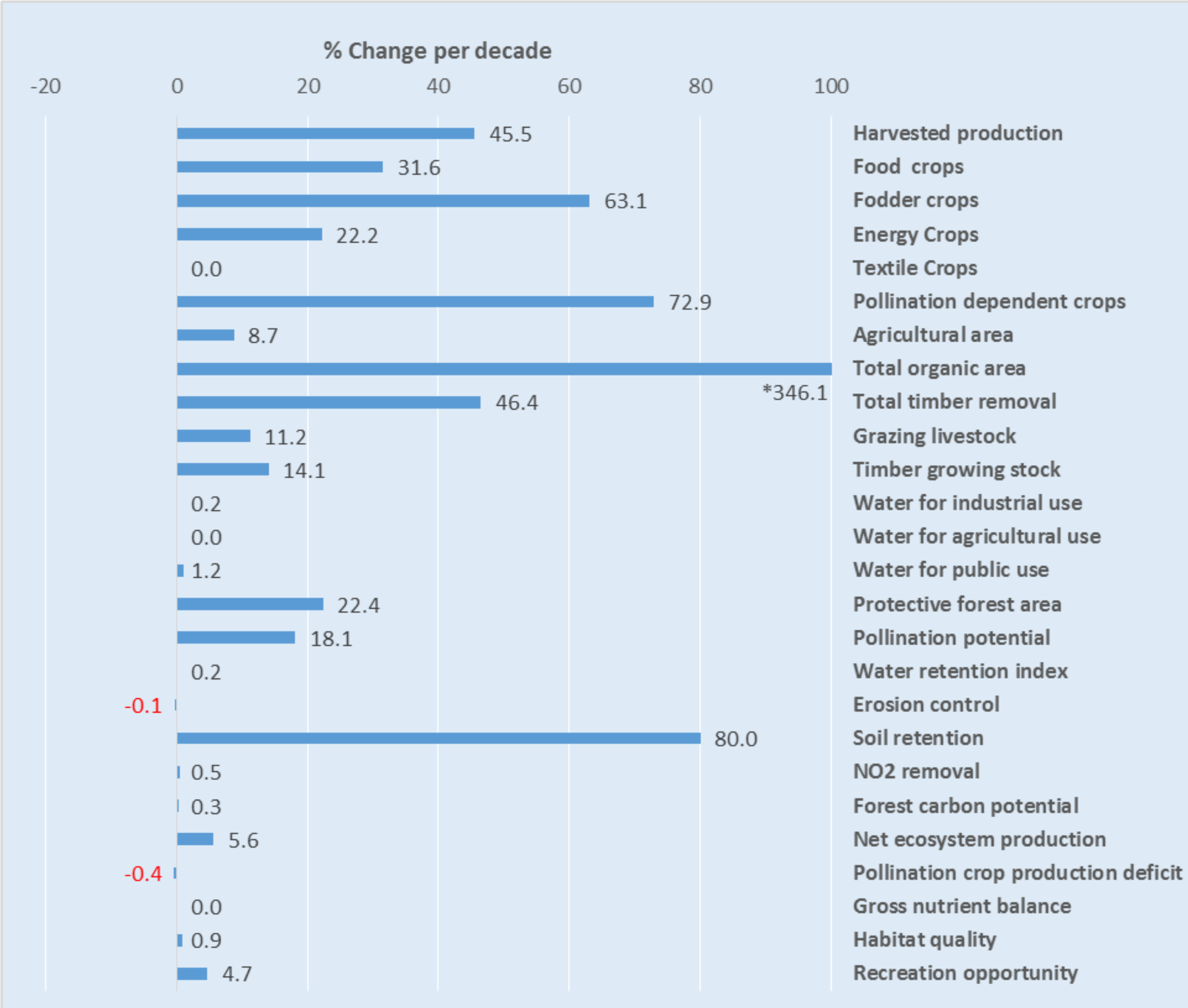
GREECE

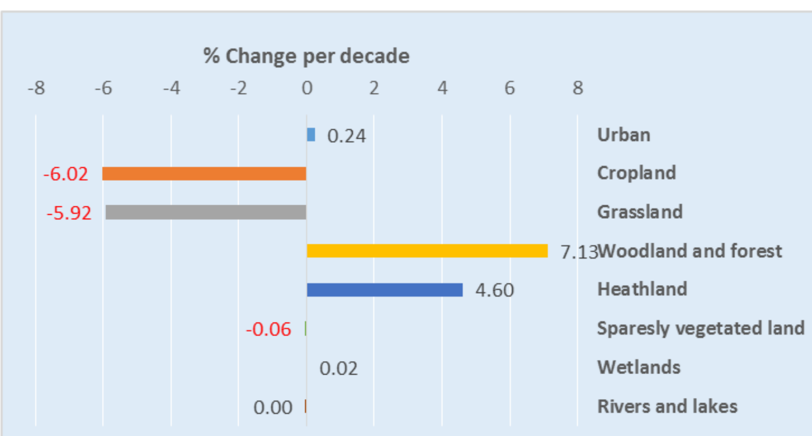




Trends in ecosystems:
Increasing heathland and forest areas while cropland and grassland decreased.
Trends in ecosystem services:
Drop in different crop production categories and timber removal. Reported increases in organic farming

CROATIA

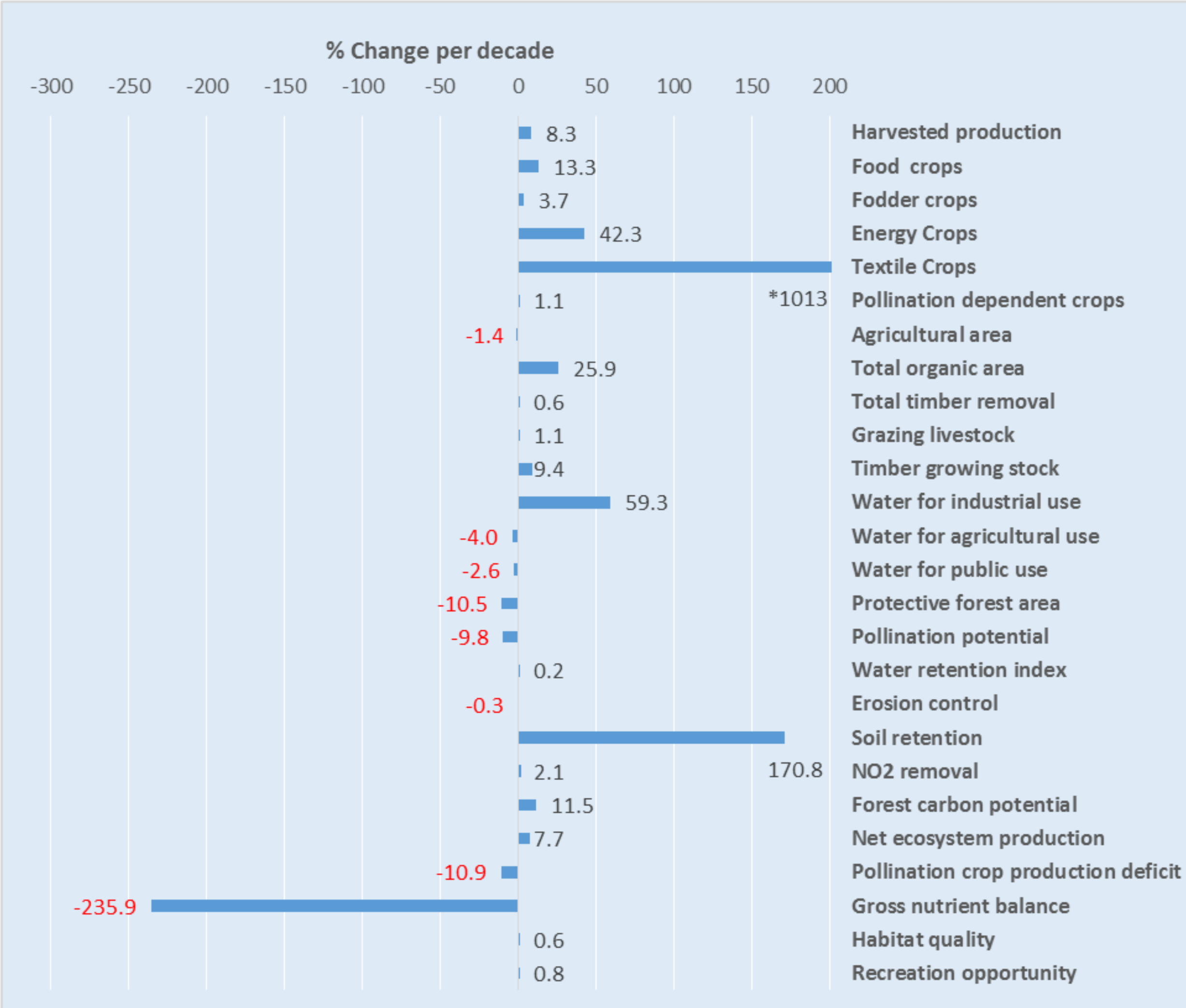


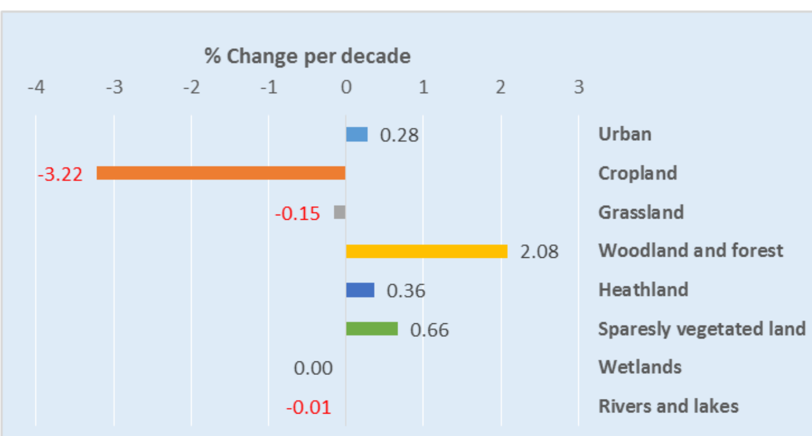


Trends in ecosystems:
Strong growth of forest and semi-natural area and losses for cropland and grassland

Trends in ecosystem services:
A very particular profile emerges. Higher production of crops and timber; increased water use and positive trends for most regulating and cultural ecosystem services.

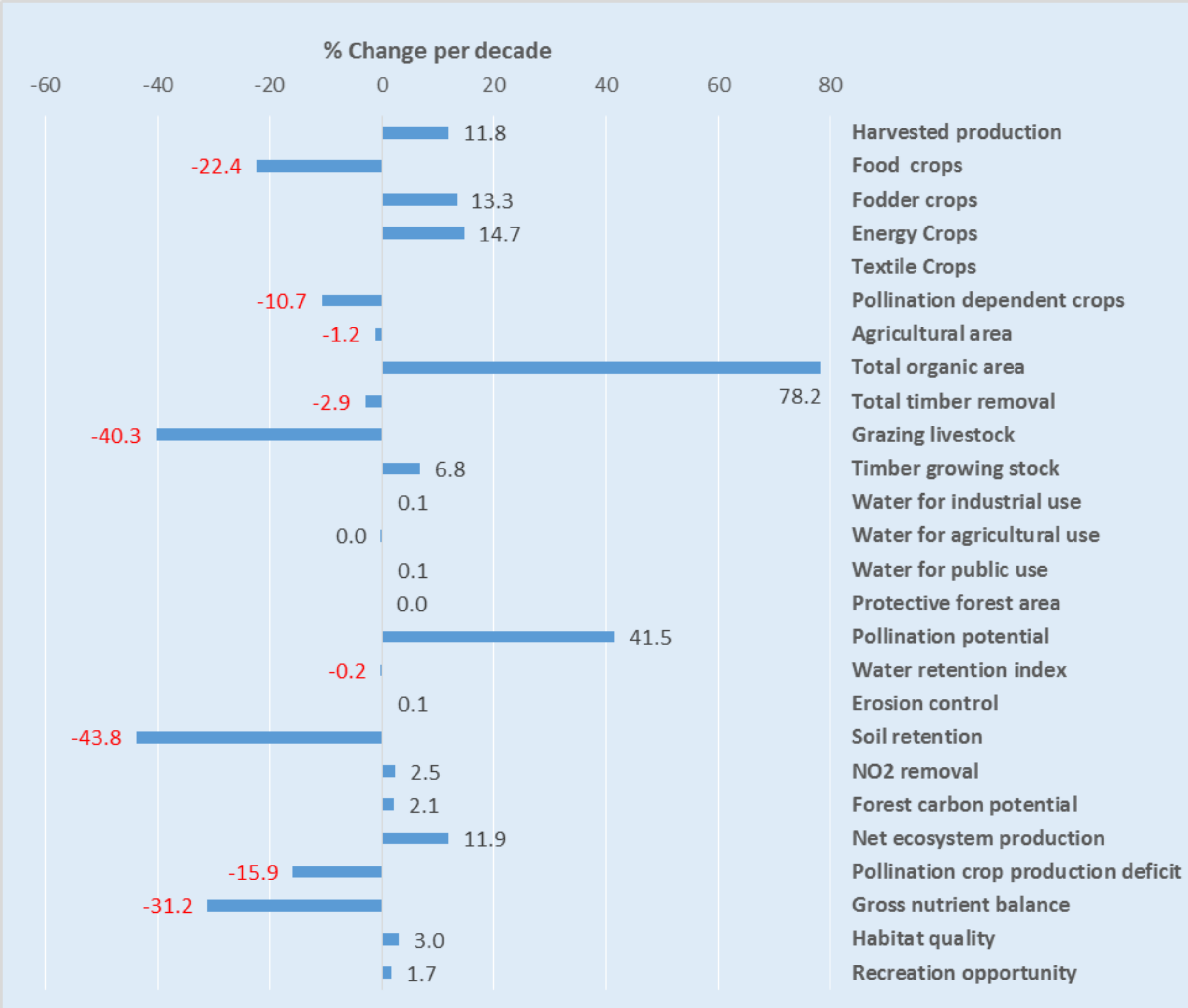
HUNGARY

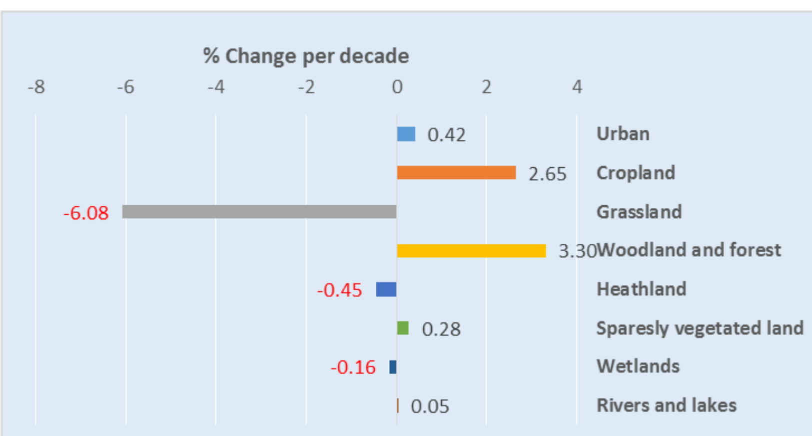




Trends in ecosystems: Cropland loss and afforestation. Moderate growth of urban areas.
Trends in ecosystem services: Increased provisioning services including higher water use and mixed trends in regulating services.

IRELAND

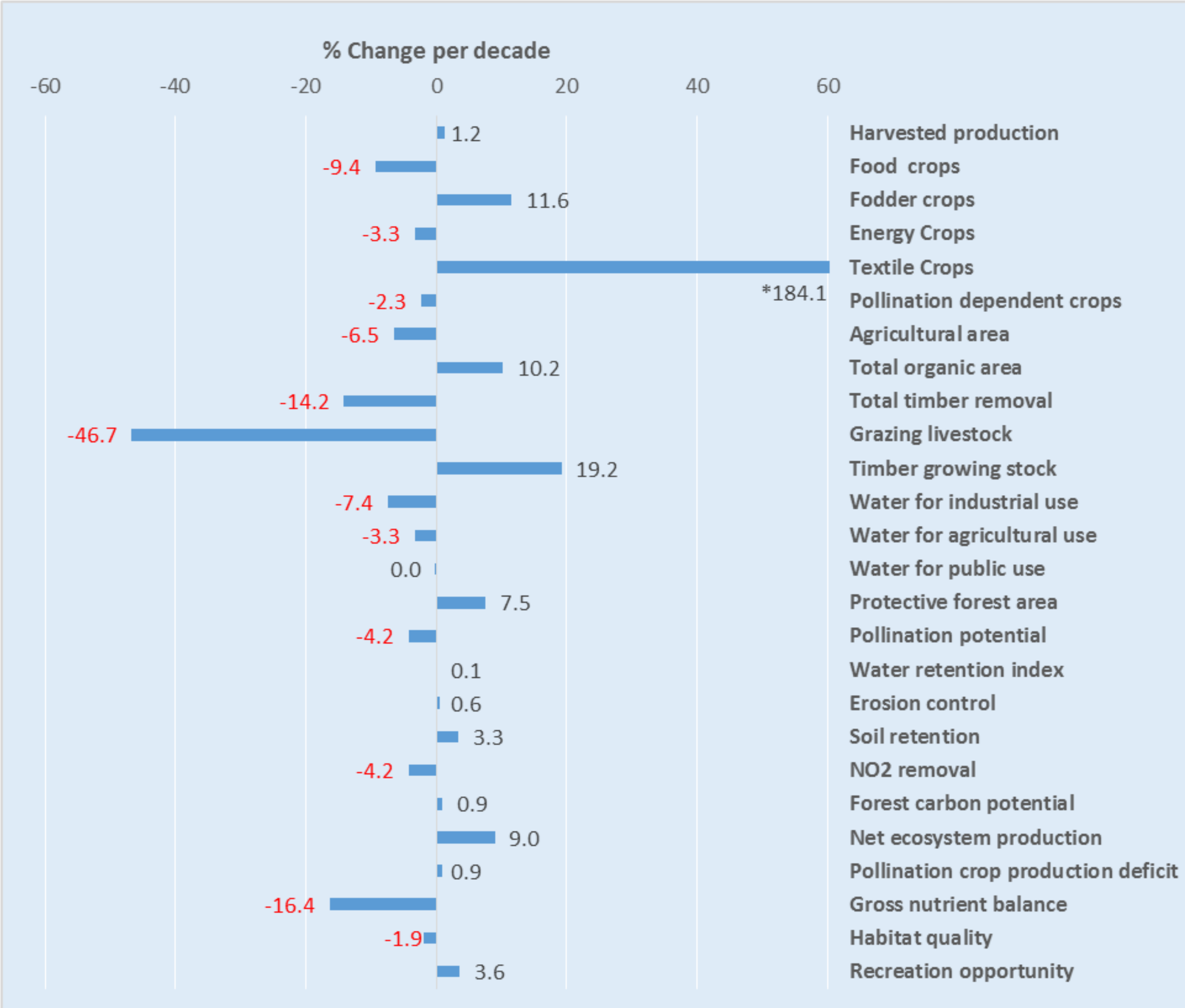


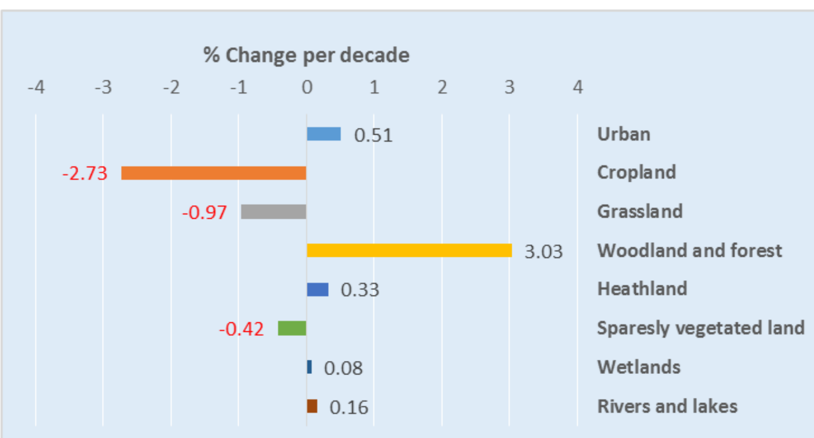


Trends in ecosystems: Increasing cropland and forest area and a significant loss of grassland. But the positive trend in cropland.

Trends in ecosystem services: Outspoken positive and negative trends in ecosystem services. Higher pollination potential is likely coupled to increased crops which supply foraging resources.

