Accounting for ecosystems and their services in the European Union

(INCA)

2021 edition

Final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU

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Table of contents

Executive summary

Background – the EU INCA project and why we need ecosystem accounting

The EU INCA project was launched in 2015 to produce a pilot for an integrated system of ecosystem accounting for the EU, while serving as a large-scale test case for the first UN handbook on ecosystem accounting *System of Environmental-Economic Accounting – Experimental Ecosystem Accounting* (SEEA EEA) published in 2014. The results and findings of the INCA project provided feedback for the revised version of the UN handbook *SEEA – Ecosystem Accounting* (SEEA EA), completed and adopted in March 2021. The INCA project has shown that the production of a wide range of ecosystem accounts following the guidance of the SEEA EEA is feasible and it is possible to produce consistent and comparable information on ecosystems and the services they provide to society at the scale of the EU. This report summarises key results of the INCA project achieved by 2020. It presents ecosystem extent accounts (for 9 broad types of ecosystems), ecosystem condition accounts (for forests, agro-ecosystems and rivers and lakes) and ecosystem services accounts (for a subset of ecosystem services) for the EU. In separate chapters, the report also presents practical examples of the possible uses of ecosystem services accounts and existing policy applications. In addition, the report outlines crucial steps for making ecosystem accounts operational.

Ecosystems contribute essential services to the economy and society. These include the provision of food, filtration of air and water, climate regulation, protection against extreme weather events such as heat waves and flooding, and many more. The ability of ecosystems to supply these services depends on their extent ('size') and condition ('health'). Despite the crucial role of ecosystems and their services for society, there is no established and regular measurement of ecosystem extent, condition and their change over time, nor of the quantity of services these ecosystems supply. Ecosystem accounting is an emerging field that aims to address this major gap and provide an internationally agreed guidance to measure and record changes in ecosystems and ecosystem services in a consistent and comparable manner.

Many of the services supplied by ecosystems are public goods and are not currently priced on markets and, consequently, are often not taken into account in economic decisions. This has had disastrous consequences for the natural world, and in turn, for society. Ecosystem accounting has adopted the language and guiding principles of economic accounts (*System of National Accounts*) that will enable ecosystems and their services to be properly incorporated into standard accounting frameworks, and thus allow for the value of nature to be included more fully in decision making.

INCA ecosystem extent accounts

Ecosystem extent accounts provide insight into the type, distribution and share of different ecosystem types within a given territory (e.g. at country level). They inform us about increase or decrease of the area of ecosystems over time and the speed at which this change occurs.

Ecosystem extent accounts of the INCA project were built using Corine Land Cover data from the Copernicus Earth observation programme. These accounts were developed at three levels of increasing ecological detail (called tiers):

- Tier I uses the coarsest level of detail and distinguishes nine broad ecosystem types, e.g. forests or grasslands.
- Tier II accounts contain 23 ecosystem categories and, for example, split the tier I inland wetlands class into inland marshes and peat bogs.
- Tier III accounts sub-divide further where possible.

The result of the INCA project suggested that many changes in the extent of most of the ecosystem types assessed have been small in relative terms in the period of 2000 – 2018. However, urban ecosystems have shown a significant increase in extent of 5.8% between 2000 and 2018. Other ecosystem types that increased in area are rivers and lakes (by 1.2%), sparsely vegetated land (by 0.5%), marine inlets and transitional waters (by 0.2%) and forests (by <0.05%). By contrast, the area of heathland and shrubland decreased by 1.2%, grassland by 0.8% and cropland and inland wetlands by 0.5%. This indicates a continued expansion of urbanised areas at the expense of farmland and semi-natural ecosystems. A specific analysis of changes within the Natura 2000 protected areas of the EU showed that changes in the extent of semi-natural ecosystem types are mostly smaller within the Natura 2000 areas than outside. This means that sites in the Natura 2000 network tend to have a higher degree of ecosystem stability than the area outside the network.

INCA ecosystem condition accounts

Ecosystem condition is often referred to as ecosystem health or ecological integrity and can be measured by selecting an appropriate set of ecosystem variables. Condition accounts record information on the quality of ecosystems in terms of their abiotic, biotic and landscape characteristics. Ecosystem condition determines what type and quantity of ecosystem services ecosystems can provide – poor management and degradation of ecosystems often leads to loss of capacity to deliver multiple ecosystem services. The report presents three initial sets of ecosystem condition accounts (for forests, agro-ecosystems, and rivers and lakes) produced using readily available data in the EU and following the Ecosystem Condition Typology approach proposed by the revised SEEA EA. The main purpose of these initial ecosystem condition accounts is to demonstrate how existing guidelines and available data can be combined to compile a series of accounting tables and use them to track changes in the condition of ecosystems. All data used in these accounts should be readily available from existing data reporting, hence compiling condition accounts at national level is within reach of most EU countries.

INCA ecosystem service accounts

Ecosystem services underpin our economies and our well-being. Ecosystem service accounts estimate and track these flows or quantities that our society is using from nature as if it were transactions between two economic sectors. In the ecosystem accounting framework, ecosystem services are the connecting concept between ecosystems and the production and consumption activities of businesses, households and governments. Ecosystem service accounts can be produced in both physical and monetary units. The report presents aggregated results for seven of the ecosystem service accounts produced by the INCA project – crop pollination, crop and timber provision, water purification, flood protection, carbon sequestration and recreation in high-value natural areas calculated for 2012. Results on four of these services (crop provision, water purification, flood protection and carbon sequestration) are presented in separate sub-chapters in greater detail. In addition, the report shows an initial estimate of the economic value provided by a wider set of ecosystem services in the EU in 2019, amounting to EUR 234 billion. This value is comparable to the gross value added of agriculture and forestry combined.

The results of INCA project suggested that the value of the seven ecosystem services totalled EUR 172 billion in the EU in 2012. Forests deliver 47.5% of the total supply of the seven measured ecosystem services, croplands contribute 36%, urban ecosystems less than 1%. Per unit of area, the value of ecosystem services supplied by forest is almost 9 times the value of ecosystem services supplied by urban areas. Water purification is the ecosystem service with the highest aggregated value (EUR 55.6 billion annually), followed by nature-based recreation, i.e. daily recreation opportunities that people have in ecosystems with a high natural quality (EUR 50.4 billion). Almost half of the supply of the seven ecosystem services is used by households, the secondary sector and the tertiary sector. Agriculture used 38% of the total supply of ecosystem services, valued at EUR 64.7 billion in 2012. More than half of the societal demand for essential ecosystem services (e.g. pollination) in the EU is not met by ecosystems.

Economic value provided by ecosystem services in the EU (EU28, 2012, million EUR)

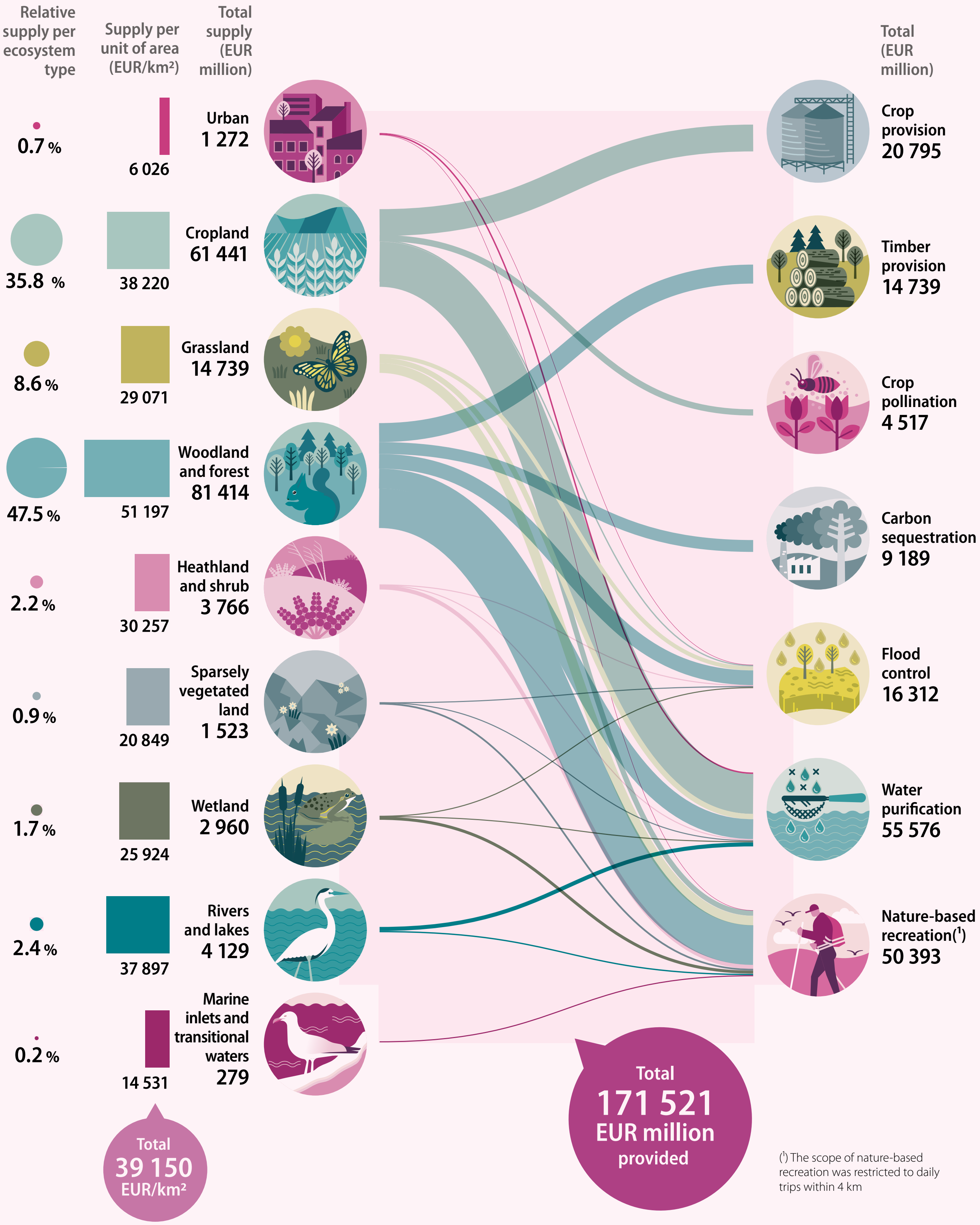
	Urban	Cropland	Grassland	Woodland and forest	Wetland	Heathland and shrub	Sparsely vegetated land	Rivers and lakes	Marine inlets and transitional waters
Crop provision	0	20 795	0	0	0	0	0	0	0
Timber provision	0	0	0	14 739	0	0	0	0	0
Crop pollination	:	4 517	:	:	0	:	0	0	0
Carbon sequestration	0	0	0	9 189	0	0	0	:	:
Flood control	89	1 015	3 129	11 388	333	357	1	:	:
Water purification	1 105	31 041	4 128	15 374	330	312	170	3 114	:
Nature-based recreation(¹)	77	4 073	7 482	30 723	2 296	3 097	1 351	1 015	279

Source: JRC

Note: (:) not available.

(¹) The scope of nature-based recreation was restricted to daily trips within 4 km from human settlements and the highest natural quality sites.

ECOSYSTEM SERVICES
ECONOMIC VALUE (EU28, 2012)



([1]) The scope of nature-based recreation was restricted to daily trips within 4 km

Innovative ways of using INCA services accounts: four research examples bridging ecology to economy

The INCA report presents four examples of the use of ecosystem services accounts. First, based on the results of the INCA project on the pollination ecosystem service, we show how to use the supply and use tables to identify the driver of change when the supply of an ecosystem service increases or decreases over time. Second, we combined our results on crop provision with economic and social variables on agricultural production, and produced a ranking of EU countries in terms of sustainability of wheat production, taking ecological, economic and social aspects into consideration. Third, we show that ecosystem services of one country can be 'exported' to another country embedded in traded agricultural crops and how this can be quantified. E.g. when a country exports an apple, nitrogen pollution resulting from (conventional) agriculture is embedded in the exported product and so is the water purification ecosystem service that is used to clean up the nitrogen pollution. Fourth, we quantified the economic effect of the invasion of an invasive alien species – the Asian hornet – through its effect on pollination and resulting changes in agricultural production, exports and prices of pollination-dependent crops.

Policy applications of the INCA project and ecosystem accounting in general

Ecosystem services accounts produced by the INCA project were used as a key input in the first *EU-wide Ecosystem Assessment* – a landmark report analysing the trends in ecosystem extent, pressures, condition, and services in the EU, published in October 2020. The INCA account for pollination has become one of the tools supporting the implementation of the EU Pollinators Initiative. It quantified the economic contribution of pollinators and effects of their decline on agricultural production, import and export. Furthermore, it identified places where the demand of the agricultural sector for pollination is currently not met (as a result of lack of/poor habitat for pollinating insects). Quantifying this unmet demand helps identify priority areas where restoring pollinator habitats can bring most economic benefit.

The EU Biodiversity Strategy for 2030, adopted in May 2020, identified natural capital accounting as one of the key tools to integrate biodiversity considerations into public and business decision making. The Strategy includes an EU nature restoration plan. The accounting framework developed by INCA can support this plan. Ecosystem accounts can be used to guide large scale restoration by mapping where ecosystems are degraded, by monitoring changes in ecosystem condition following restoration, and by assessing the benefits of ecosystem restoration through ecosystem services.

Introduction

Have you ever wondered how much ecosystems contribute to our economy and wellbeing, whether anybody measures this and how it could be measured in the first place? How much of the society's CO_2 emissions do ecosystems sequester and which ecosystems do the most? What is the contribution of bees and other pollinators to the production of crops that feed our society? How much would it take to replace the water purification function of wetlands if it suddenly stopped? Ecosystem accounts help answer these and similar questions.

What are accounts and how can we account for nature?

Accounting is used in many different contexts, including to keep track of the balance between expenses and income or to analyse economic activities at business level or in the national economy. Accounts can be described as a system of tables with an internal logic (e.g. sums across rows and columns) and defined relationships between the different tables. They allow recording and organising data in a systematic way, exploring relationships between variables and tracking changes over time. Ecosystem accounting is a system developed specifically to record, explore relationships and track changes in ecosystems, their size ('extent') and condition ('health'), and to measure the interaction between ecosystems and the economy. This includes measuring how human actions affect ecosystems and, on the other hand, how and how much ecosystems contribute to the economy and the human society. This contribution of ecosystems to the society is referred to as 'ecosystem services'. Ecosystems, in a broader sense, include both living nature (plants, animals, and all other organisms) and non-living nature (air, water, rocks, etc.); however, ecosystem accounting focuses on organisms and the ecological processes they drive.