ITALY

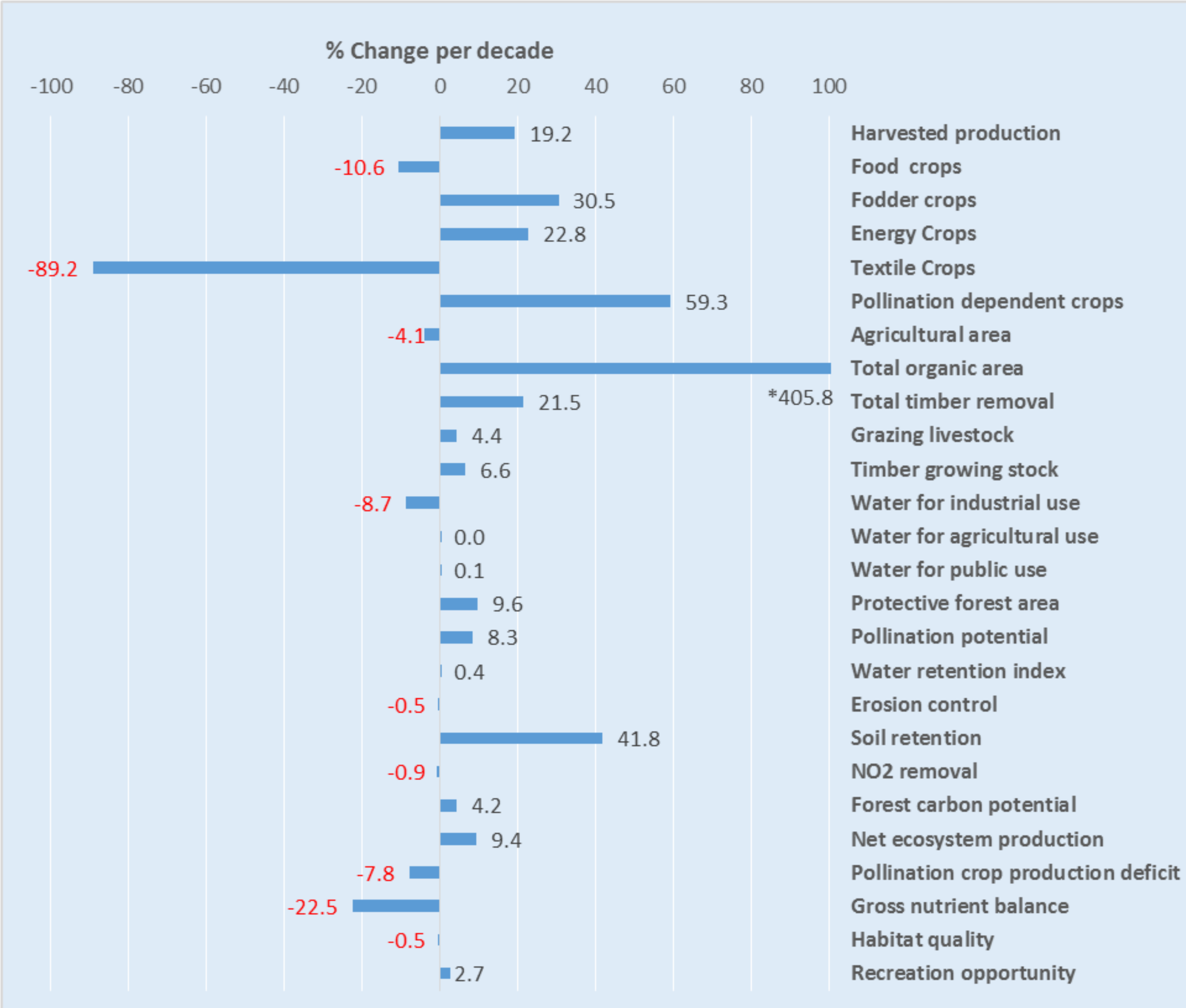


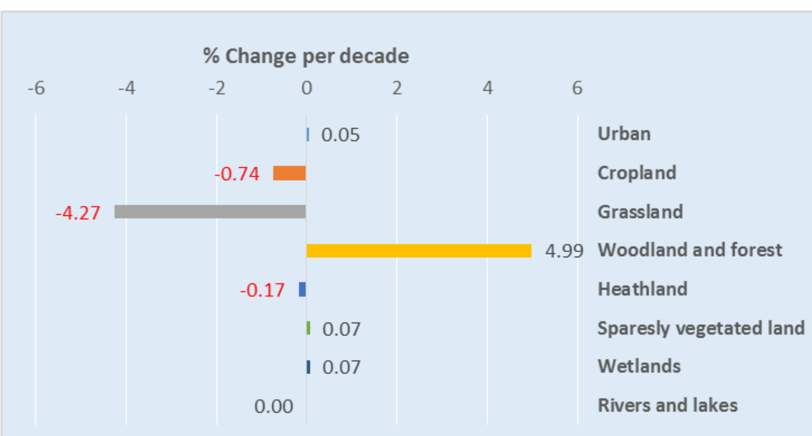


Trends in ecosystems:
Losses in cropland and grassland while increases in forests. Growth of urban areas

Trends in ecosystem services:
Shifts in crop categories under constant total production. Decreases in water usage. Positive and negative trends in regulating services but the decrease in air quality regulation suggests loss of urban green areas.

LITHUANIA

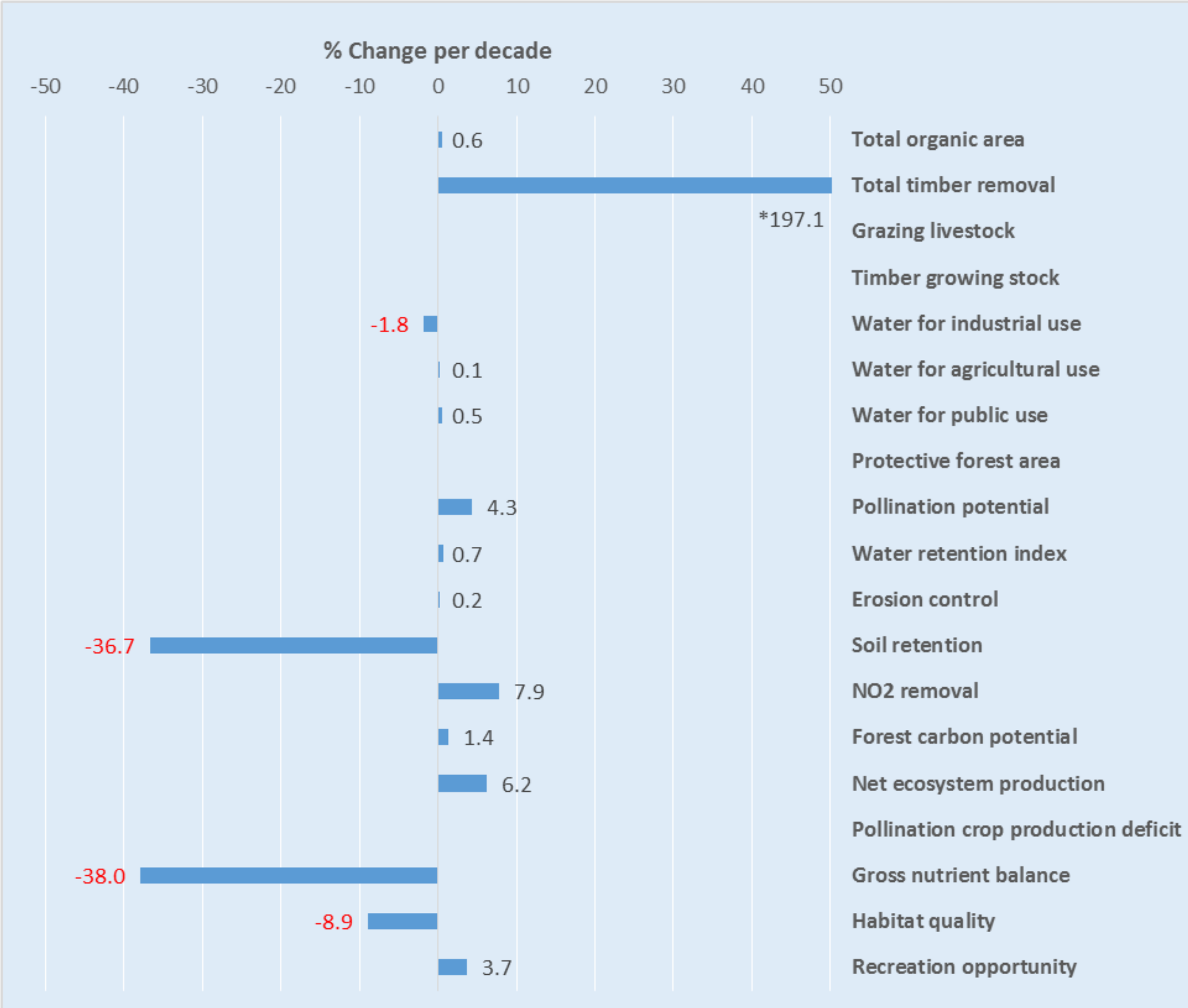


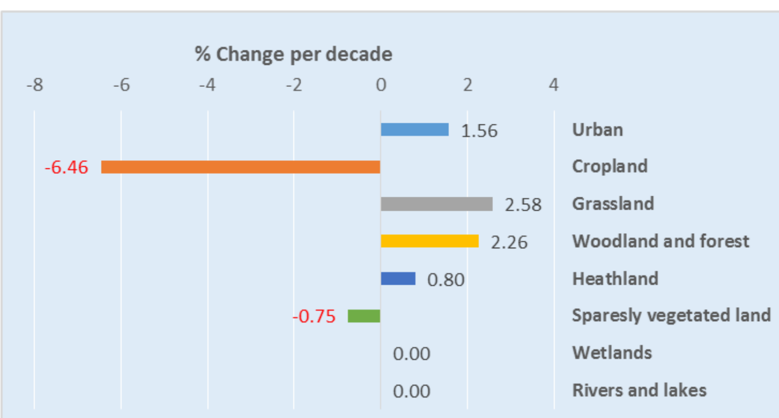


Trends in ecosystems:
Important gains of woodland and forest in balance with losses of grassland and to a lesser extent cropland. Slow urban growth.

Trends in ecosystem services:
Biomass built up in agriculture and in forests. More sustainable water use. Positive trends for several ecosystem services.

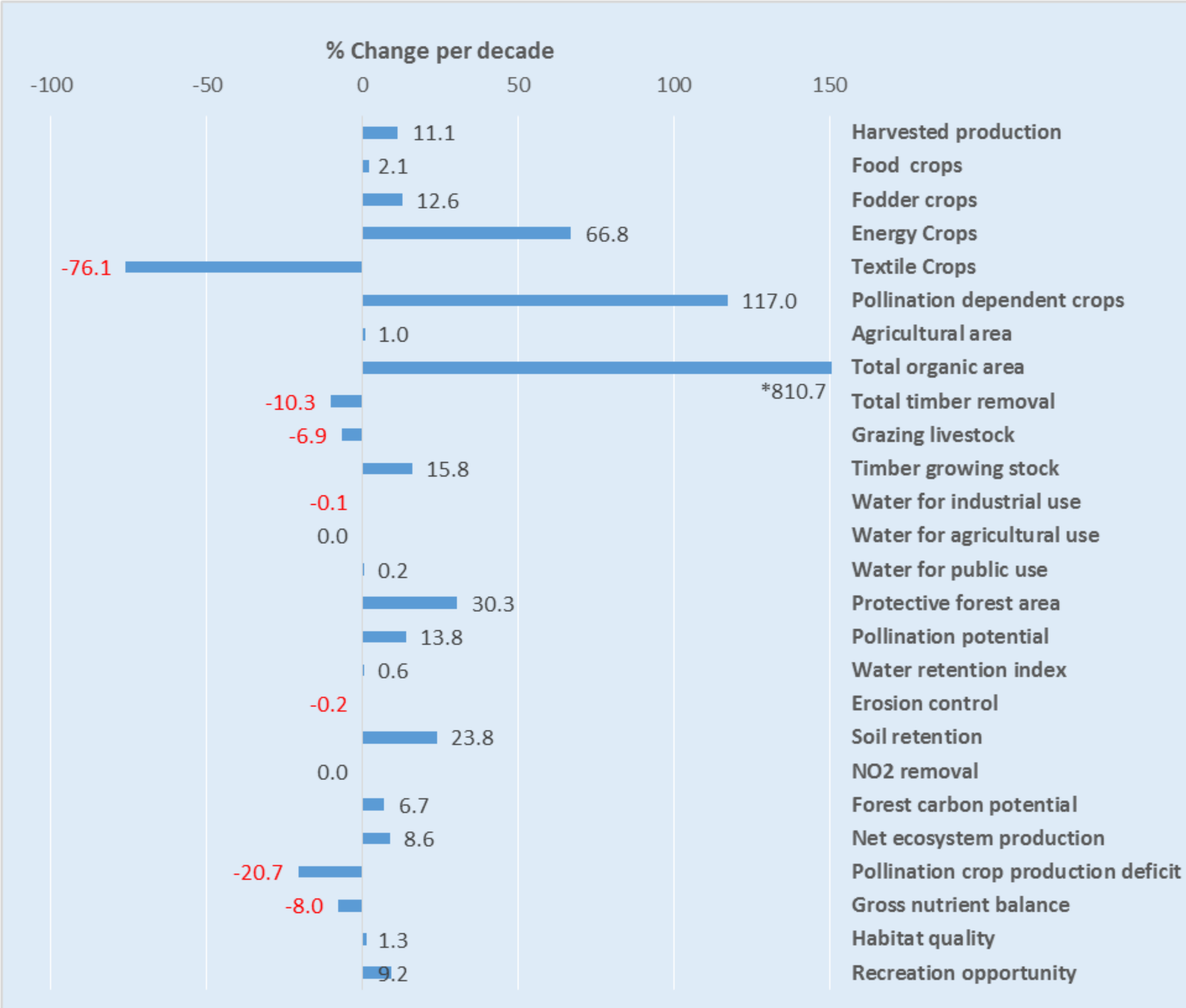
LUXEMBOURG

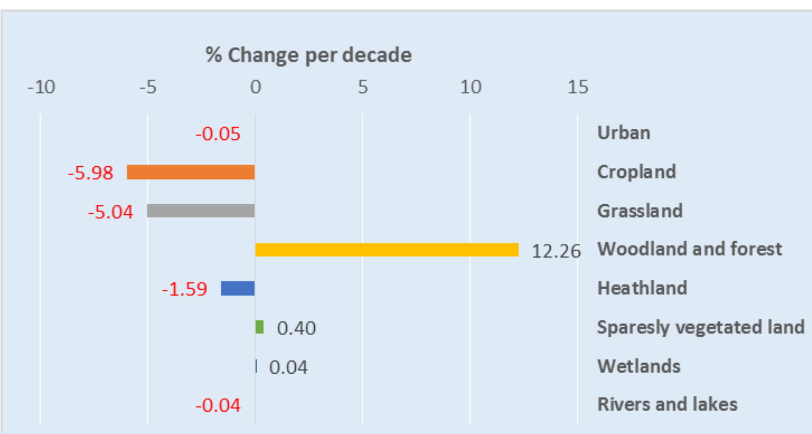




Trends in ecosystems:
Important growth of urban area and strong loss of cropland.
Trends in ecosystem services:
Status quo or increases for several services but notable loss of habitat quality

LATVIA

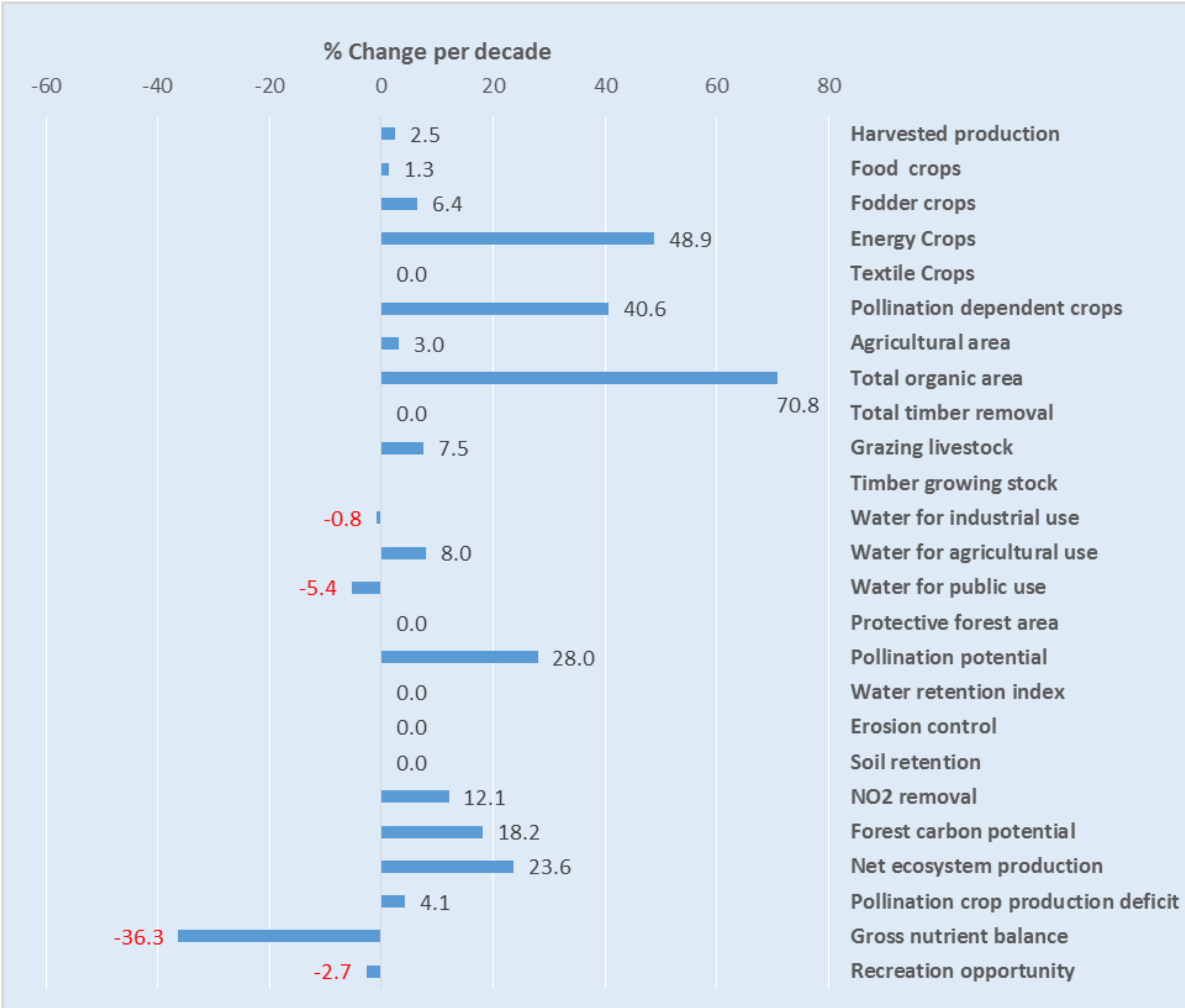


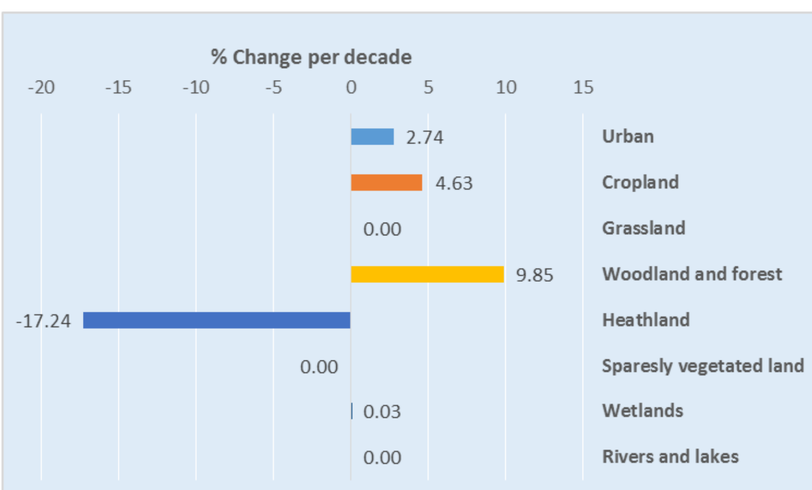


Trends in ecosystems:
Notable afforestation.

Trends in ecosystem services:
Strong growth of area under organic farming. Increment of several regulating and cultural ecosystem services.

MALTA

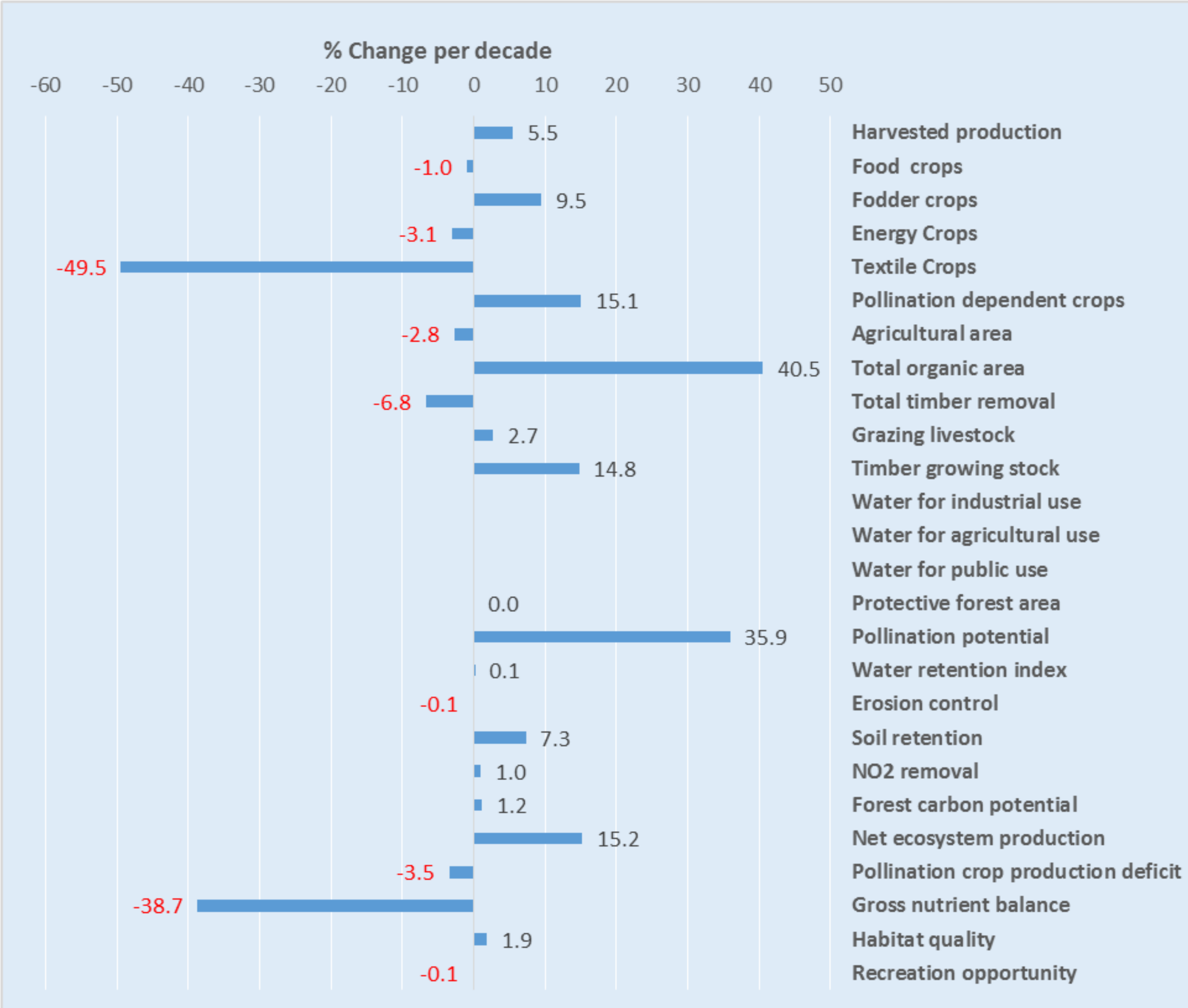


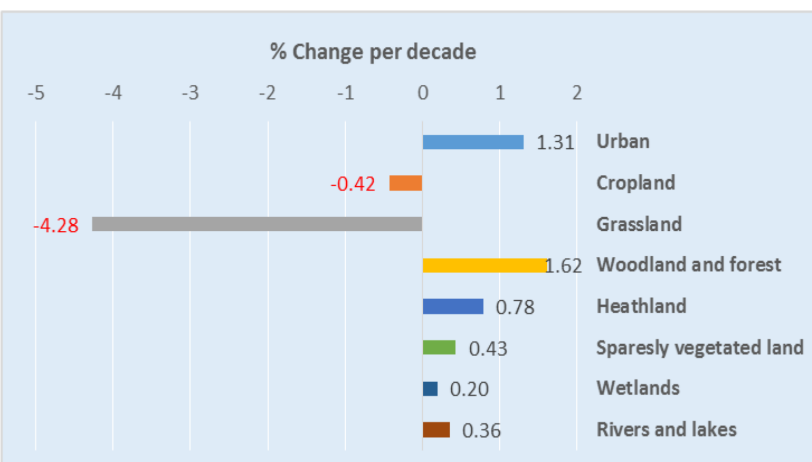


Trends in ecosystems: High rate of urban area increment. Forest and cropland grew. Heathlands are taken.