Ecosystem accounting has adopted the language and guiding principles of economic accounting. These are defined in the *System of National Accounts* (SNA)([1]), an internationally agreed standard on how to measure and record economic activity, so that these records are internally coherent and comparable across time and countries, and can provide high quality data for economic policies. A well-known summary result from the national accounts is the gross domestic product (GDP).

However, conventional economic accounts lack sufficient consideration of the importance and state of the environment – neither the (mostly negative) effects of economic activity on natural environment nor the vital contributions of nature to human economy and wellbeing are reflected well in economic accounts. To address this, an international framework to link economic and environmental data was established – the *System of Environmental-Economic Accounting* (SEEA)([2]). The SEEA uses the terms and principles of the SNA and applies them to account for the environment. Therefore, it is perceived as a 'satellite' set of accounts to the SNA (i.e. an 'add-on'). The SEEA covers accounts for a range of topics for which the interaction between the economy and the environment are known to be important, such as agriculture, forestry and fisheries, air emissions or environmental taxes. One of the topics of the SEEA are ecosystem accounts.

The following core ecosystem accounts are part of the SEEA framework:

- **Ecosystem extent accounts** – record the extent or size of different types of ecosystems and how they change over time, such as forests, grassland, or wetland.
- **Ecosystem condition accounts** – record data on various abiotic, biotic and landscape characteristics of ecosystems, such as pH or the concentration of nutrients in rivers and lakes; the stocks of organic carbon in grassland soils; the diversity of species present; the amount of deadwood in forests or degree of fragmentation.
- **Ecosystem services accounts** – record the **supply** of various ecosystem services, such as providing recreational opportunities in nature or protection of human property from floods, by ecosystems to the society and how the society benefits from their **use**. These accounts may be produced in two forms – measuring the flow of service from ecosystems to society in physical units (e.g. number of visits to nature per year, thousand ha of land protected from flood per year) and measuring the value of these flows using a range of valuation methods to express the supply and use in monetary terms.

- **Ecosystem asset accounts** – record stocks of assets and changes in these assets. Ecosystem asset accounts estimate the value of ecosystems. The asset value in monetary terms is usually determined based on the value of the ecosystem services expected to be provided by a particular ecosystem in the future, discounted to the present.

The first three types of ecosystem accounts from above are shown in this report. Further types of accounts may be produced to answer questions on a specific subset of nature of policy interest – so called thematic accounts – e.g. on carbon, urban areas, oceans or biodiversity.

EU bodies have helped develop ecosystem accounting concepts and methods for many years; however, their practical application only gained real momentum with the start of the INCA project in 2015(*). The INCA project aimed to pilot an integrated set of ecosystem accounts at EU level by 2020. Five partners worked together on the project, **Eurostat** (the statistical office of the EU) providing knowledge on accounting and coordinating the project, the **Directorate General for Environment** providing policy direction, the **Directorate General for Research and Innovation** ensuring coordination with EU research priorities, **the Joint Research Centre** (the in-house research service of the European Commission) providing expertise on modelling and producing ecosystem services accounts and the **European Environment Agency** producing ecosystem extent and condition accounts and developing a geo-spatial data platform.

The INCA project was set up to address certain policy needs. Specifically, it was the 7th Environment Action Programme – Living well, within the limits of our planet (2014 – 2020)([3]) which called for the EU to establish a sound method for natural capital accounting with a strong focus on ecosystems and the services they provide, and the EU Biodiversity Strategy to 2020 (2010 – 2020). The new EU Biodiversity Strategy for 2030([4]), adopted in May 2020, identified natural capital accounting as one of the key tools to integrate biodiversity considerations into public and business decision making.

The INCA project was closely linked with the initiative Mapping and Assessment of Ecosystems and their Services (MAES). MAES was set up in 2011 to address one of the targets of the above mentioned EU Biodiversity Strategy to 2020. It brought together policy makers and scientists from Member States and EU institutions and developed methods to classify and map ecosystems, and assess their condition using a set of agreed indicators in a consistent way for the whole of EU. In 2020, MAES completed and published the results of the first *EU Ecosystem Assessment*([5]). The INCA project used the classification of EU ecosystem types developed by MAES(**) to build ecosystem extent accounts, and the results of the assessment of ecosystem condition of MAES to provide examples how readily available data may be used to build initial ecosystem condition accounts. MAES, on the other hand, used part of the outputs of the INCA ecosystem services accounts for the *EU Ecosystem Assessment*. In comparison with the MAES assessment, the INCA used a more rigorous and structured approach of accounting to describe ecosystems, their services and how they change over time.

The INCA developed a set of ecosystem accounts for the whole of the EU. As a result of the experience gained in this process, the INCA provided valuable input into global developments in ecosystem accounting. At global level, the UN published the first ever international handbook on ecosystem accounting, *SEEA – Experimental Ecosystem Accounting* (SEEA EEA), in 2014. This publication sparked interest among researchers, economists and accountants in several countries and an extensive testing of proposed concepts and methods followed, bringing together ecological and economic information to produce internationally comparable statistics. INCA was one of the projects that used the SEEA EEA as working guidance and thus tested its concepts and recommendations in practice. Resulting experience and verified, newly proposed concepts served as input into the revised handbook *SEEA – Ecosystem Accounting*, adopted at the UN level in March 2021([6]). The large geographic scope and the international element of the INCA project, combined with the wide range of different accounts the project produced, made the INCA an important test case of the original SEEA EEA handbook and a substantial source of experience for its revised version.

This report aims to communicate the main results of the INCA project in a way accessible to wider audiences including: national and EU policy makers, statisticians at national statistical institutes, practitioners of ecosystem accounting, other experts and the public interested in this topic. The INCA project has shown that the production of a wide range of ecosystem accounts following the guidance of the SEEA EEA is feasible and it is possible to produce consistent and comparable information on ecosystems and the services they provide to society at the scale of the EU. Further results of the INCA project are published on the INCA website([7]) and in technical reports that are referenced in this publication. The INCA website contains a map tool and online charts and tables to visualise main results but also links to input data used to create these accounts and options to download output data for further analyses.

The INCA project started in 2015 and the vast majority of the work was completed before the UK left the EU. Due to the complexity of modelling and other work involved, all results could not be recalculated to the current composition of the EU (EU27) at the time this report was due to be published. The EU28 aggregate used throughout the report refers to the former composition of the EU with 28 Member States, before the withdrawal of the UK on 1 February 2020.

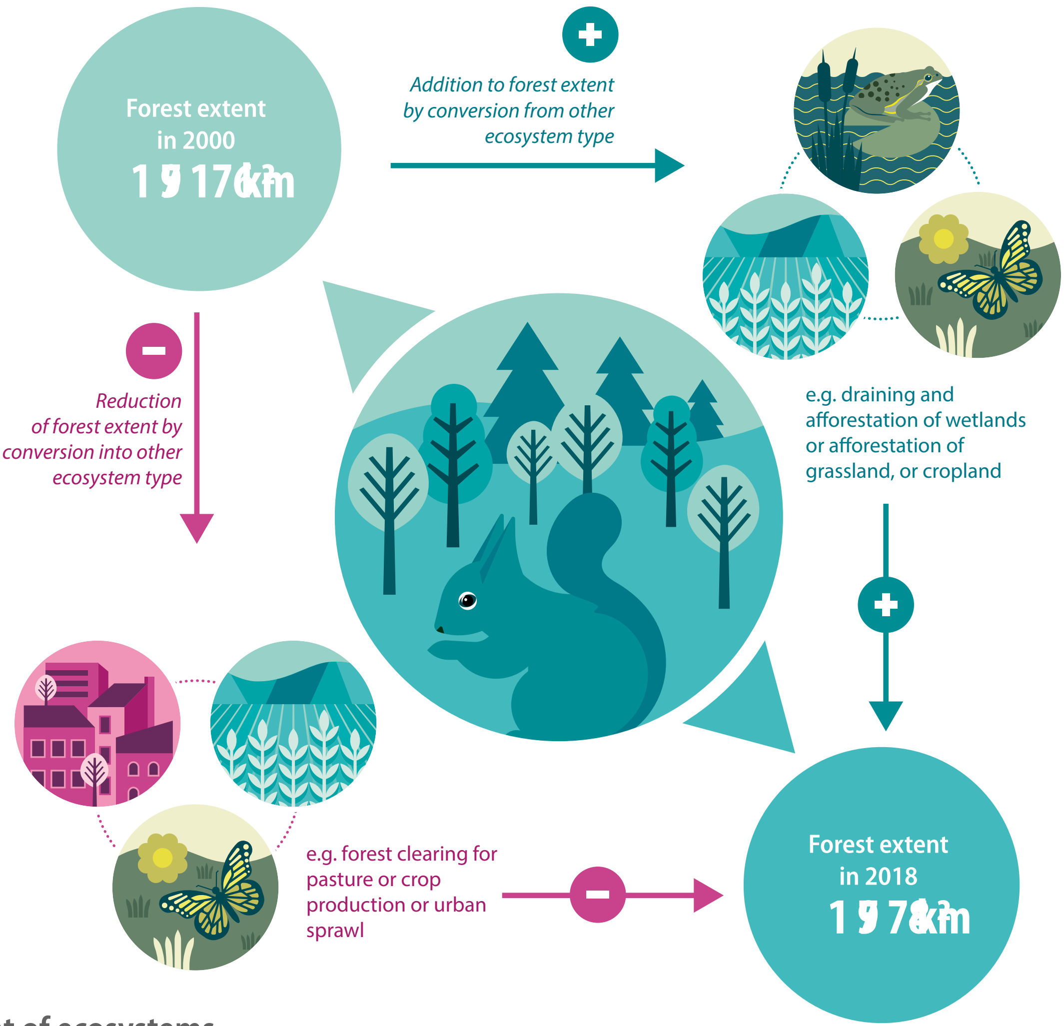
(*) The official name of the INCA project is knowledge innovation project on an Integrated system of Natural Capital and ecosystem services Accounting for the European Union

(**) These are referred to as 'tier I ecosystem types' in this report, see section 'Ecosystem extent accounts'.

Ecosystem extent accounts: Measuring changes in ecosystem area over time

FIGURE 1: GENERAL LOGIC OF ECOSYSTEM EXTENT ACCOUNT

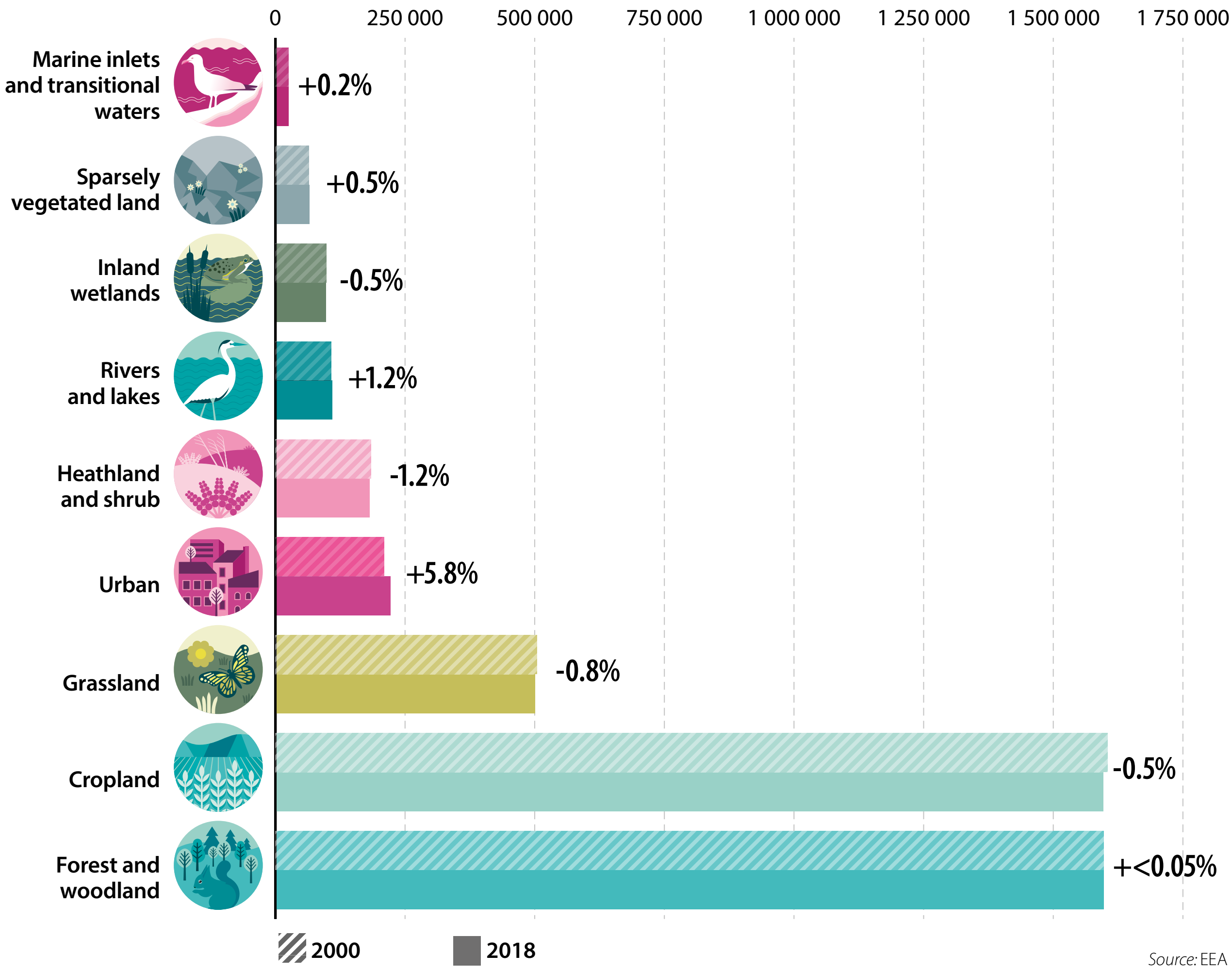
Source: EEA



How has the extent of ecosystems changed in the EU in the past decades?

Ecosystem extent accounts provide insight into the type, distribution and share of different ecosystem types at country level (or other chosen territory). They provide data on the increase or decrease of the total area ('stock' in accounting language) of ecosystems across a country (or territory) over time and at which speed this change occurs. Figure 1 shows how extent accounts trace the opening and closing stock of different ecosystem types in a spatially explicit manner (e.g. in ha or km²). The spatial data on distribution of ecosystem types compiled in extent accounts provide a key data input to the calculation of other ecosystem accounts, such as on ecosystem condition or ecosystem service flows.