Trends in ecosystem services: Production increments for forest and agricultural products and for several ecosystem services. Some values are uncertain due to errors that arise from using models with an inappropriate spatial resolution relative to the size of the island.

NETHERLANDS

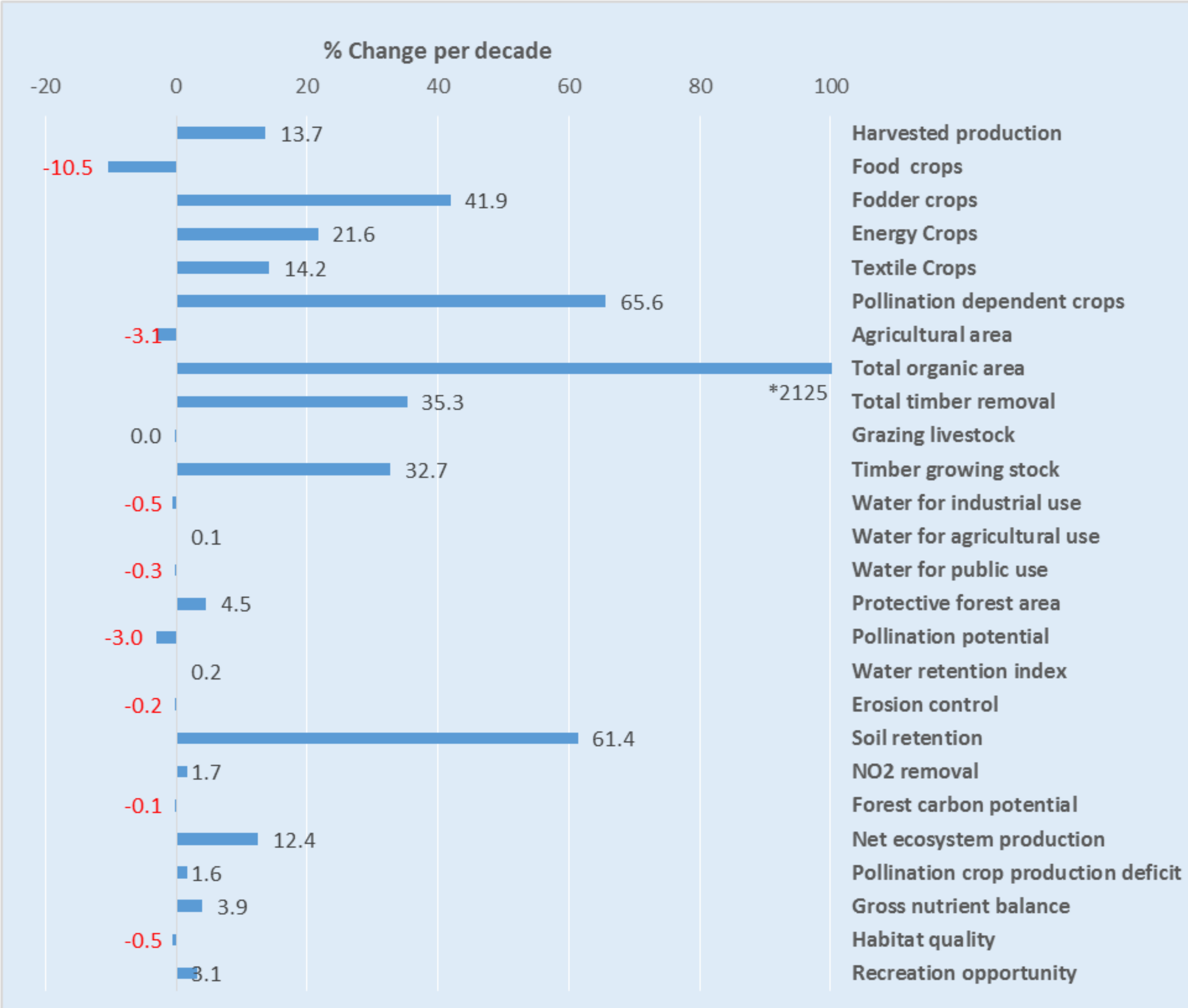


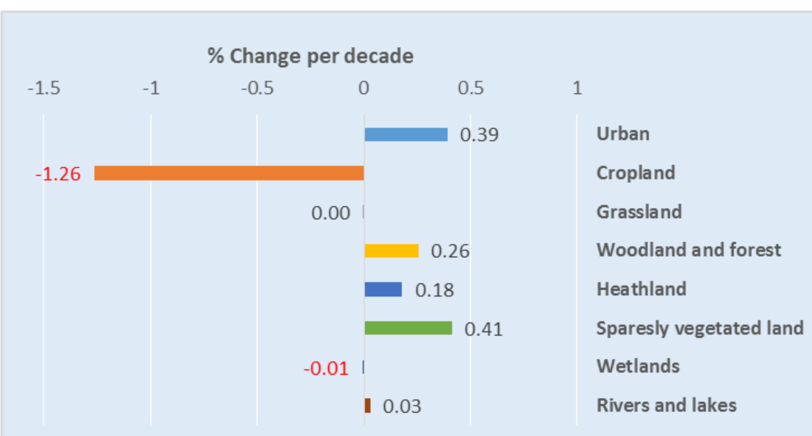


Trends in ecosystems: Increments of urban land and forest, loss of grassland.

Trends in ecosystem services: Improvements for several services relative to 2000.

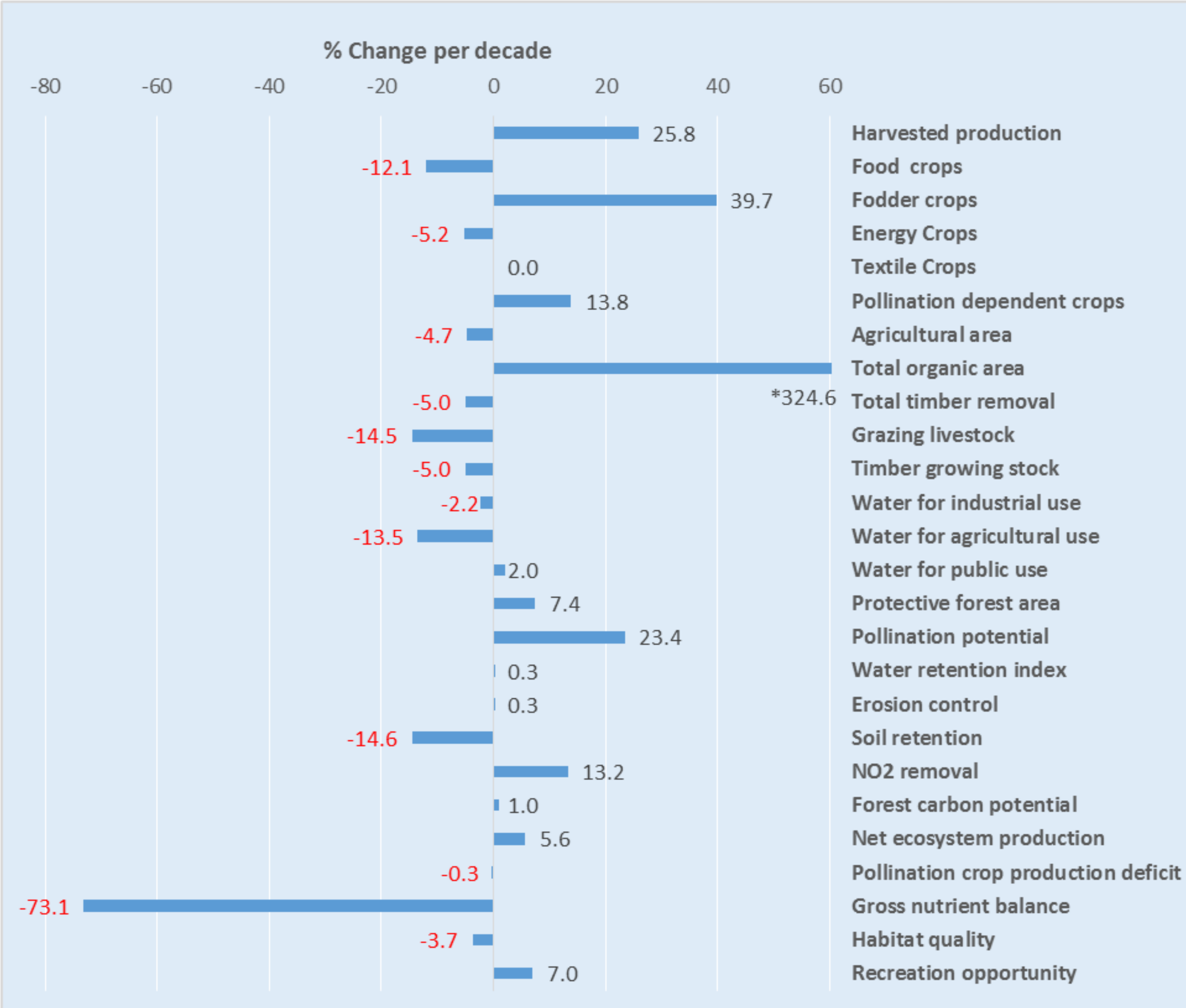
POLAND

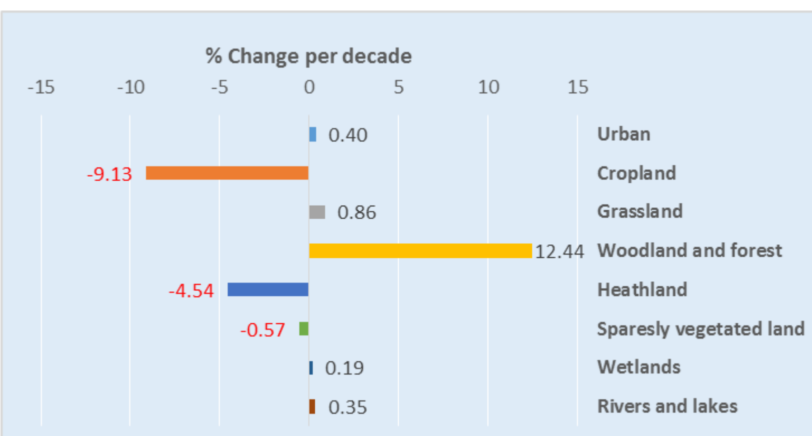




Trends in ecosystems:
Relatively small changes.
Trends in ecosystem services:
Increasing biomass built up and slightly negative trends several services.

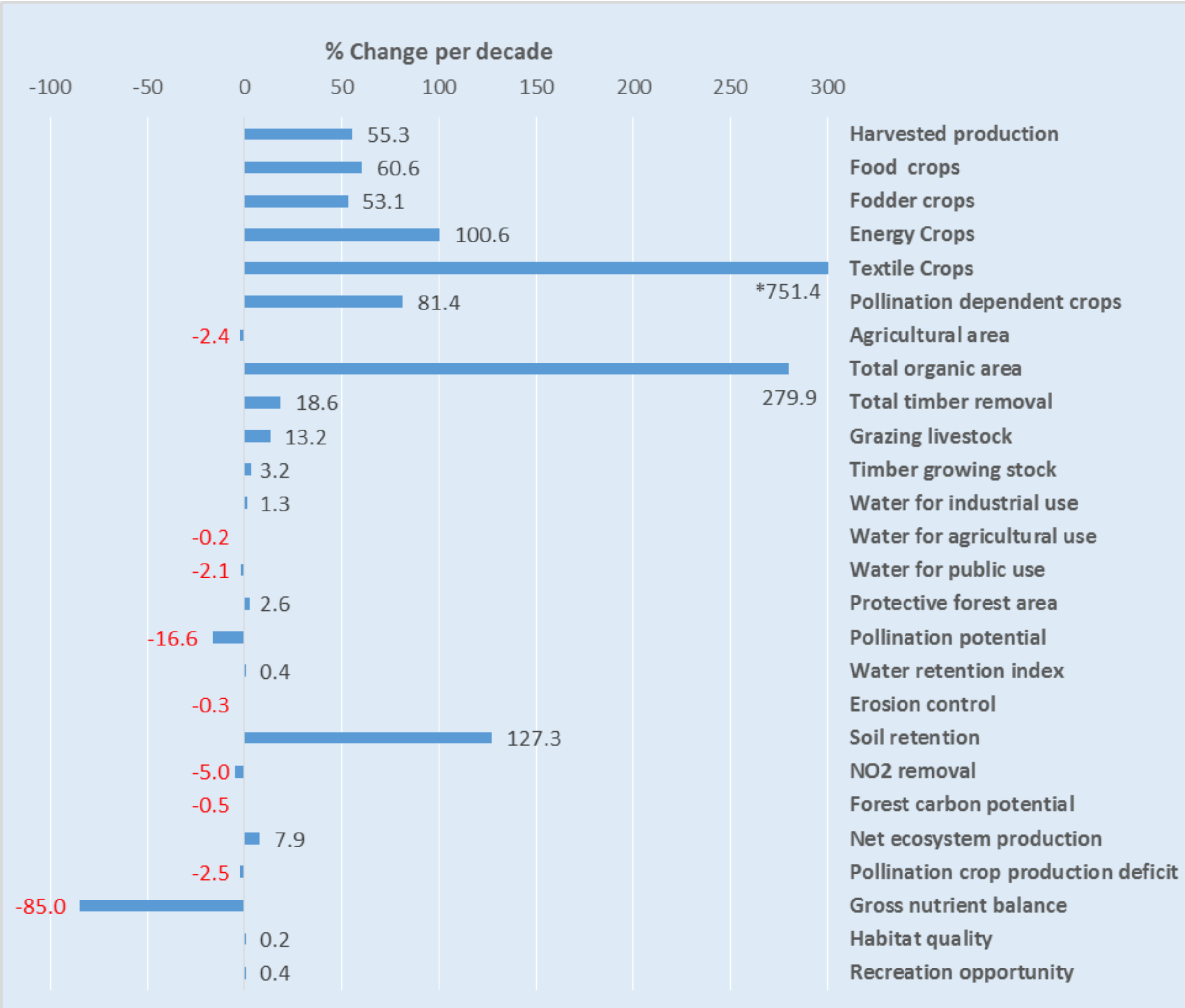
PORTUGAL

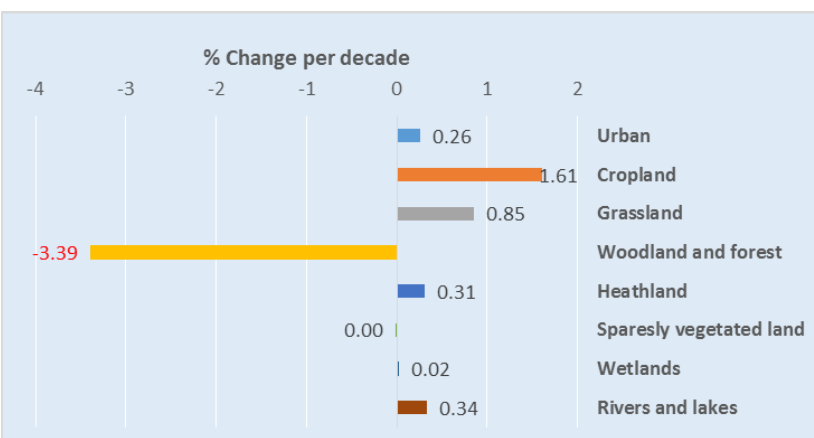




Trends in ecosystems:
Substantial loss of cropland but strong growth of forest
Trends in ecosystem services:
Agricultural intensification with higher yields on less area. Reported data suggest more sustainable water use in agriculture and industry. Varying trends for regulating services.

ROMANIA

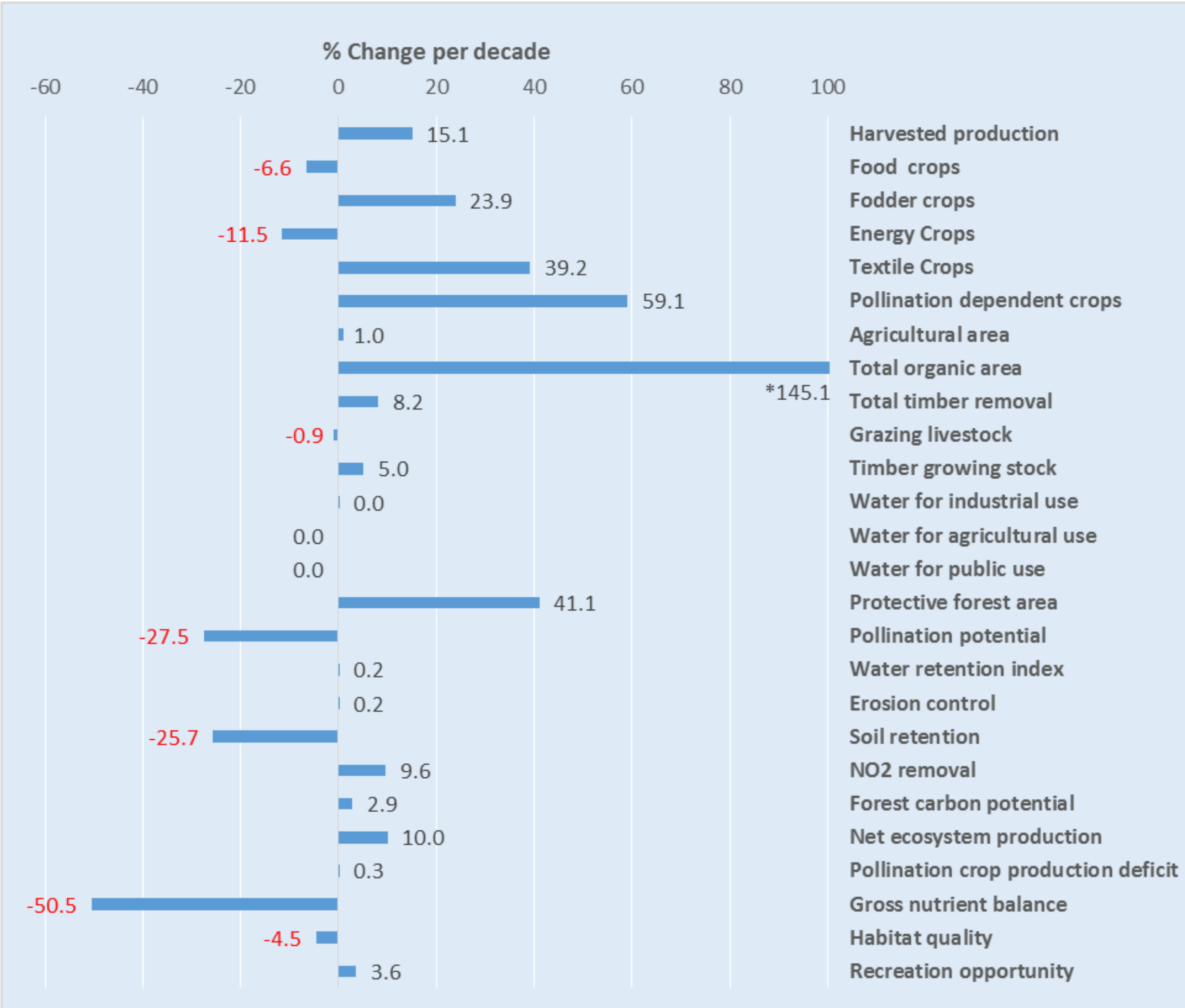


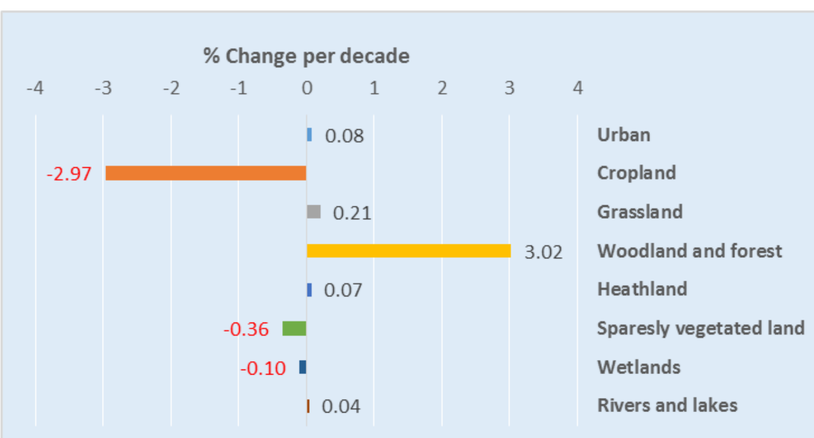


Trends in ecosystems: Cropland and grassland show positive trends but forest area decreased. Contradiction with the trend in agricultural area.

Trends in ecosystem services: Strongly increased agricultural production which trades off with several regulating ecosystem services.

SWEDEN

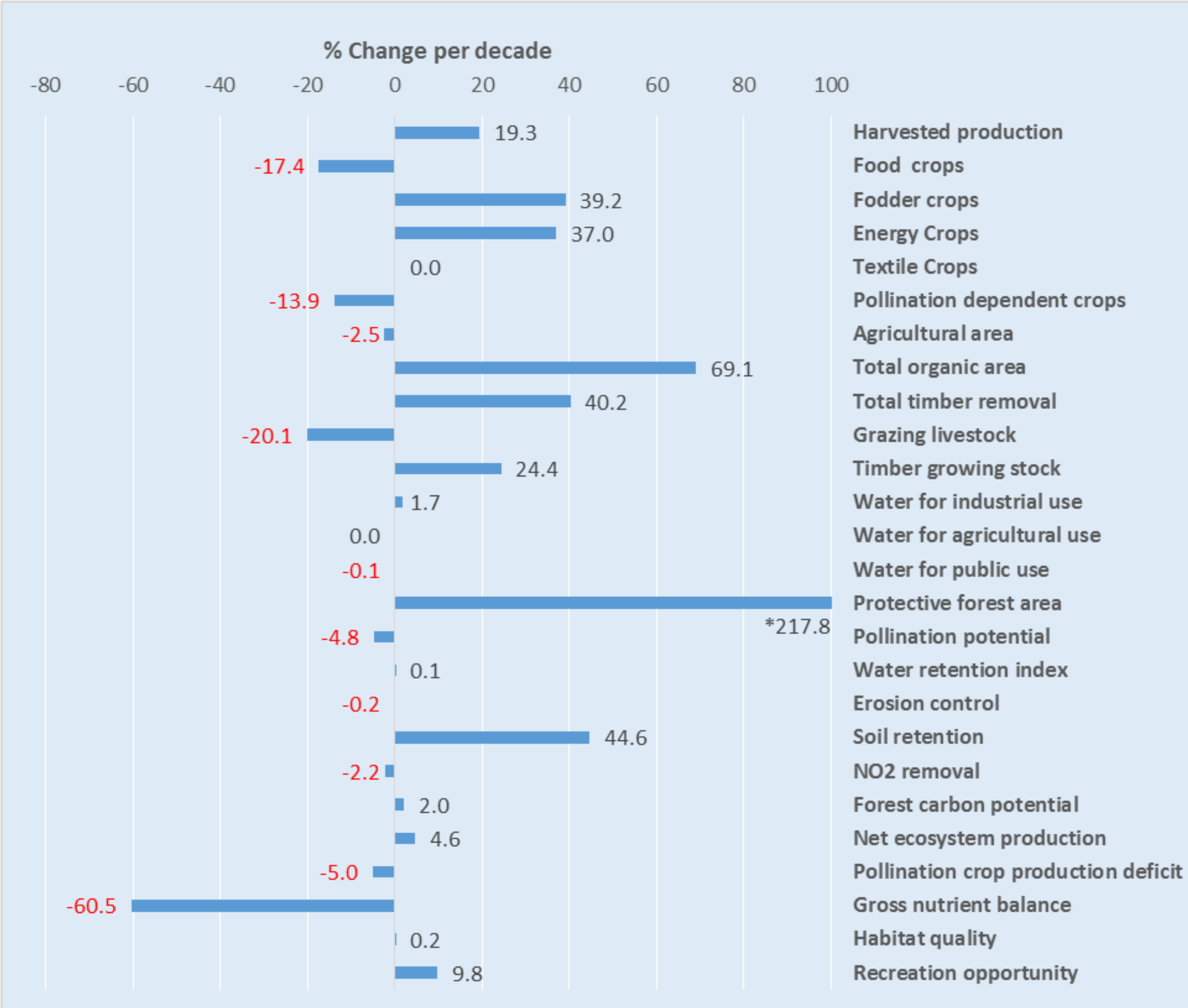


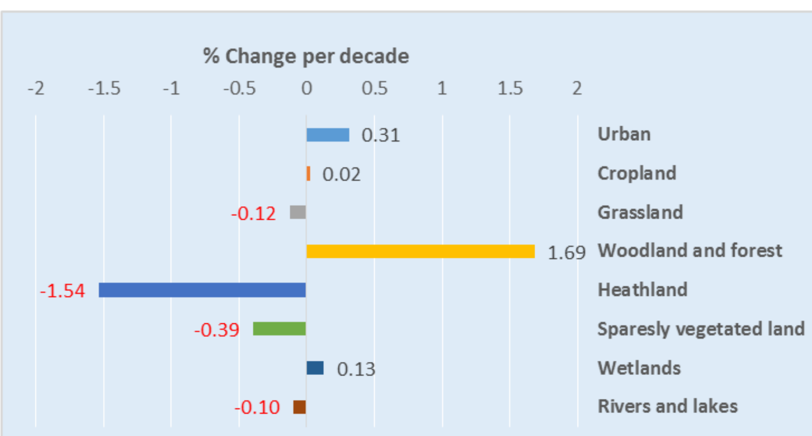


Trends in ecosystems:
Gains in forest and woodland but losses in cropland.

Trends in ecosystem services:
Doubling of area under organic crop production. Increasing harvests of crops and round wood. Higher ecosystem productivity but losses of pollination potential and habitat quality.

SLOVENIA

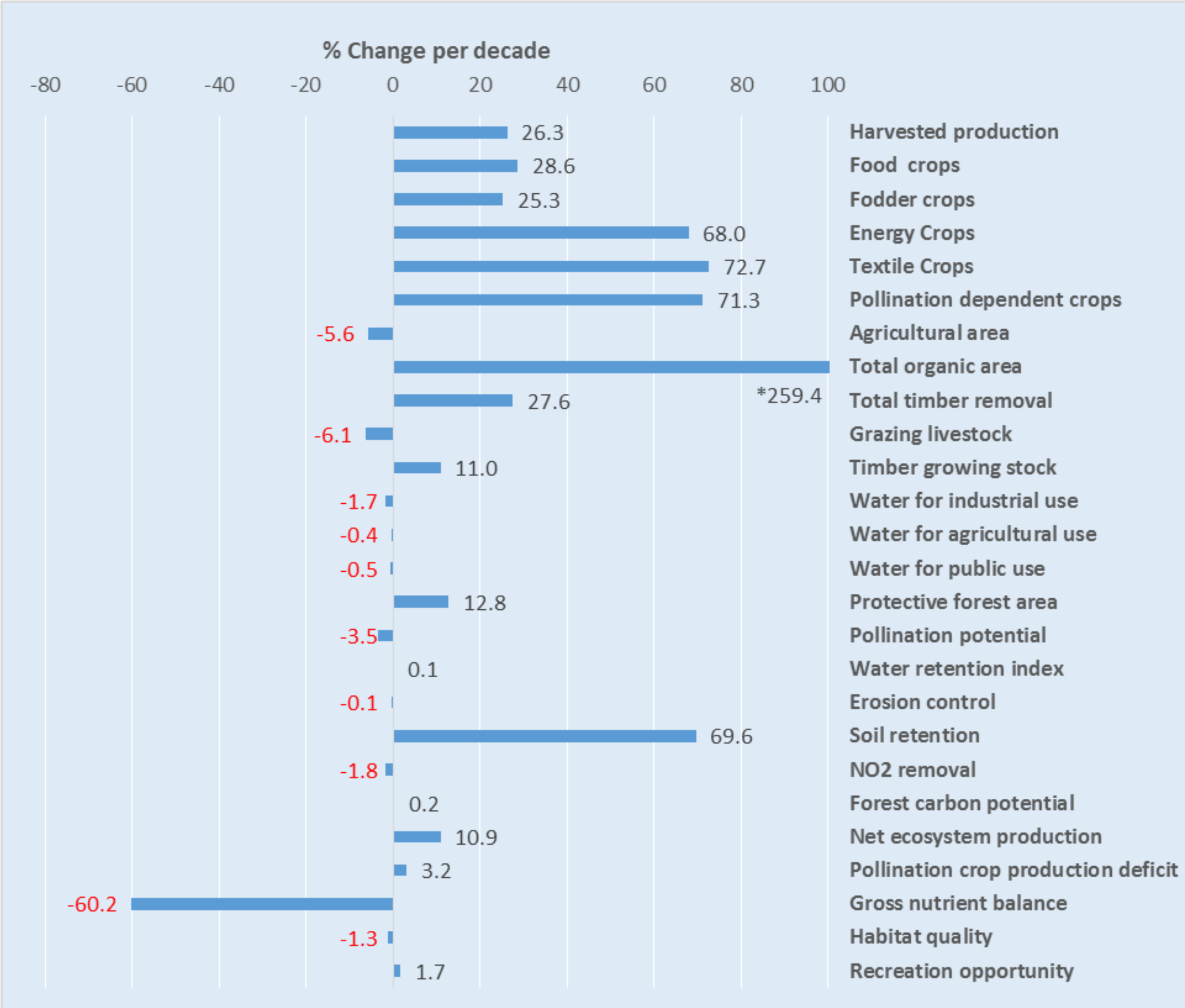


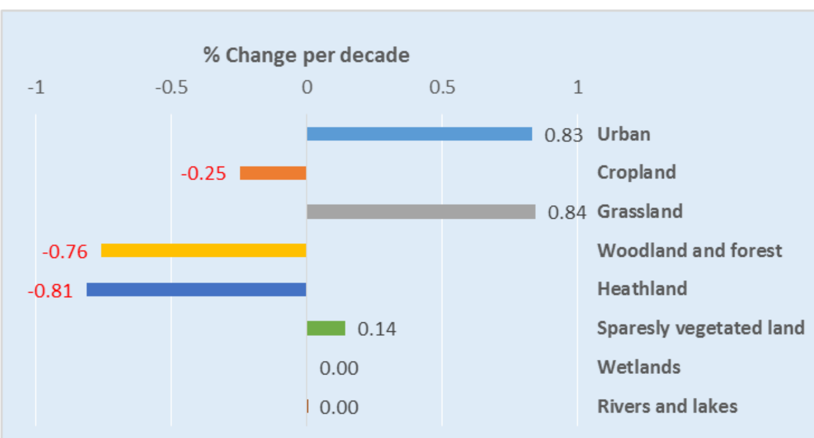


Trends in ecosystems:
Succession from heathland to forest but no trends in cropland.

Trends in ecosystem services:
Varying trends but in general a positive profile with increasing regulating services.

SLOVAKIA

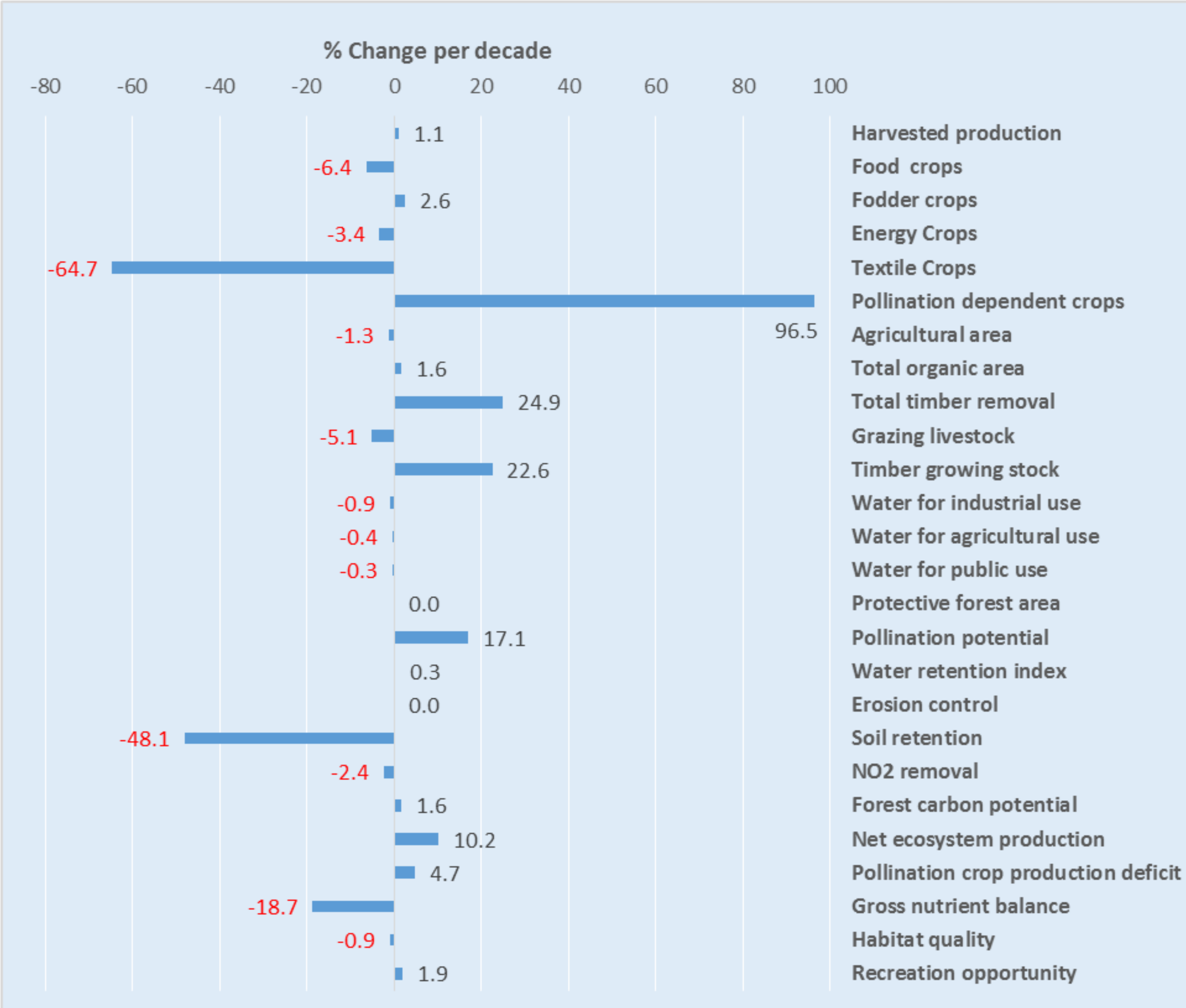


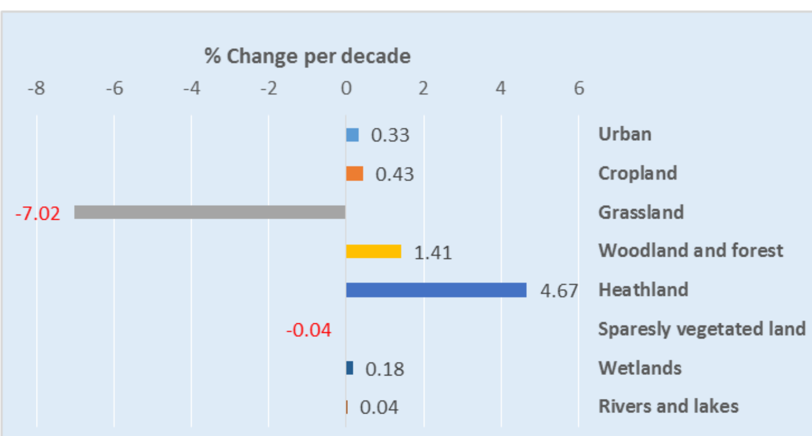


Trends in ecosystems: Considerable growth of urban area and loss in forest and woodland which contradicts the direction of other forest indicators.

Trends in ecosystem services: Increased production of crops on less area suggestion more intensive use. Negative trends for pollination and habitat quality.

UNITED KINGDOM





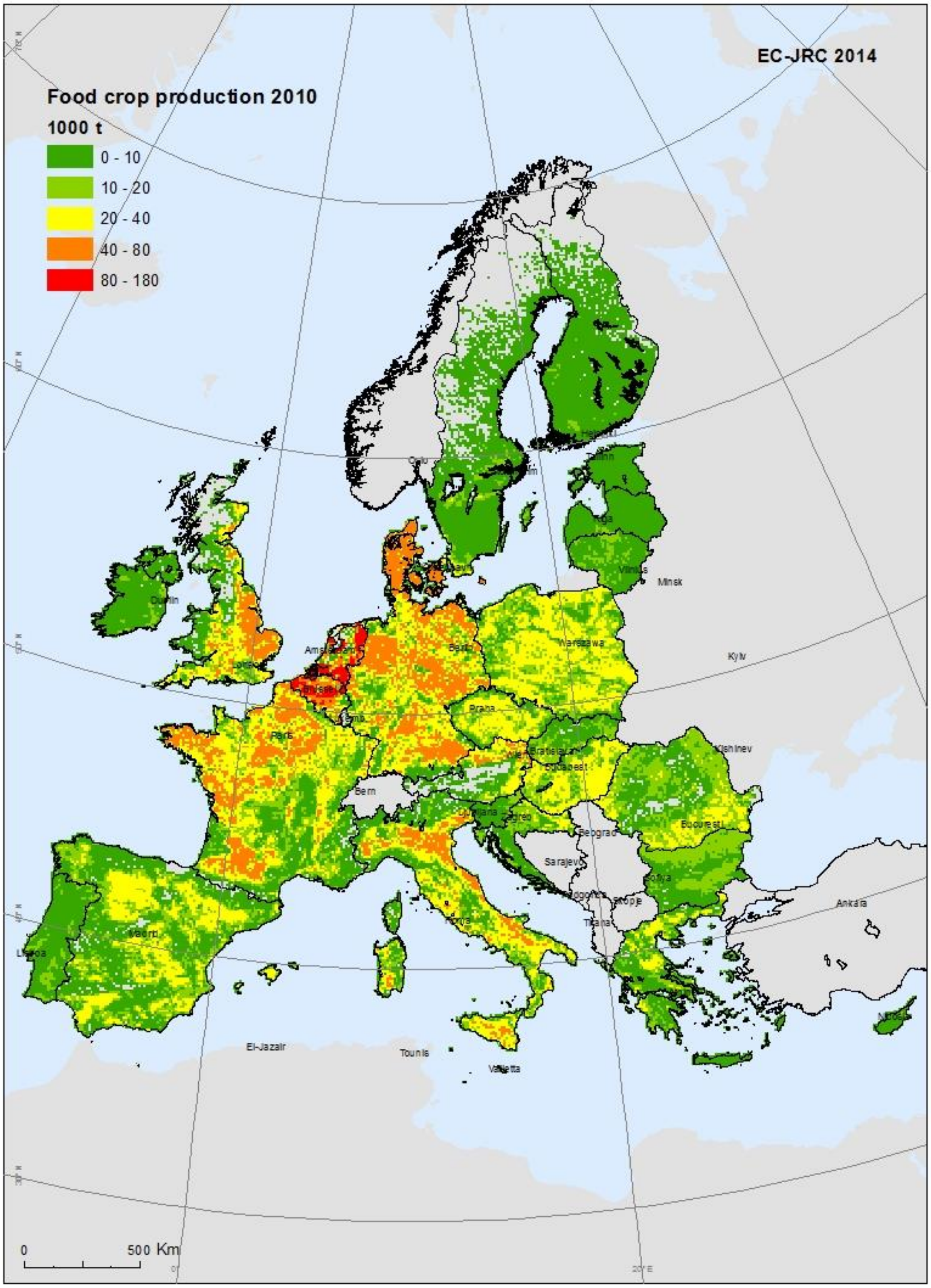
Trends in ecosystems:
Notable loss of grassland and increasing heathland and shrub.

Trends in ecosystem services:
Varying trends in ecosystem services with a notable increase of crops which require pollination.