Figure 2: Tier I ecosystem extent, 2000 and 2018, EU28 (km²)(10)



Source: EEA

The ecosystem extent accounts produced by INCA build on Corine Land Cover (CLC) data(8) to support the identification of different ecosystem types. The INCA project has developed ecosystem extent accounts at three different levels of increasing detail (called tiers) which are nested in each other. This means tier I ecosystem types divide into tier II categories, which are then further split up into tier III sub-categories.

Tier I uses the coarsest level of ecological detail and distinguishes nine broad ecosystem types, e.g. forests or grasslands. The tier II accounts contain 23 ecosystem categories and, for example, splits up the tier I forest class into broad-leaved forest, coniferous forest, mixed forest and transitional woodland/shrub. The tier III accounts sub-divide further where possible and comprise 30 ecosystem sub-categories, for example salt marsh, semi-natural grassland or mosaic farmland. The increasing sub-divisions allow fine-tuning the analysis of trends in ecosystem extent on less widespread or more vulnerable ecosystem types. Further detail on the EU ecosystem extent typology developed under INCA is provided in Annex 1. In order to assist ecosystem accounting practitioners in their analyses, the EEA have now created the ecosystem extent accounts interactive dashboard(9). This allows users to compile accounts for different administrative areas using the three tier ecosystem extent typology presented in Annex 1.

Figure 2 shows the relative size of ecosystems in the EU28 area as well as their trend from 2000 to 2018 for tier I. The cropland as well as forest and woodland ecosystems dominate the accounting area, each comprising approximately 1.6 million km² (ca 36%) out of the total extent of approximately 4.4 million km². Of the remaining broad ecosystem types, only grassland extent exceeds 500 000 km² (ca 11% of the total area). Urban ecosystems are at 222 000 km² in 2018 (ca 5%), with the remaining terrestrial ecosystems varying in extent between approximately 60 000 km² and 180 000 km². The extent of marine and transitional waters is approximately 25 000 km².

Figure 2 also indicates the relative increase or decline of area for all tier I ecosystem types between 2000 and 2018. The relative rate of increase or decrease in extent is fairly small for most ecosystem types; however, urban ecosystems show a significant increase in extent of 5.8%. This represents a land take for urban development of ca 12 800 km² which corresponds in size to the area lost by the cropland and grassland ecosystem types combined (although all ecosystem types are affected by the urban increase to varying degrees).

Increases in extent are also found for the ecosystem types rivers and lakes (+1.2%) and sparsely vegetated land (+0.5%, or 333 km²). The increase in rivers and lakes extent is probably influenced by the creation of artificial lakes and reservoirs as a result of infrastructure development and mineral extraction activities.

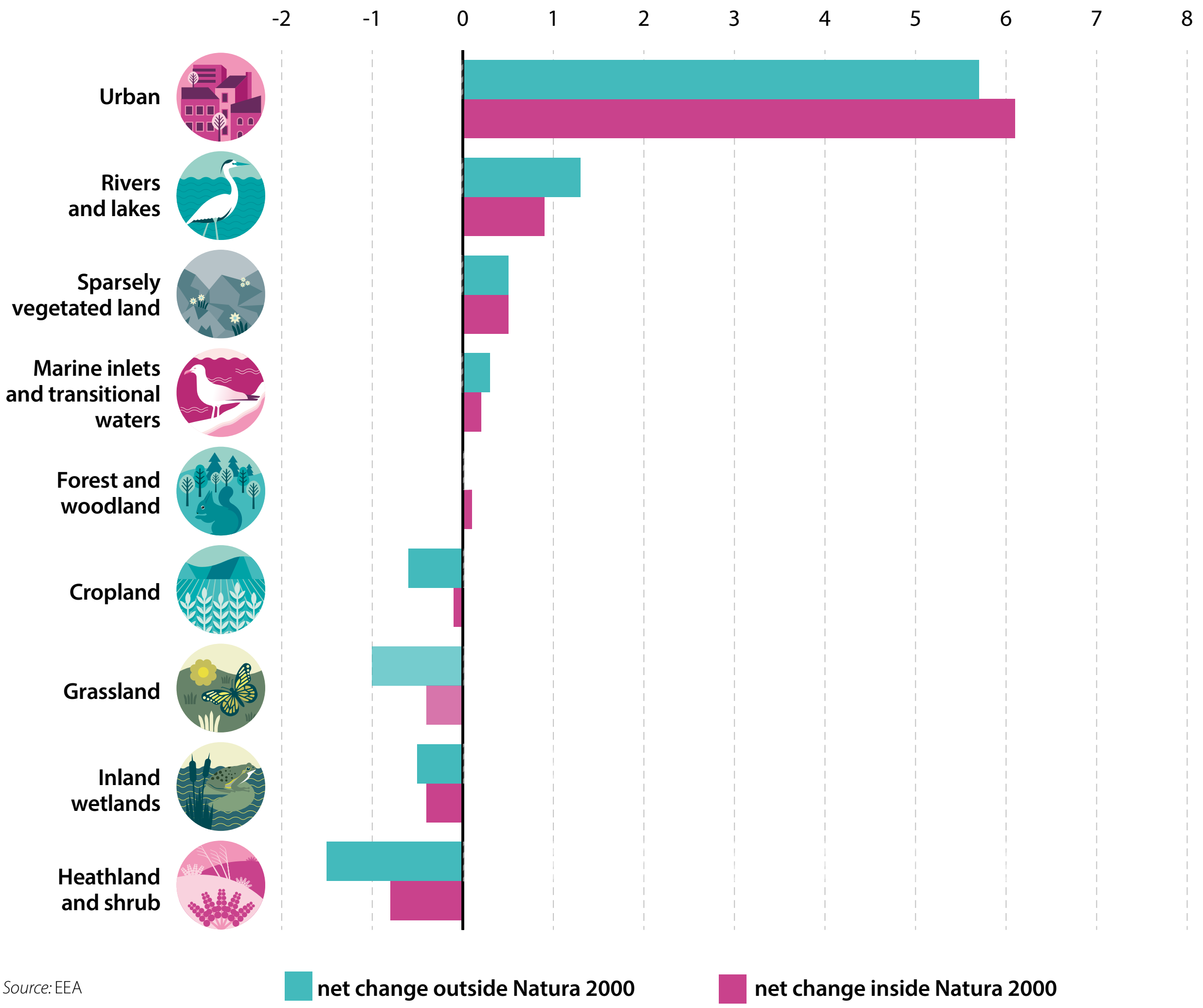
The ecosystem types of heathland and shrub, grassland and cropland all declined in extent. The rate of loss of heathland and shrub (1.2%) raises concern given its nature conservation importance and relatively small extent in the EU (approximately 182 000 km² in 2018). For grassland, the reduction of 0.8% is associated with a fairly large stock of approximately 500 000 km² but more detailed data would be useful to understand whether grassland sub-types of high species diversity are particularly affected by this decline. The decline of cropland extent of 0.5% is equivalent to a loss of 8 753 km² of productive arable area over 18 years.

The extent of forest and woodland ecosystems in the EU28 is considered to be stable over the 2000 to 2018 accounting period. The extent of marine inlets and transitional waters also changed little between 2000 and 2018 (an increase of 0.2%, or 49 km² in absolute terms).