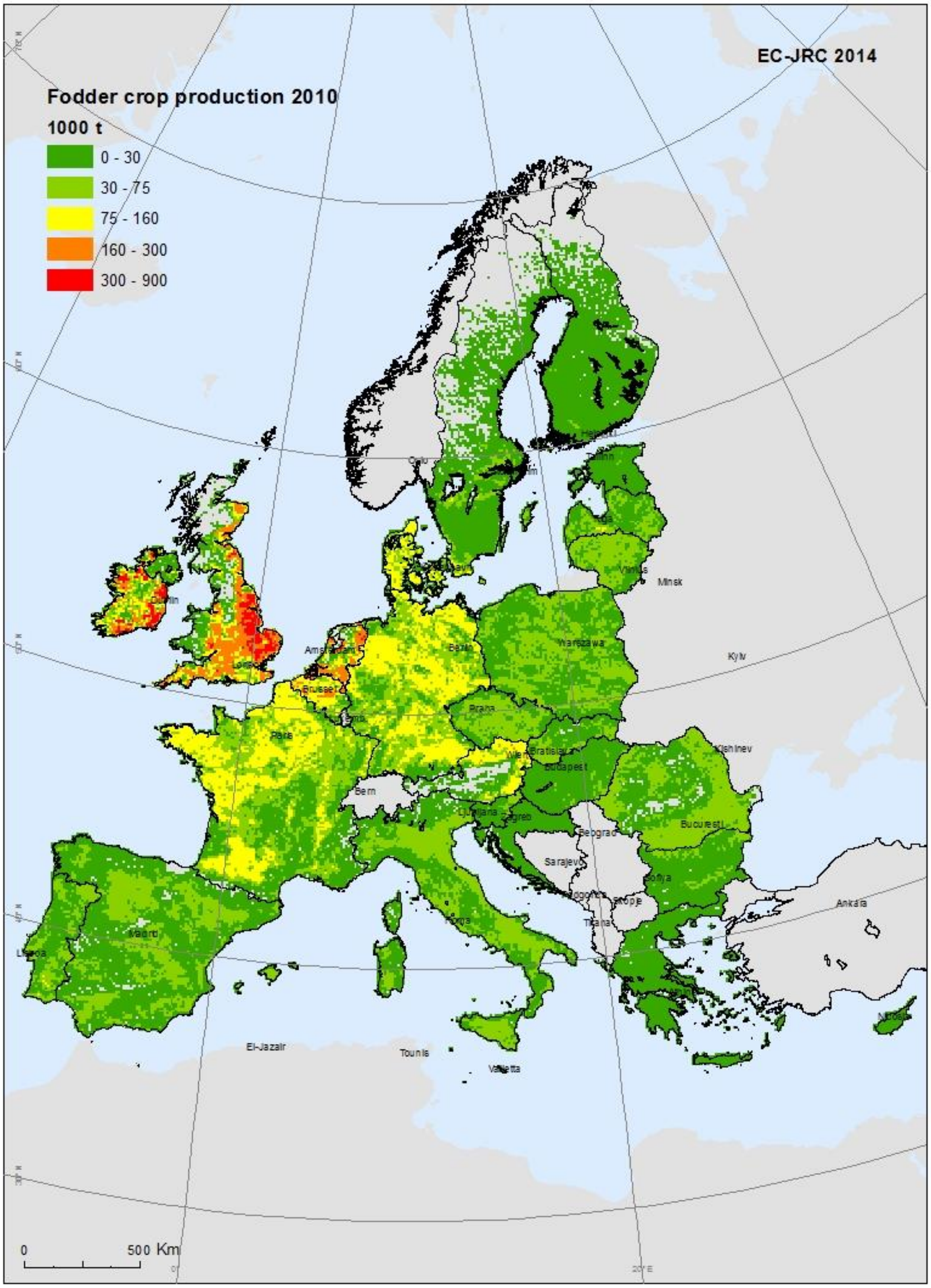
Annex 4. Maps

Table A4.1. Ecosystem services maps

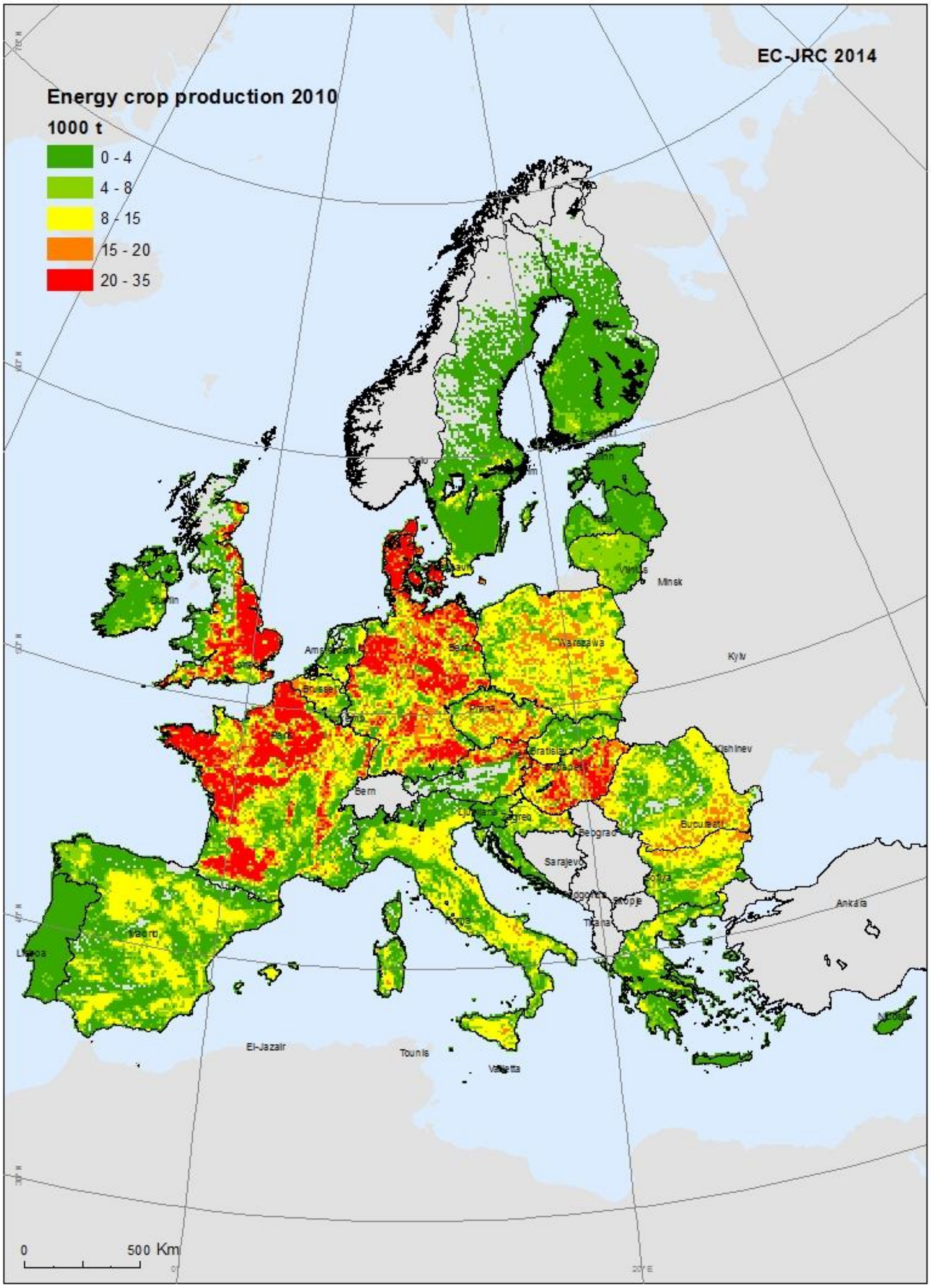
Indicator	Year	Mapping method	Map number
Agricultural area		Not mapped	
Harvested production food crops	2010	Downscaled	A1
Harvested production fodder crops	2010	Downscaled	A2
Harvested production energy crops	2010	Downscaled	A3
Harvested production textile crops	2010	Downscaled	A4
Area under organic farming	2010	Downscaled	A5
Grazing livestock	2010	Downscaled	A6
Total timber removal	2010	Downscaled	A7
Growing stock in forests and other wooded land	2010	Downscaled	A8
Water abstraction for industrial use	2010	Downscaled	A9
Water abstraction for agricultural use	2010	Downscaled	A10
Water abstraction for public use	2010	Downscaled	A11
Proportion of renewable water withdrawn for industrial use		Not mapped	
Proportion of renewable water withdrawn for agricultural use		Not mapped	
Proportion of renewable water withdrawn for public use		Not mapped	
Forest area with protective function	2010	Downscaled	A12
Pollination potential	2010	ESTIMAP	A13
Water Retention Index	2010	ESTIMAP	A14
Capacity of ecosystems to avoid soil erosion	2010	ESTIMAP	A15
Average soil retention	2010	ESTIMAP	A16
Removal of NO_2 by urban green areas	2010	ESTIMAP	A17
Habitat quality	2010	ESTIMAP	A18
Proportion of green areas in the high density area of cities		Not mapped	
Net ecosystem productivity	2009-2011	Average based on Spot Vegetation NDVI data	A19
Forest carbon potential	2010	ESTIMAP	A20
Pollination crop production deficit	2010	Downscaled	A21
Gross nutrient balance	2008	Downscaled	A22
Proportion of high provision easily accessible areas in the recreation opportunity spectrum	2010	Mapped the Recreation Opportunity Spectrum using ESTIMAP	A23
SPA		Map of the Natura 2000 sites	A24
SCI			



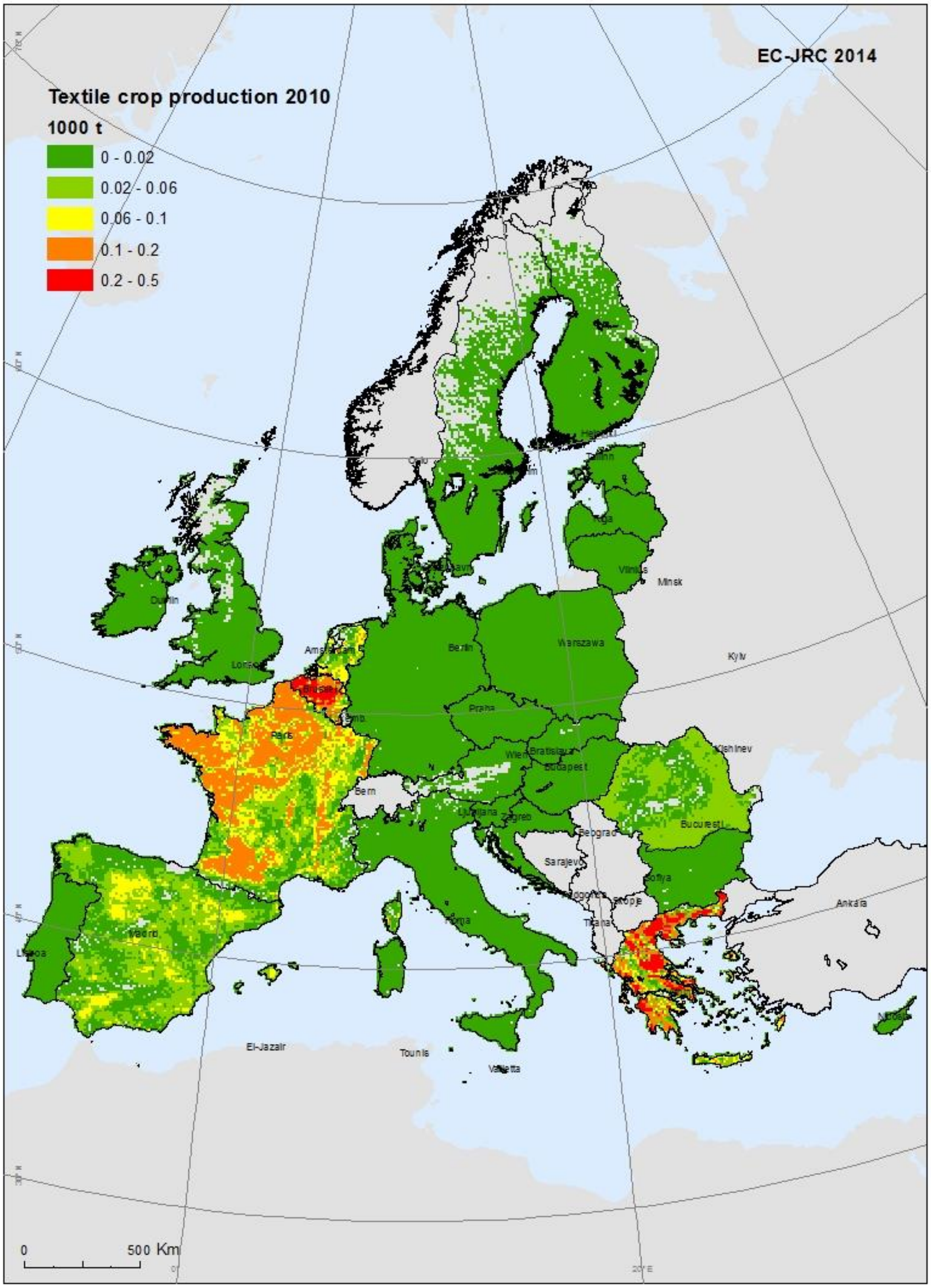
MAP A1 Harvested production food crops



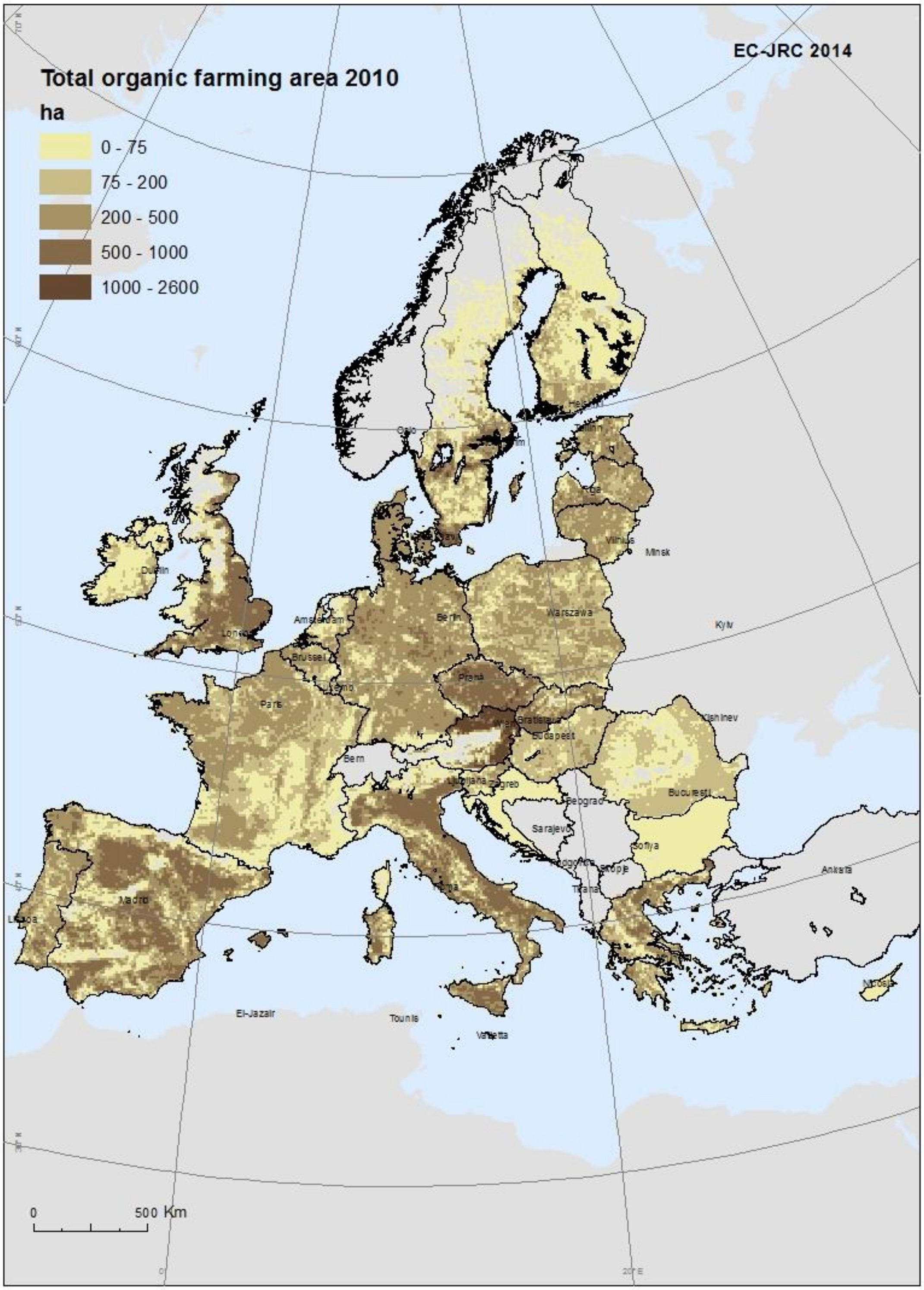
MAP A2 Harvested production fodder crops



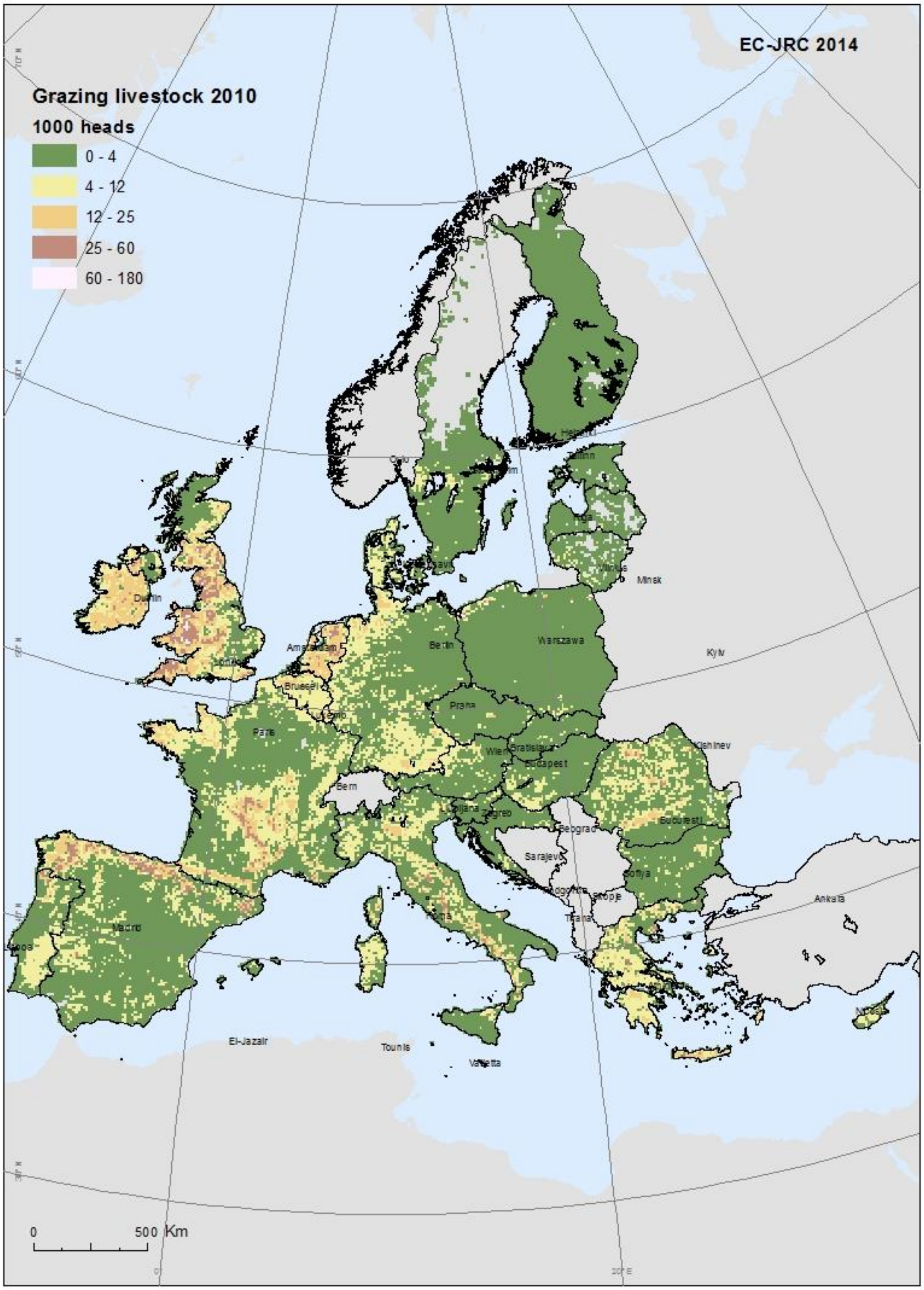
MAP A3 Harvested production energy crops



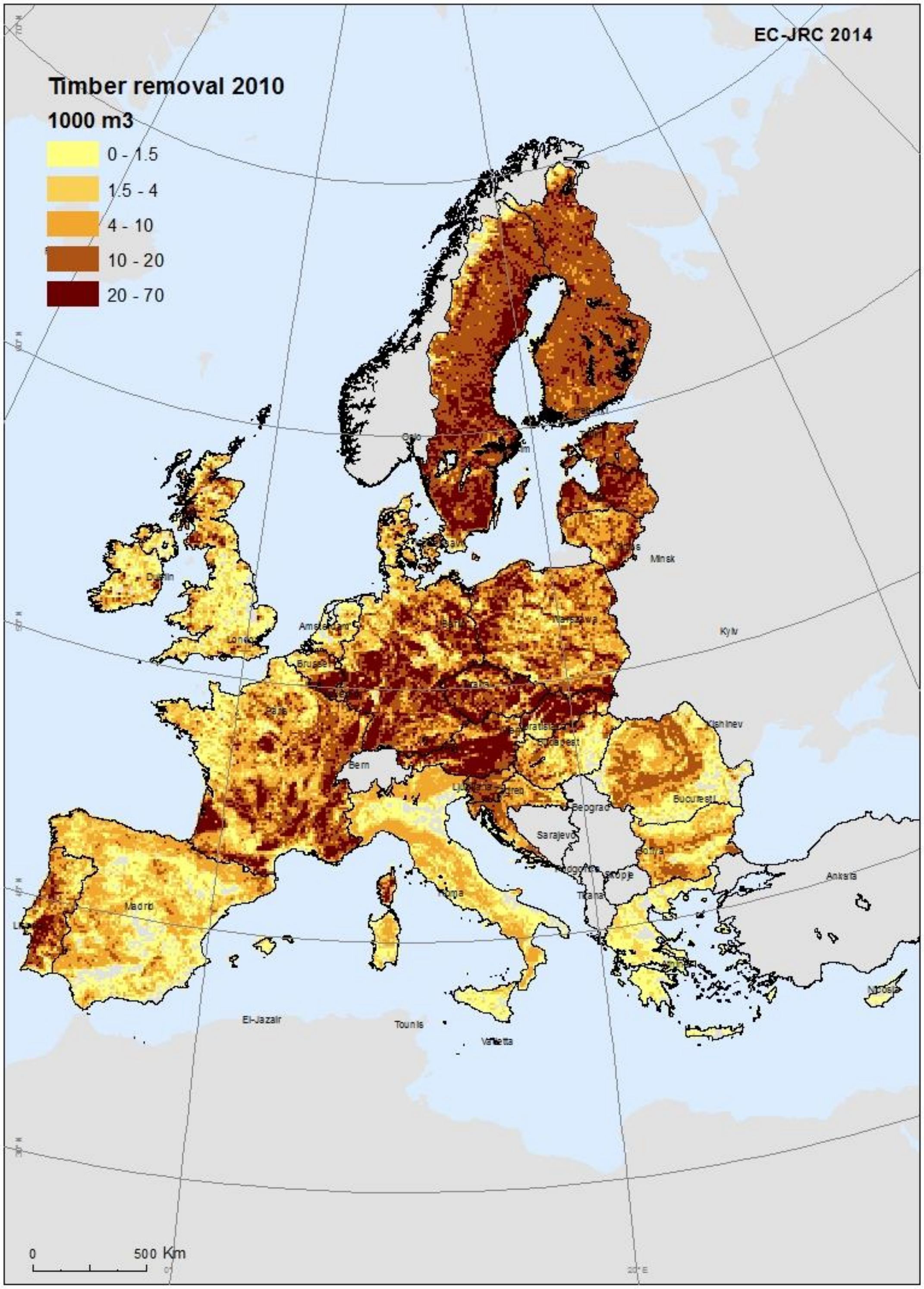
MAP A4 Harvested production textile crops



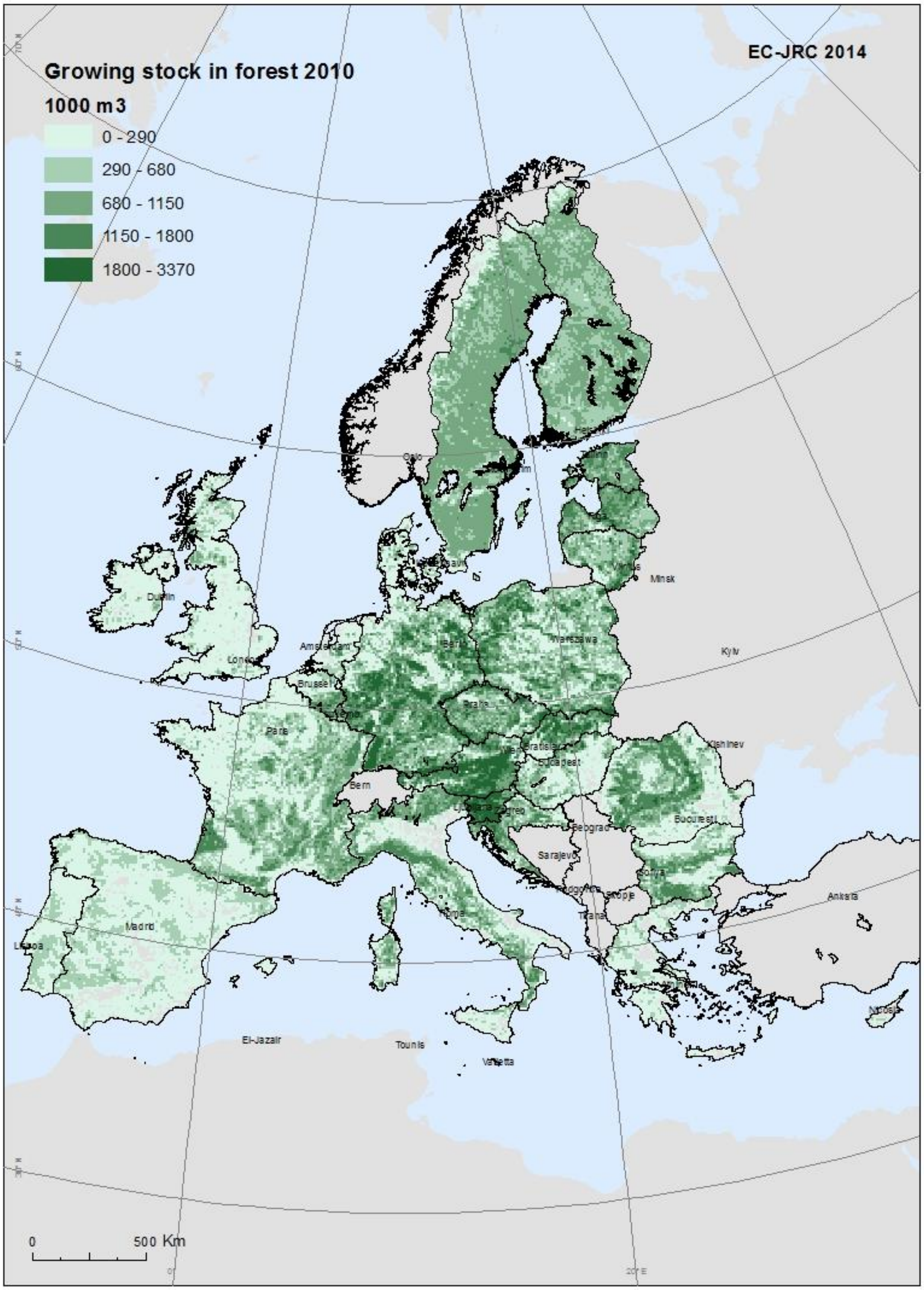
MAP A5 Area under organic farming



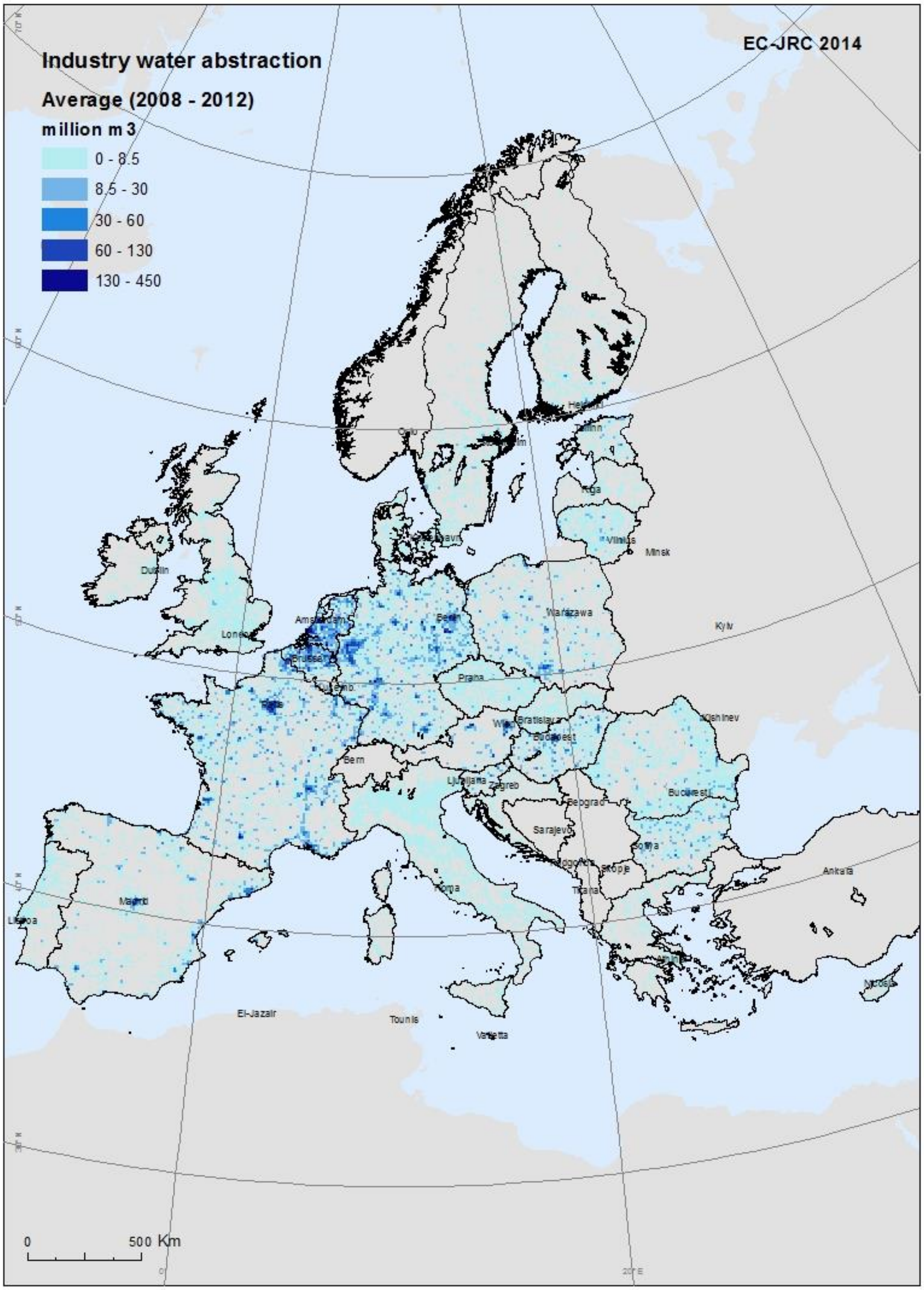
MAP A6 Grazing livestock



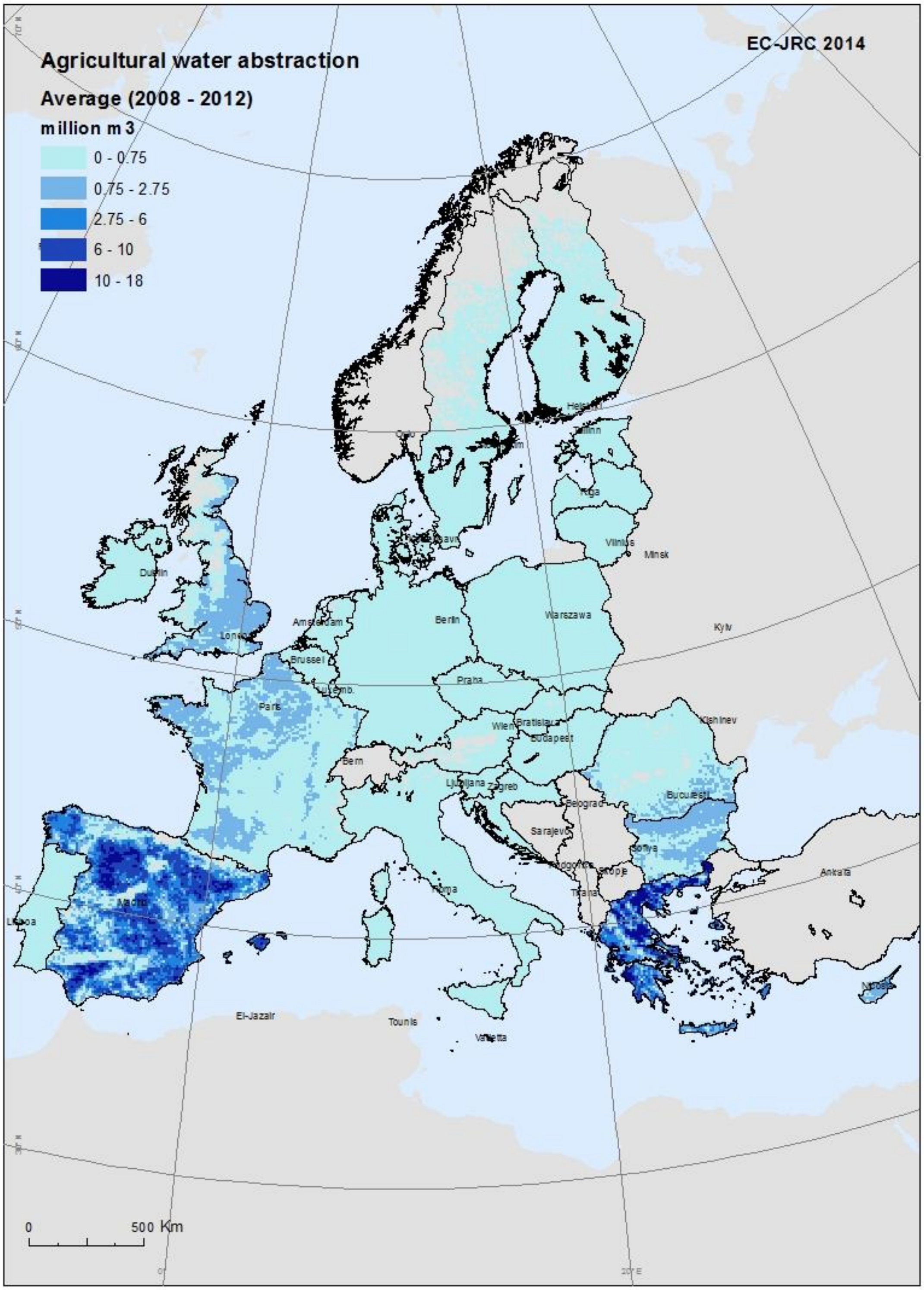
MAP A7 Total timber removal



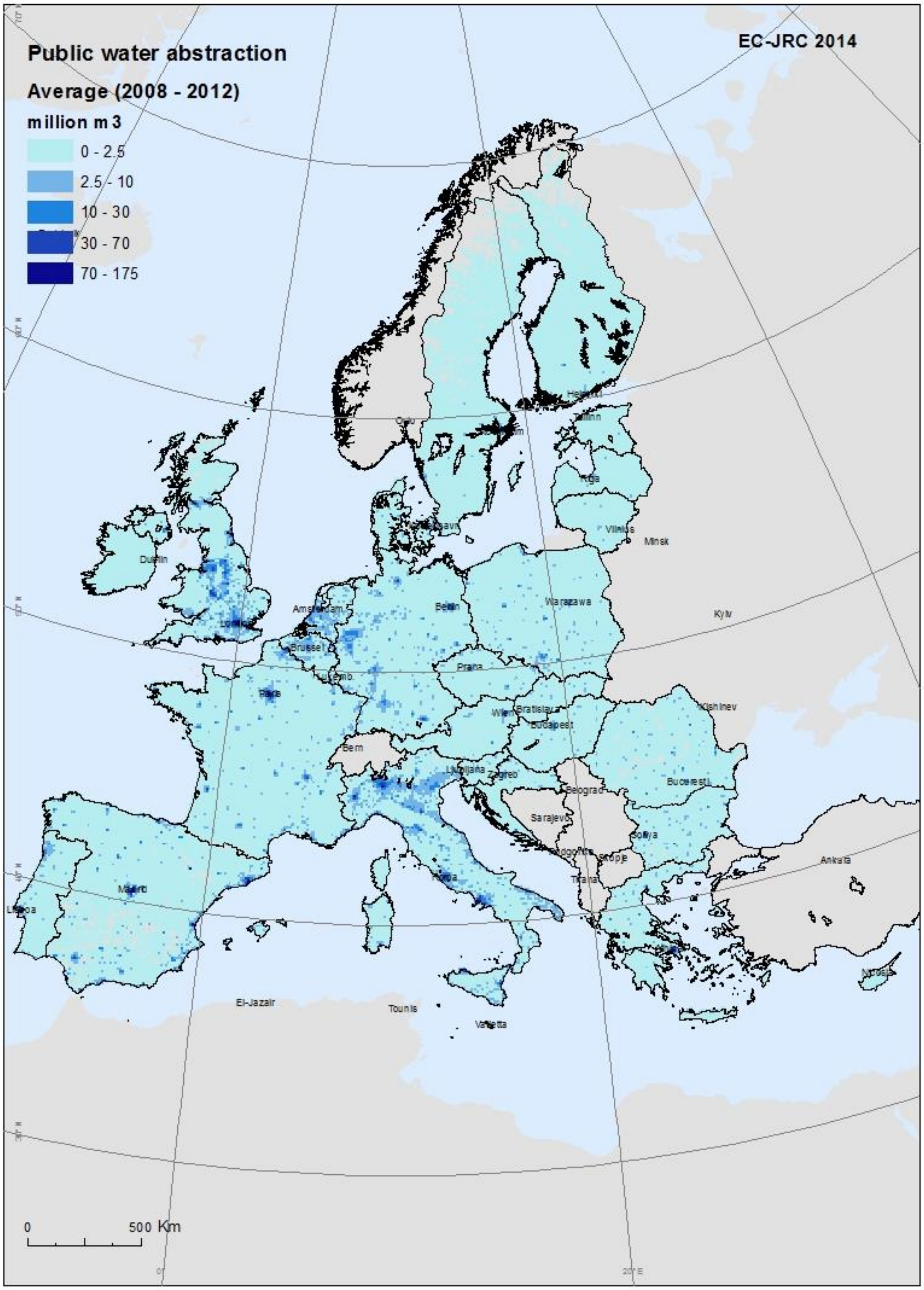
MAP A8 Growing stock in forests and other wooded land



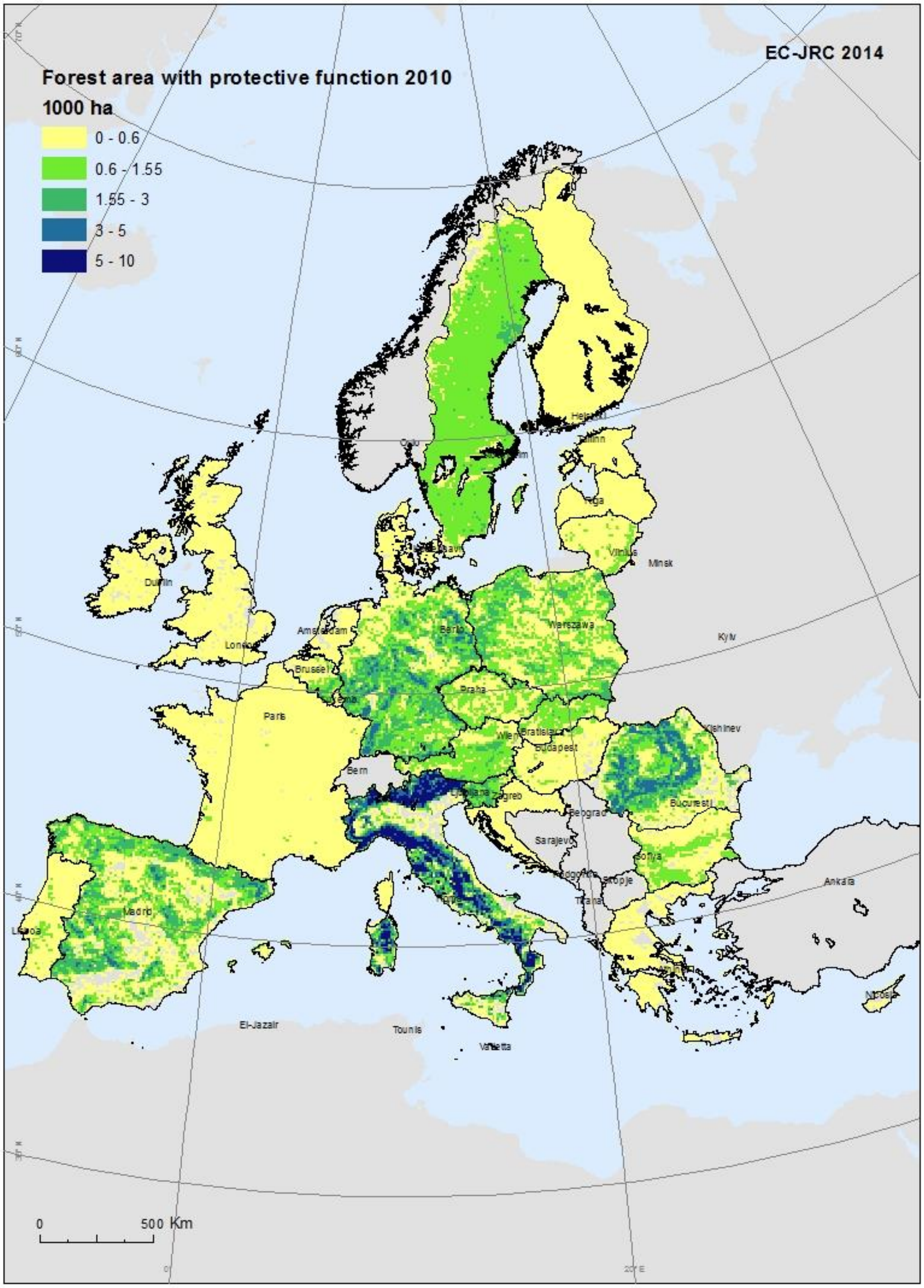
MAP A9 Water abstraction for industrial use



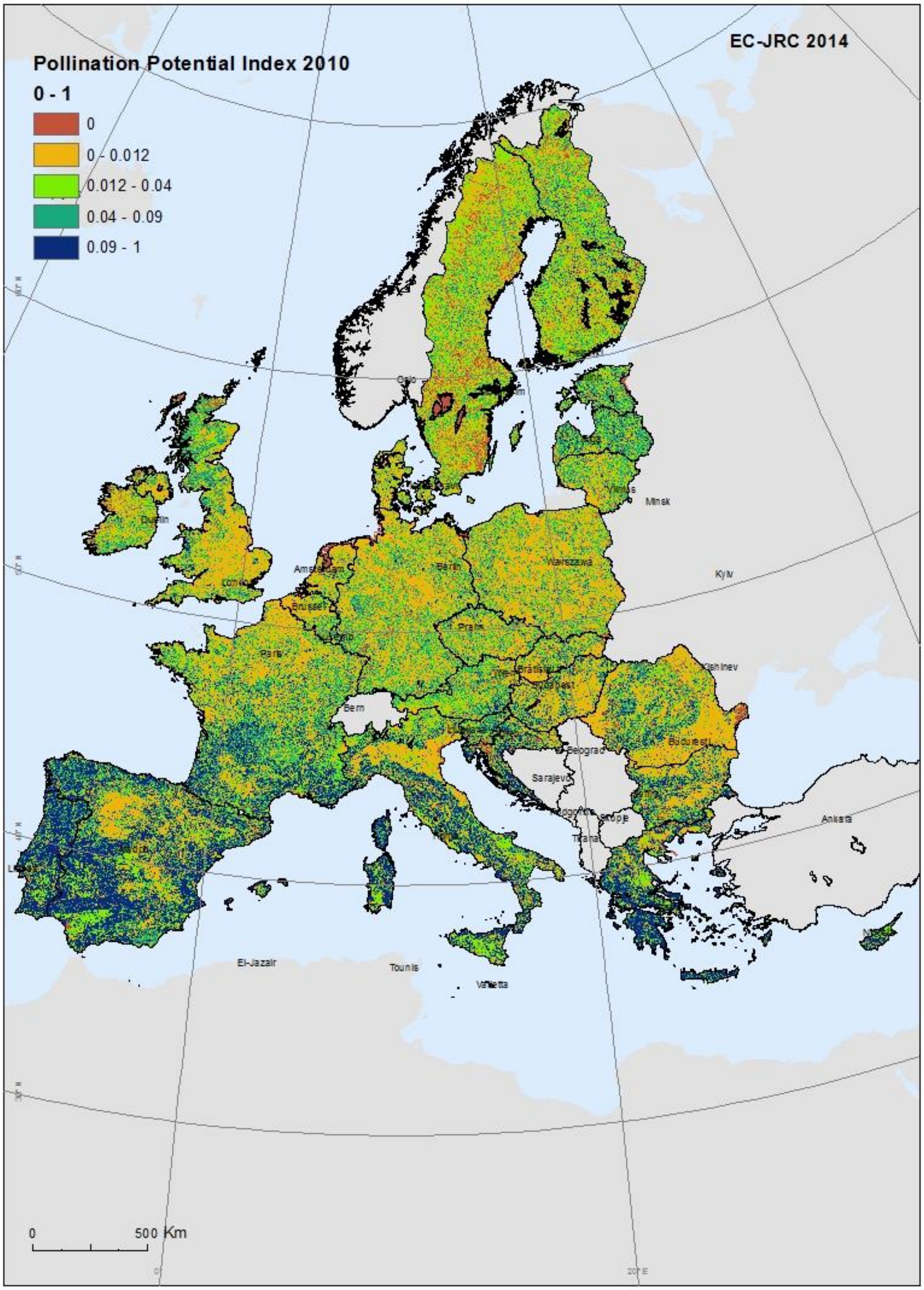
MAP A10 Water abstraction for agricultural use