Key results for tier I ecosystem extent accounts for the 2000 to 2018 period include:

- The strong increase in urban ecosystem extent (5.8% for EU28) happened mainly in regions with large coastal areas (e.g. the Mediterranean Sea), which is linked to the fast pace of urban development for coastal tourism in southern Europe;
- The Mediterranean region also contributes most to the increase in river and lake ecosystem extent of 1.2% in the EU28, probably due to an expansion of reservoirs and other artificial water bodies;
- The decline of inland wetlands (-0.5%) at EU28 level is mainly driven by losses in the Atlantic biogeographical region in north-western Europe.

Figure 3: Changes in ecosystem extent inside and outside Natura 2000 areas, 2000-2018, EU28 (%)



Source: EEA

Detailed ecosystem extent accounts for Natura 2000 areas and semi-natural ecosystem types

The EU has established a network of protected areas across all Member States, called Natura 2000 sites, which protect ecosystems and species of European importance. The INCA ecosystem extent accounts allows comparing changes within and outside these protected areas, which is a potential indication of their effectiveness. Figure 3 shows that reductions in the extent of most ecosystem types — cropland, grassland, heathland and shrub, and inland wetlands — are lower within the Natura 2000 areas. This means that protected sites in the Natura 2000 network have a higher degree of ecosystem stability than the area outside the network. The exceptions are the rate of urban expansion (although urban extent remains relatively small and is <1% of the total Natura 2000 area).

This analysis shows that trends in ecosystem extent can be analysed at country level but also with a targeted geographic focus (see section 'Making ecosystem accounts operational' for further detail). The combination of spatial focus and higher ecological detail (via tiers II and III) yields further useful insights into patterns of change in European ecosystem types.

More detailed (tier II) ecosystem extent accounts for EU28

The tier II accounts allow for a more detailed analysis improving the analytical power of the accounts. Table 1 shows trends for tier II categories. The overall extent of natural and semi-natural ecosystems remained stable in the EU28 area between 2000 and 2018. However, there is substantial variation between different tier II ecosystem categories, some of which show substantial variation within the broader tier I ecosystem types.

Key results for tier II ecosystem extent accounts for the 2000 to 2018 period include the following:

- Some transformation of coniferous forests, and to a lesser degree also broad-leaved forests, to mixed forests.
- The strong increase of transitional woodland/shrub is likely connected to forest harvesting cycles (in particular in coniferous forests) but may also be associated with afforestation.
- The relative stability in the extent of sparsely vegetated land observed at tier I masks relatively large decreases in the extent of glaciers and perpetual snow (which has a smaller relative size). This reduction is fully compensated by increases in sparsely vegetated habitat.
- Decreases in the extent of peat bogs are the key reason for the lost area of tier I ecosystem type inland wetlands.
- The increase in rivers and lakes ecosystems type observed in the tier I ecosystem extent accounts is due to increases in the extent of inland water bodies (supporting the notion that this is likely associated with reservoir construction or other artificial water bodies).

Table 1: Ecosystem extent trends for all tier II ecosystem categories between 2000 – 2018, EU28

tier I	tier II
Urban	Dense urban area
	Dispersed urban area
	Total urban
Cropland	Arable land
	Rice fields
	Permanent crops
	Mixed farmland
	Total cropland
Grassland	Modified grassland
	Semi-natural grassland
	Total grassland
Forest and woodland	Broad-leaved forest
	Coniferous forest
	Mixed forest
	Transitional woodland/shrub
	Total forest and woodland
Heathland and shrub	Sclerophyllous vegetation
	Moors and heathland
	Total heathland and shrub
Sparsely vegetated land	Sparsely vegetated habitats
	Glaciers and perpetual snow
	Total sparsely vegetated land
Inland wetlands	Inland marshes
	Peat bogs
	Total inland wetlands
Rivers and lakes	Water courses
	Water bodies
	Total rivers and lakes
Marine inlets and transitional waters	Salt marshes
	Salines and intertidal area
	Coastal waters
	Total marine inlets and transitional waters
Total area in EU28	

Source: EEA

Area 2000 (km²)	Area 2006 (km²)	Area 2012 (km²)	Area 2018 (km²)	Net change 2000-2018 (km²)	Net change 2000-2018 (%)
189 875	194 531	198 212	200 471	10 595	5.3%
19 603	20 481	21 409	21 801	2 198	10.1%
209 479	**215 011**	**219 621**	**222 272**	**12 793**	**5.8%**
1 105 007	1 100 618	1 096 521	1 095 846	-9 161	-0.8%
6 500	6 530	6 530	6 559	59	0.9%
117 835	119 025	119 277	119 990	2 156	1.8%
375 523	374 630	374 073	373 727	-1 796	-0.5%
1 604 865	**1 600 804**	**1 596 402**	**1 596 122**	**-8 743**	**-0.5%**
398 203	397 288	396 433	394 608	-3 595	-0.9%
106 646	106 193	106 091	106 029	-617	-0.6%
504 849	**503 481**	**502 523**	**500 637**	**-4 212**	**-0.8%**
447 279	444 585	444 609	441 519	-5 761	-1.3%
703 047	686 242	686 220	672 222	-30 824	-4.6%
254 864	254 324	258 631	262 715	7 850	3.0%
191 986	213 017	209 524	221 292	29 306	13.2%
1 597 176	**1 598 169**	**1 598 984**	**1 597 748**	**572**	**0.0%**
93 802	93 048	92 643	92 001	-1 801	-2.0%
90 338	90 246	90 153	89 882	-456	-0.5%
184 140	**183 294**	**182 796**	**181 882**	**-2 258**	**-1,2%**
63 811	63 686	63 998	64 264	453	0.7%
1 363	1 296	1 273	1 243	-120	-9.7%
65 175	**64 982**	**65 271**	**65 508**	**333**	**0.5%**
10 606	10 624	10 716	10 653	48	0.4%
87 870	87 399	87 413	87 373	-497	-0.6%
98 475	**98 023**	**98 130**	**98 026**	**-449**	**-0.5%**
10 272	10 262	10 261	10 279	7	0.1%
97 717	98 299	98 784	99 024	1 307	1.3%
107 989	**108 561**	**109 045**	**109 303**	**1 314**	**1.2%**
3 844	3 865	3 874	3 879	35	0.9%
11 644	11 667	11 658	11 664	20	0.2%
9 657	9 661	9 653	9 651	-6	-0.1%
25 146	**25 192**	**25 185**	**25 195**	**49**	**0.2%**
4 397 294	**4 397 518**	**4 397 957**	**4 396 692**	**-602**	**0.0%**

Ecosystem condition accounts: Tracking the fitness of ecosystems over time

Ecosystem condition is the quality of an ecosystem in terms of its abiotic, biotic and landscape characteristics at a particular point in time. Other terms that are often used are ecosystem integrity or ecosystem health. The condition of ecosystems determines what type and level of ecosystem services they can provide. Poor management and degradation of ecosystems often leads to loss of capacity to deliver multiple ecosystem services. For instance, healthy wetlands have a high potential to purify water, store and sequester large amounts of carbon, protect people and infrastructure against floods, and attract high numbers of birdwatchers. Degraded wetlands that are fragmented, drying out and have lost their natural habitats have a more limited capacity to supply these functions. It should be noted that there can be important trade-offs between ecosystem productivity and species richness. For example, agricultural grassland that is improved by fertilisation and re-seeding has a far lower flower density than semi-natural grasslands but it provides more grass biomass and the same or higher level of regulating services, for example carbon sequestration or water flow regulation. However, it has lower interest to birdwatchers and also hosts far fewer pollinator species (if any).