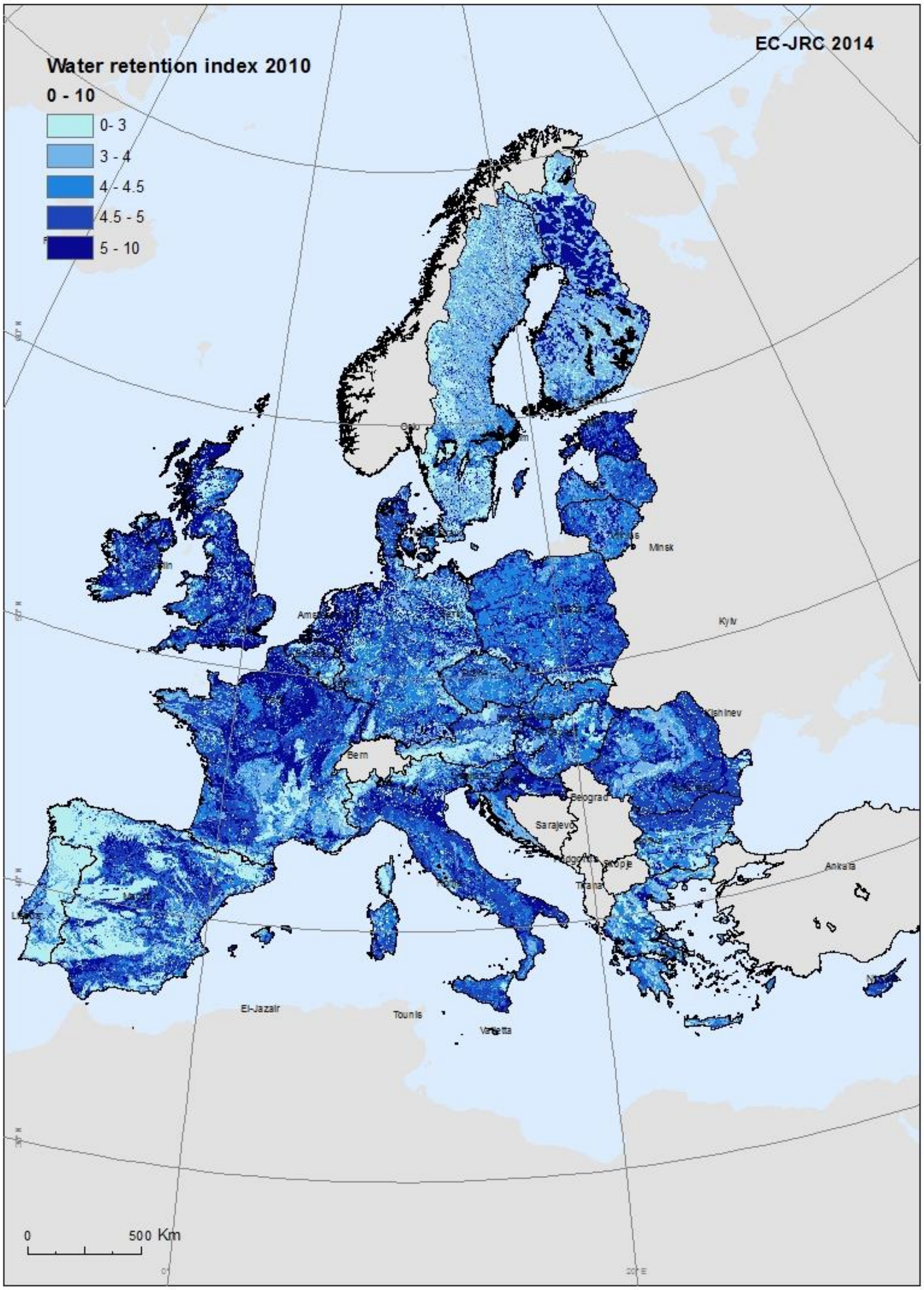
MAP A11 Water abstraction for public use



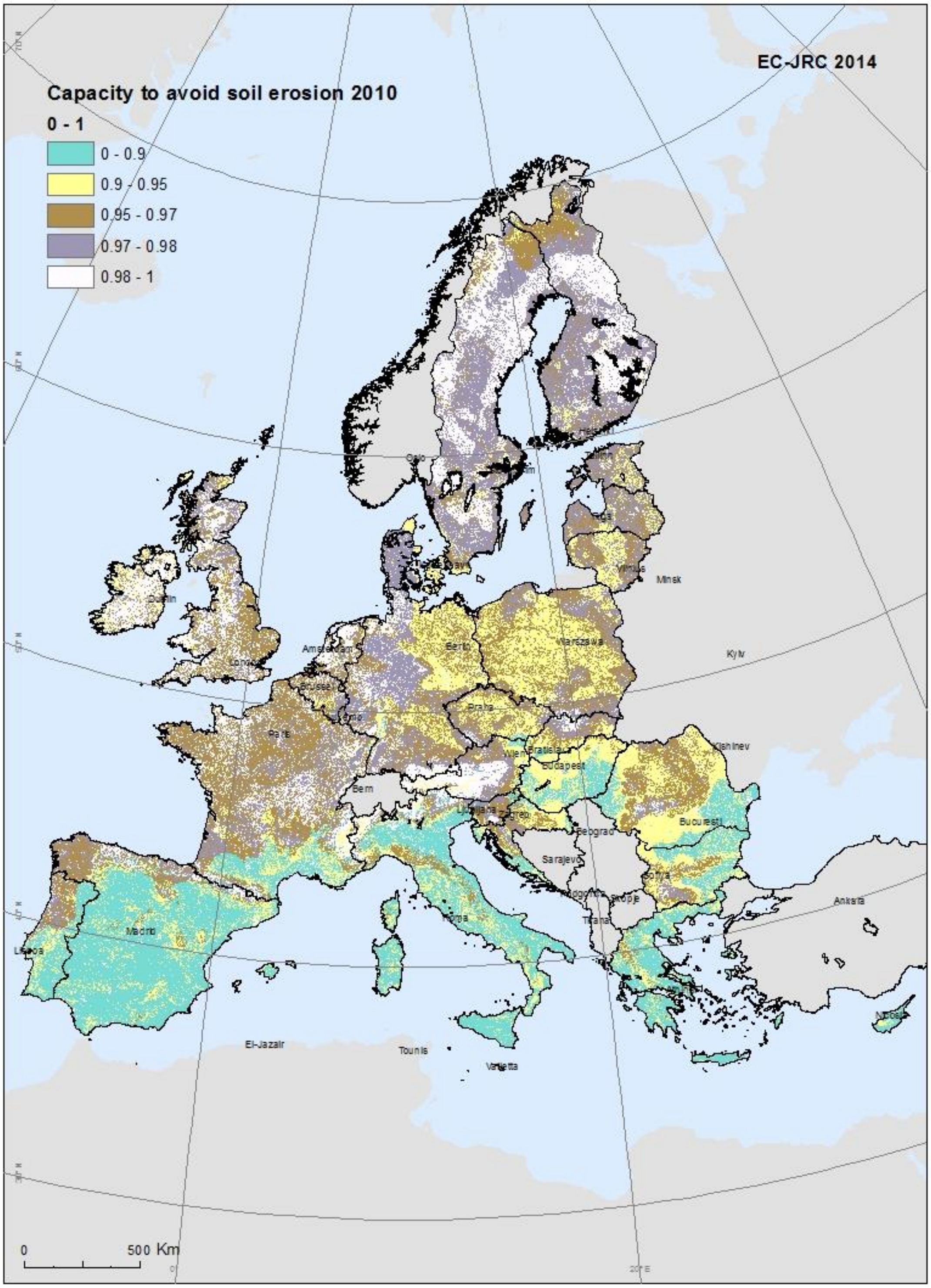
MAP A12 Forest area with protective function



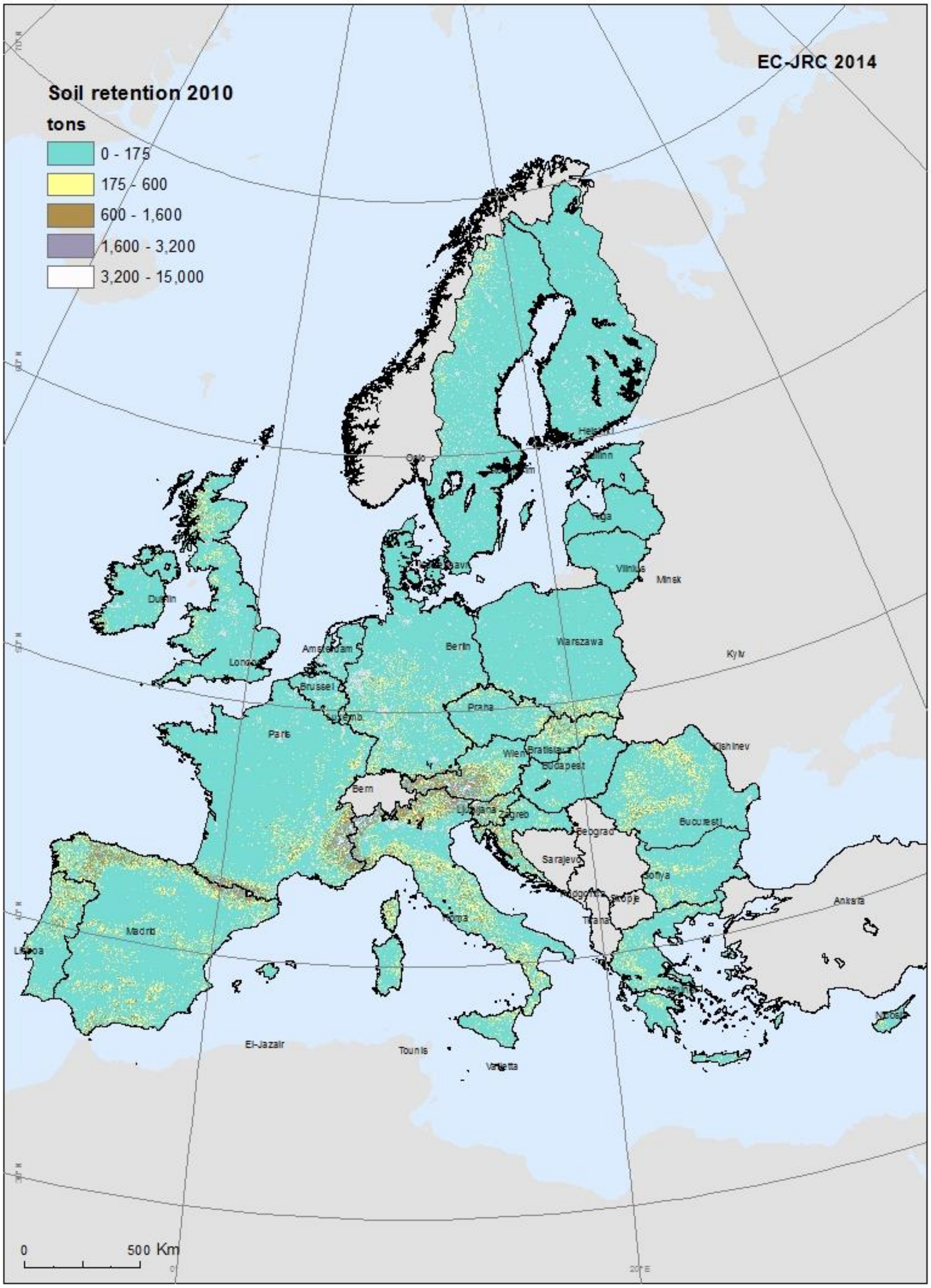
MAP A13 Pollination potential



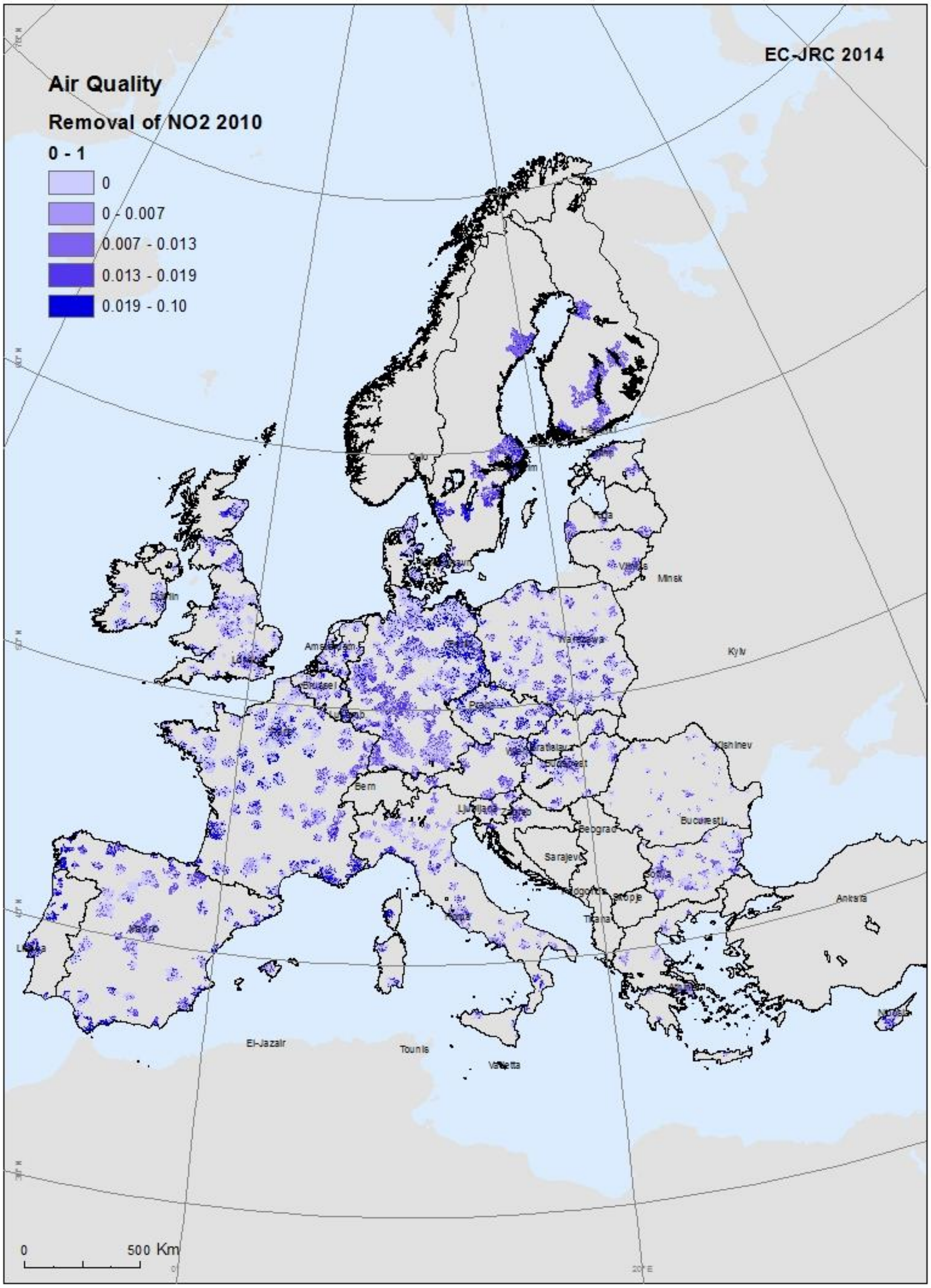
MAP A14 Water Retention Index



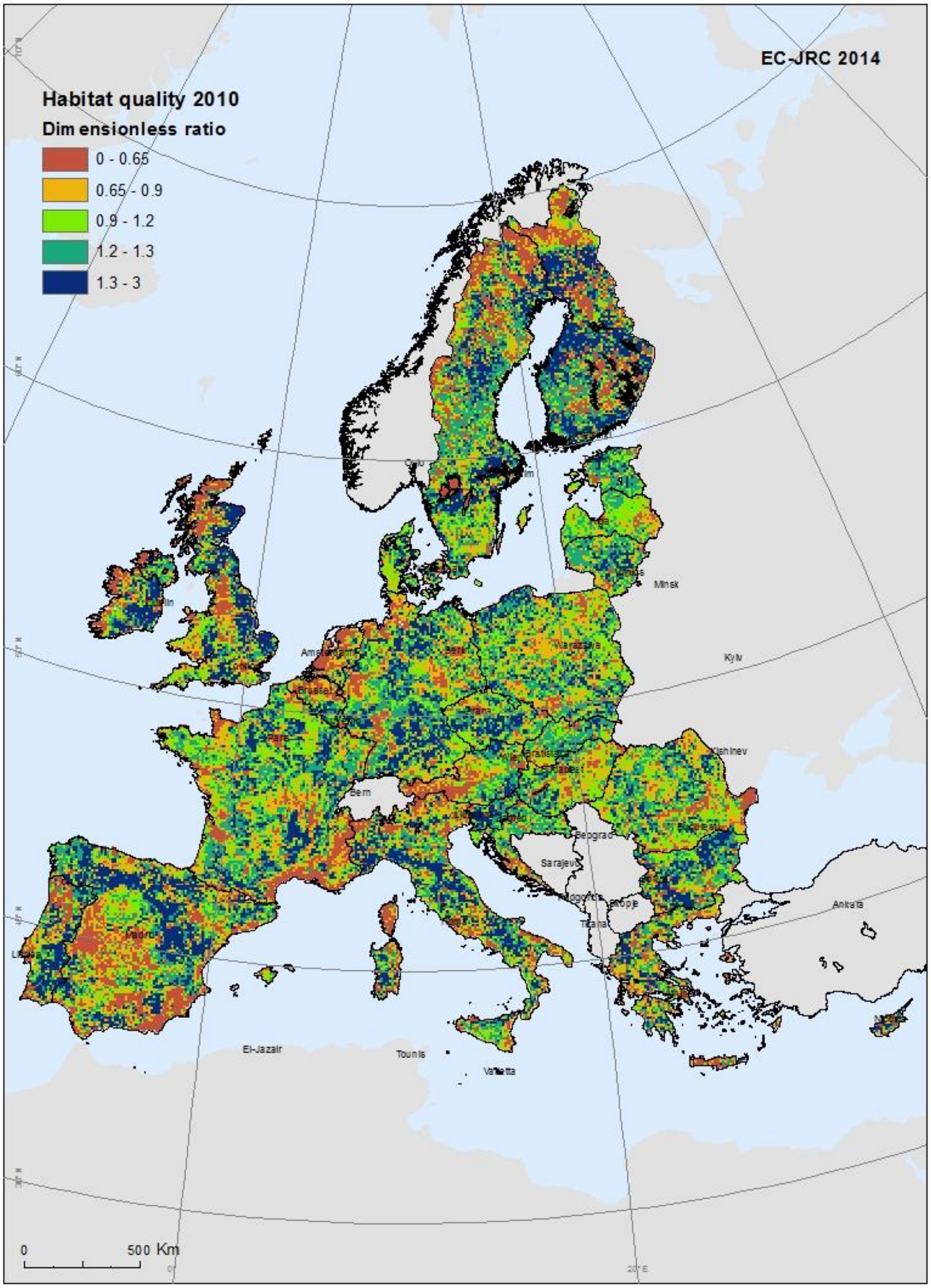
MAP A15 Capacity of ecosystems to avoid soil erosion



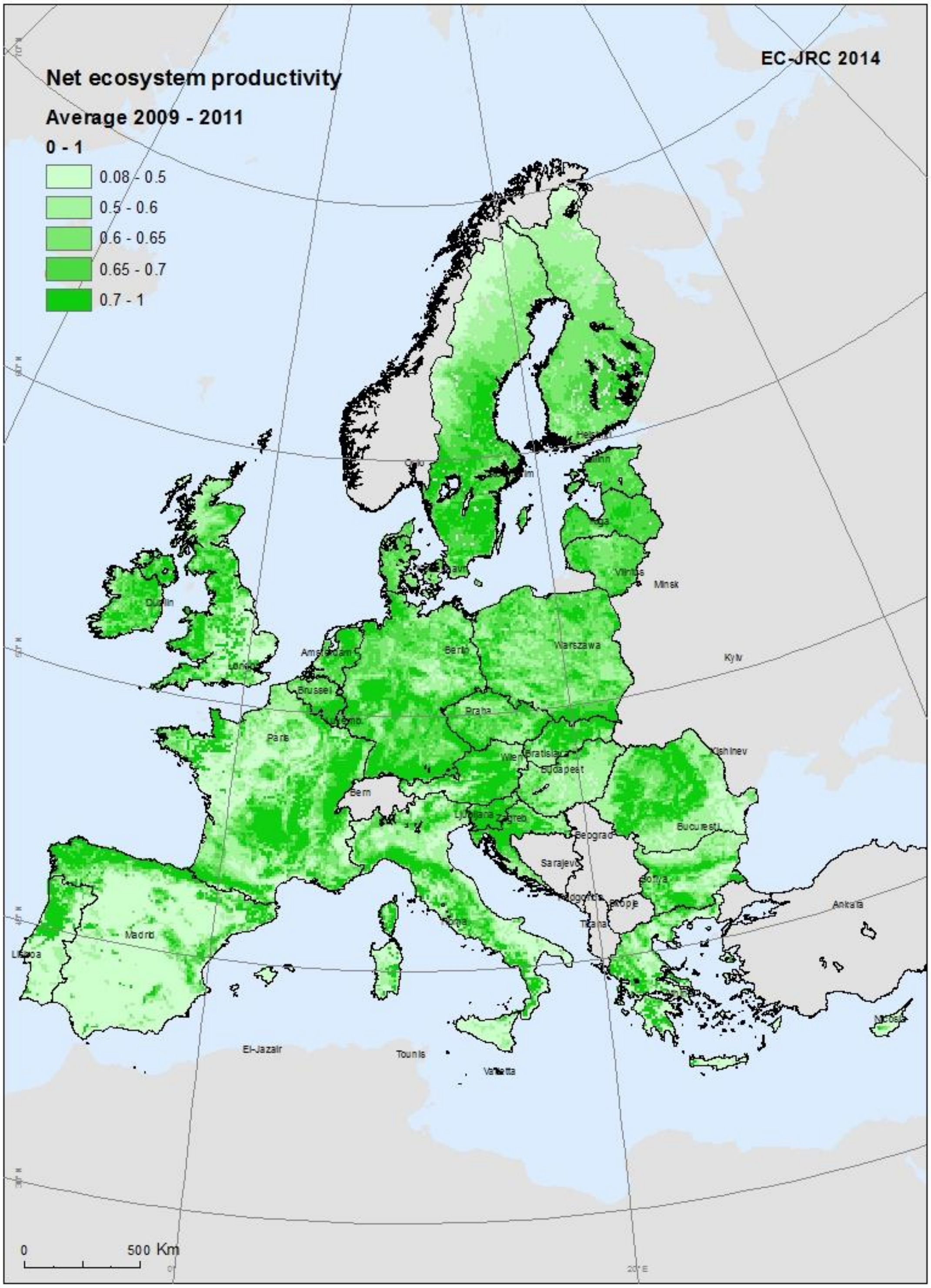
MAP A16 Average soil retention



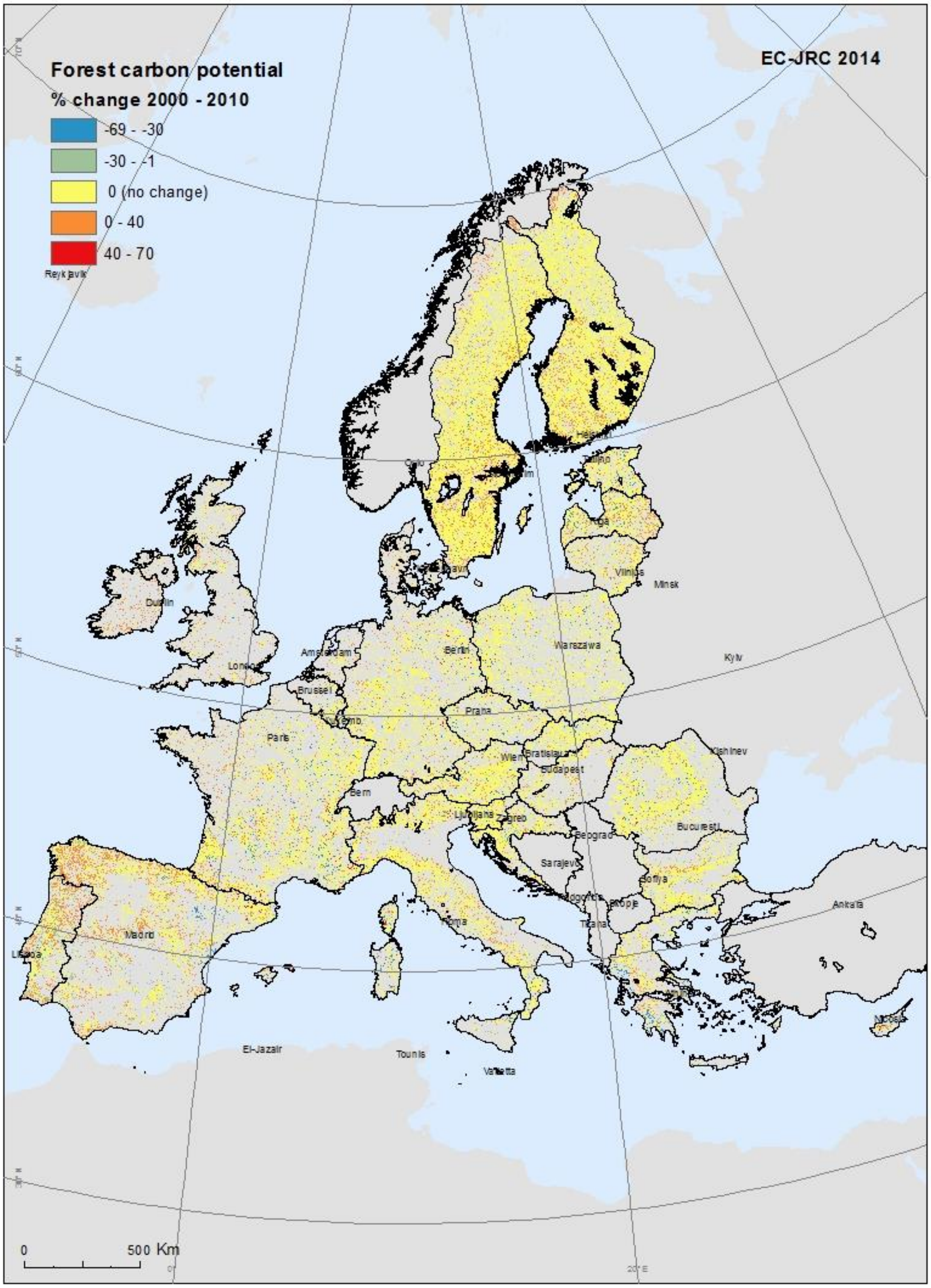
MAP A17 Removal of NO2 by urban green areas



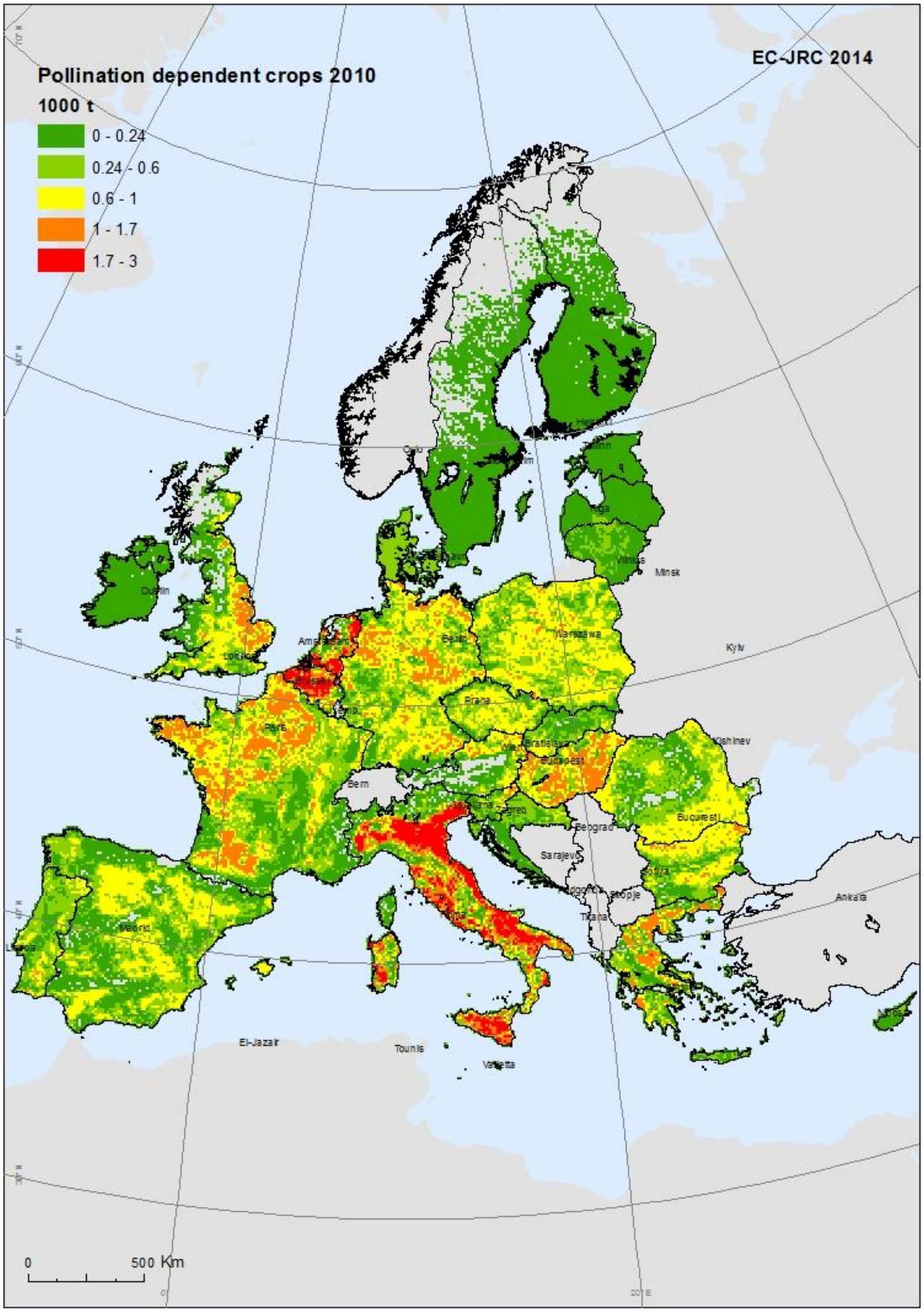
MAP A18 Habitat quality



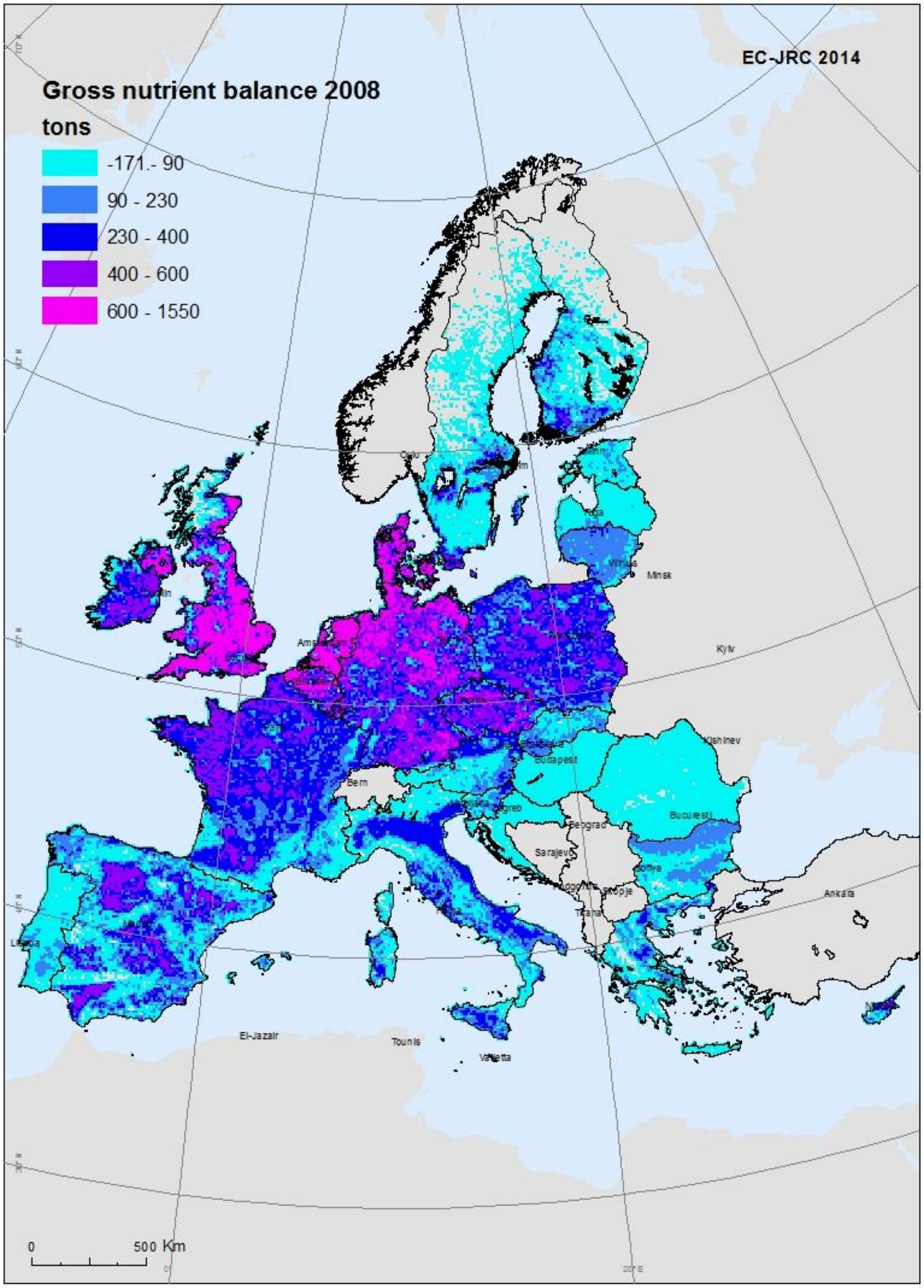
MAP A19 **Net ecosystem productivity**



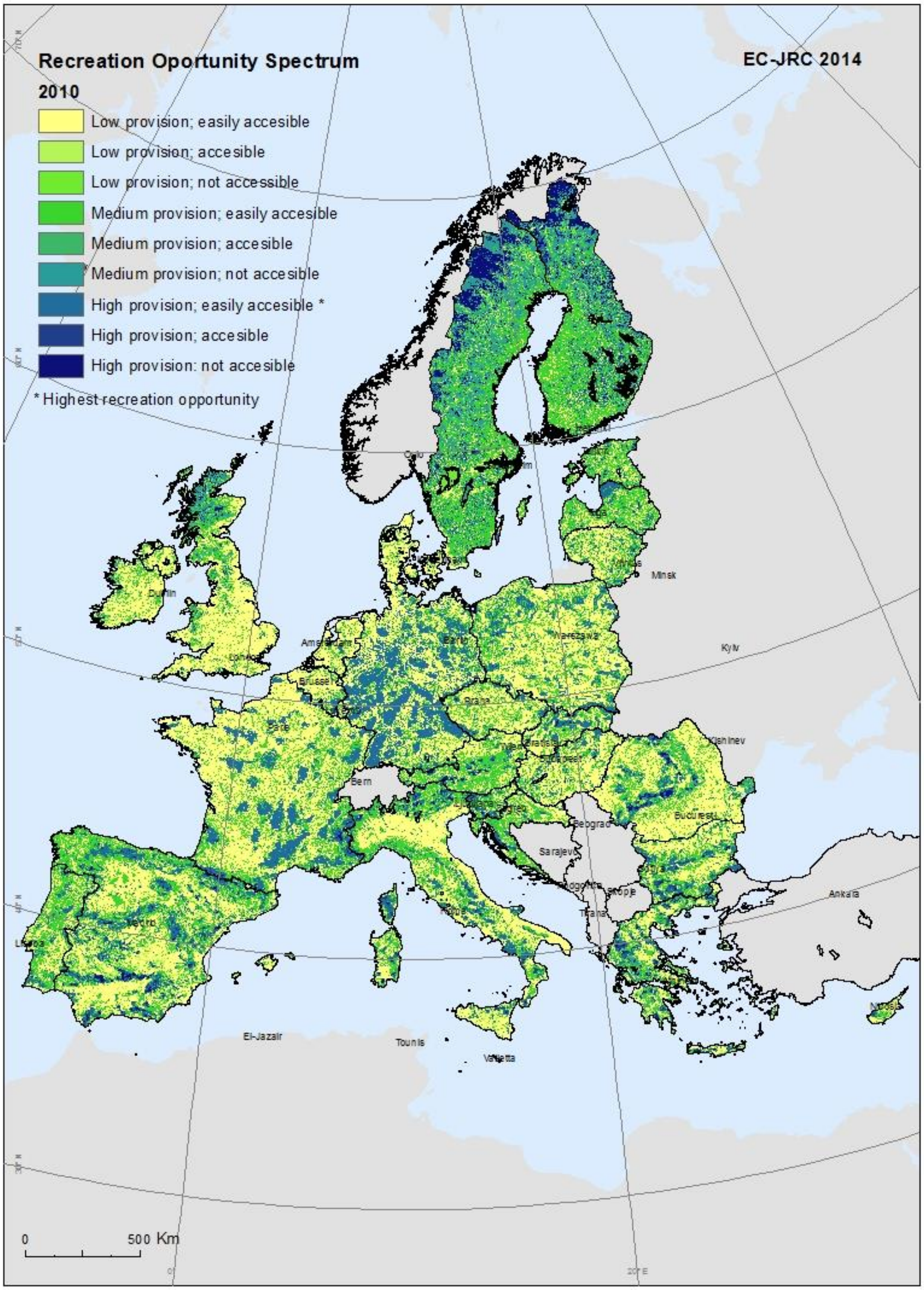
MAP A20 Forest carbon potential



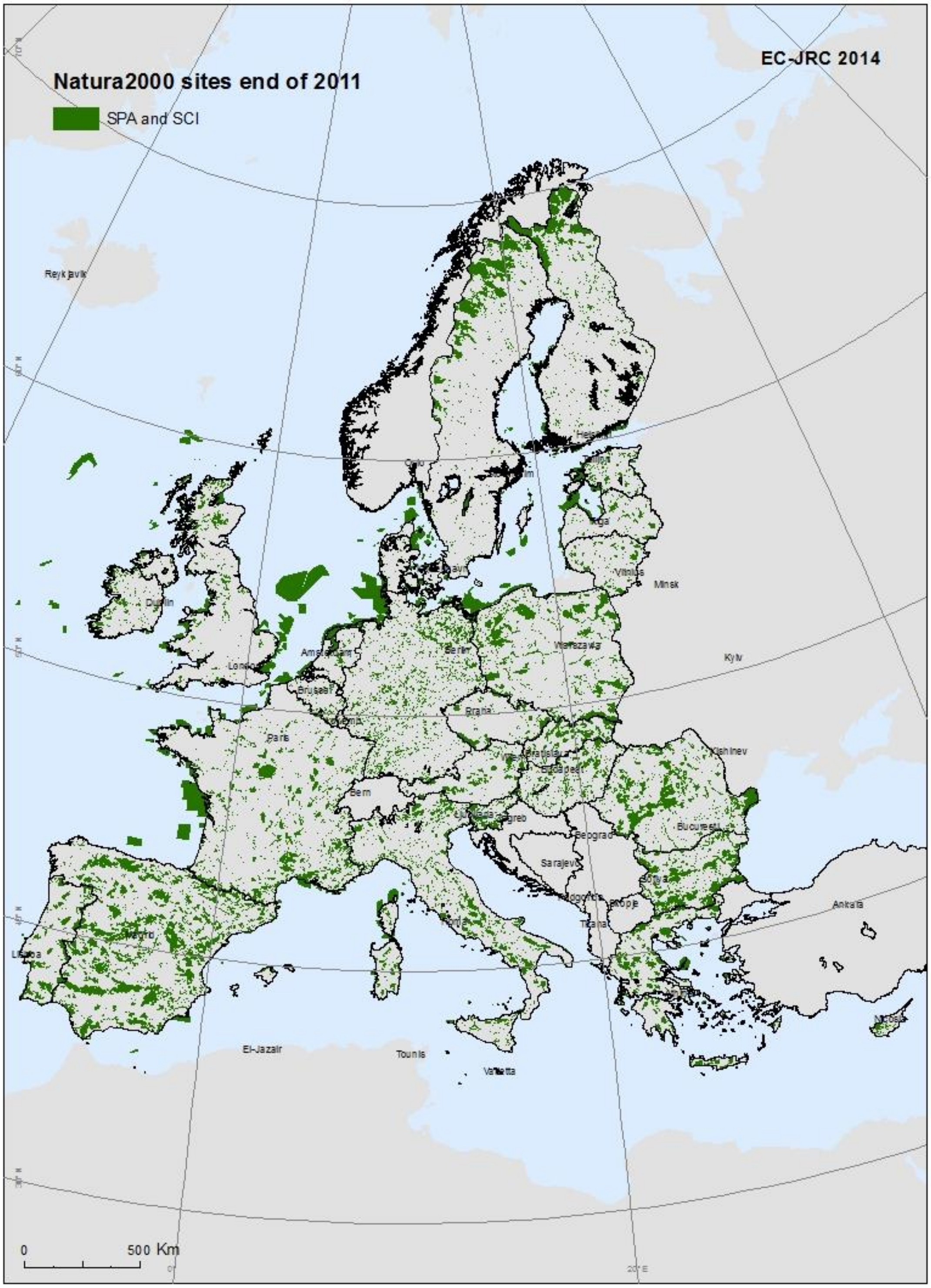
MAP A21 **Pollination crop production deficit (production of crops dependent on pollination)**



MAP A22 Gross nutrient balance



MAP A23 Proportion of high provision easily accessible areas in the recreation opportunity spectrum



MAP A24 The Natura 2000 network

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