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

Ecosystem condition can be measured selecting an appropriate set of ecosystem variables that can describe how the condition of ecosystems changes. Examples include number of bird species at a site, tree or vegetation coverage, the oxygen concentration in water or the amount of soil organic carbon in soils. Higher values of such variables are in most cases associated with a higher condition of ecosystems, and thus a higher potential to deliver multiple ecosystem services. Alternatively, the condition of ecosystems can also be approximated by measuring the pressures acting on ecosystems, such as nitrogen pollution, land conversion, invasive alien species or the extraction of natural resources. Higher values of pressures are related to a lower condition, although this relationship is not necessarily linear, e.g. due to time lags in the response of ecosystems to pressures.

This chapter presents three condition accounts for forests, agro-ecosystems (the combination of cropland and grassland), and rivers and lakes. The main purpose of these initial ecosystem condition accounts is to demonstrate how the new SEEA EA guidelines and available data on ecosystem condition can be combined to compile a series of tables that can be used to track changes in the condition of ecosystems. The presented condition accounts use the SEEA EA Ecosystem Condition Typology (SEEA ECT) – a hierarchical approach to structuring data on ecosystem condition into pre-defined groups, assuring a good balance between statistical requirements and ecologically meaningful sets of variables, and increasing comparability across produced experimental condition accounts.

The three presented condition accounts use indicators and data taken from the *EU Ecosystem Assessment*([11]). The *EU Ecosystem Assessment* provides an analysis of pressures on terrestrial, freshwater and marine ecosystems and their condition using a single, comparable methodology based on European data on trends of pressures and condition relative to the policy baseline 2010. In addition, two demonstration ecosystem condition accounts are presented (1) spatial condition accounts for nitrogen input to agro-ecosystems and (2) rivers and lakes ecosystem condition accounts based on data reported for the Water Framework Directive.

All the data used in these accounts should be readily available; therefore, compiling an initial condition account at national level for different years is within reach of most EU countries.

Forest condition

Table 2 is a simple condition account that presents the values for 11 forest variables for 2010 and 2020 (unless indicated differently). The account reports mean values for the EU28. It also reports the percentage change for this decade and adds a qualitative level of confidence to the change estimate(*).

Table 2 shows that forest pollution levels due to eutrophication, damaging ozone concentrations, and acidification are declining across the EU28 but the absolute levels of these pollutants are still very high and there is a high probability of continued ecosystem deterioration. Forest productivity as well as volume of living and dead woody biomass increased. So, too, has the short-term trend in abundance of common forest birds.

Table 2 also reveals that pressures from climate change on forests are increasing. This is evident from an increasing evapotranspiration in forests and most notably, a substantial decline in effective rainfall, a variable that measures climatic water deficit. These declines are more pronounced in the Mediterranean region.

A trend of particular concern in Table 2 is the estimated level of defoliation. Defoliation is a key variable of tree condition and describes the loss of needles or leaves in the crown. In the EU28, the average level of defoliation in 2017 was 21.7% and this share is increasing. In fact, 25.1% of all assessed trees had needle or leaf loss exceeding 25% which is considered a critical level of damage.

Forest area density, an indicator for fragmentation, remained virtually constant since 2010.

All data including confidence levels come from the *EU ecosystem assessment* except the common forest bird index. The EU ecosystem assessment used 33 indicators to describe the pressures and condition of forests. A selection of 11 indicators was made to illustrate a condition variable account table structured by the SEEA ECT typology consisting of six classes as shown in the table. For these variables, the opening stock is represented by the value for year 2010 and the closing stock is projected for 2020 using the short-term decadal change (% per decade) assuming a linear trend. For evapotranspiration, effective rainfall and soil moisture content: long-term trends are used to project the closing stock values. For common forest bird index: EU28 unsmoothed estimate for 2010 as opening stock and 2017 as closing stock.

Agro-ecosystems condition

Agro-ecosystems can be divided into cropland and grassland. Cropland includes land area under temporary and permanent crops cultivation, land temporarily fallow, horticultural and farmstead habitats. Grasslands are areas covered by grass-dominated vegetation, which include pastures, meadows

(*) The confidence assessment can be consulted in the EU ecosystem assessment (chapter 2, section 2.9.5). https://publications.jrc.ec.europa.eu/repository/handle/JRC120383

Table 2: **Forest condition variable account for EU28 (spatially averaged values)**

Condition group	Condition class	Descriptor	Units	Opening stock (2010)	Closing stock (2020 - projected)	Change (% per decade)	Confidence
Abiotic characteristics	**Physical state**	Soil moisture content	%	13.50	13.45	-0.4	medium
	Chemical state	Effective rainfall	mm/year	-32	-44	-38	high
		Exceedances of critical loads for eutrophication	equivalent/ha/year	251.8	173.7	-31	medium
		Tropospheric ozone concentration	ppb hours	19 265	13 293	-31	high
Biotic characteristics	**Composition**	Common forest birds index (1)	Index (1990 = 100)	93.23	104.86	17.8	medium
	Structure	Biomass volume	m³/ha	200	220	10	medium
		Dead wood	tonne/ha	4.1	4.5	10.3	medium
		Defoliation	%	20	22	10	high
	Function	Evapotranspiration	mm/year	482.0	490.2	1.7	high
		Dry matter productivity	tonne/ha/year	11.8	13.1	11.1	high
Landscape characteristics		Forest area density	%	72.0	72.1	0.1	high

Source: sdg_15_60, EU Ecosystem Assessment

(1) Closing stock for the common forest bird index uses year 2017

and (semi-)natural grasslands. In both cases field margins, hedges, grass strips, lines of trees, ponds, terraces, patches of uncultivated land are considered an integral and important part of agro-ecosystems. They are often managed by the same land managers, the farmers. From an ecological perspective, agro-ecosystems provide nesting and breeding sites, food sources, migratory corridors to fauna, and support ecosystem services such as food provisioning, pollination, pest control and other regulating and cultural ecosystems services.

Table 3 is a simple condition account for grasslands in the EU28. This account is based on the *EU ecosystem assessment* that used 36 indicators to describe the pressures and condition of agro-ecosystems. A selection of 10 indicators was made to illustrate a condition variable account table assorted by the SEEA ECT. For data taken from the *EU ecosystem assessment*, the opening stock is represented by values for year 2010 and the closing stock is projected for 2020 using the short-term decadal change (% per decade) assuming a linear trend. The account reports spatially averaged values for EU28 as the accounting area. It also reports the percentage change per decade and adds a qualitative level of confidence to change estimate.

Surveyed farmland biodiversity (common birds and grassland butterflies) shows slightly declining trends between 2010 and 2017, following a loss of more than 30% between 1990 and 2010. The area of high nature value farmland appears largely stable.

Agricultural soils lost organic carbon between 2010 and 2017, although Table 3 reveals the rate of change is slow (-0.4% per decade). 50% more agricultural land is under organic farming in 2018 relative to 2010 but its share still only reaches 7.5% of total farmland area. The number of stations with groundwater nitrogen concentrations that exceed the WHO standard for drinking water has decreased by 12%. Utilised agricultural area decreased but the productivity of cropland and grassland increased. Crop diversity is reported for 2010 only.

The *EU ecosystem assessment* also reported that gross nitrogen balance and pesticide use remained stable during 2010 – 2020. The impact of climate change and biological invasions of invasive alien species is increasing in agro-ecosystems.

Box 1 presents an approach for spatial analysis of nitrogen use in agriculture, which allows a more differentiated analysis of nutrient pressures at the level of more detailed ecosystem types.

Table 3: Agroecosystem condition variable account, EU28 (spatially averaged values)

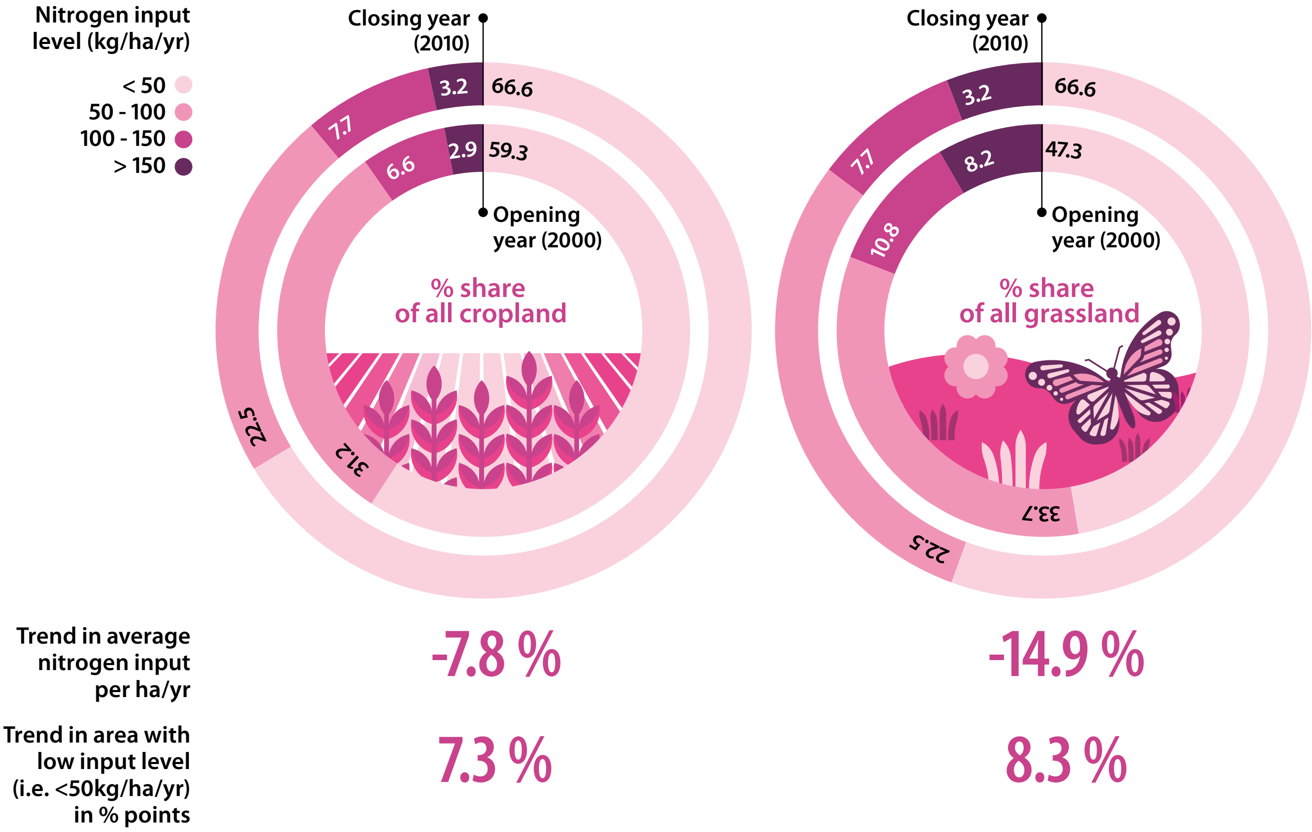
Condition class	Descriptor	Units	Opening stock (2010)	Closing stock (year)	Change (% per decade)	Confidence
Physical state	Utilised Agricultural Area	million ha	180.14	179.14 (2018)	-1	high
Chemical state	Soil organic matter content	tonne/ha	80.5	80.2 (2020 – projected)	-0.4	medium
	Nitrogen concentration in groundwater	% stations > 50 mg/l	14.4	12.7 (2020 – projected)	-11.9	medium
Composition	Common farmland bird index	Index (1990 = 100)	67.4	66.8 (2017)	-1.3	high
	Grassland butterfly indicator	Index (1990 = 100)	61.06	60.74 (2017)	-0.8	high
Structure	Share of organic farming in UAA	%	5.2	7.5 (2018)	55.3	high
	Crop diversity	Index [0 – 1]	0.59	:	:	:
Function	Gross primary production in cropland	J/ha/year	921	1 036 (2020 – projected)	12.5	medium
	Gross primary production in grassland	J/ha/year	998	1 143 (2020 – projected)	14.5	medium
Landscape	High nature value farmland area (1)	million ha	75.16	75.08 (2018)	-0.2	medium

Source: tag00025, sdg_15_60, sdg_15_61, sdg_02_40, EU Ecosystem Assessment

Note: (:) not available

(1) Opening stock for high nature value farmland area uses year 2012

Figure 4: Account for nitrogen input in grassland and cropland ecosystems, EU28, 2000–2010[34]



Source: EEA

Box 1

Spatial nutrient accounts for agro-ecosystems[12]

Nutrient enrichment is a key pressure indicator for ecosystem condition, it negatively affects all terrestrial and aquatic ecosystems. Nitrogen (N) input to agro-ecosystems mainly derives from agriculture but also from atmospheric deposition of emissions from transport, energy and industry.

Spatial data on agricultural N use were generated via the CAPRI agro-economic model at the scale of 1x1 km. These were then spatially allocated to different tier I ecosystem types. This allows ecosystem condition accounting tables to be produced that can show the average nutrient pressures on different ecosystem types over time, at EU, country or regional level. They can also show a breakdown of nutrient pressure by varying input levels and their spatial distribution.

Using the maps that underpin the nutrient accounts, it is possible to identify areas where nutrient inputs exceed certain load levels. Figure 4 presents information on the trend of respective shares of four different N input levels for cropland and grassland ecosystems between 2000 and 2010.

The data suggest that the area under the N input category of <50 kg/ha increased, whereas the area share of all higher N input levels decreased between 2000 and 2010. This confirms that overall N input to farmland decreased during the studied period and that areas of particularly high nutrient pressures decreased somewhat in extent.

Differentiation of grasslands into sub-types by their ecological characteristics and sensitivity to N input is needed to make spatial condition accounting as analytically powerful as it can be. For example, highly-productive grasslands are adapted to N input levels of 100 kg/ha but are often species-poor. The botanic species diversity of semi-natural grasslands can only be maintained if yearly N input levels stay <30 kg/ha.

Rivers and lakes condition

Rivers and lakes ecosystems form a network that links land to the sea, transporting water, materials and biota across systems. Rivers ecosystems are characterised by running water (lotic habitats) while lakes ecosystems by standing waters (lentic habitats). The condition of ecosystems at the interfaces between water bodies and their catchment, including riparian zones, floodplains, and lakeshores, are also highly influential on the condition of river and lake ecosystems.

Table 4 is a simple condition account reporting nine condition variables aligned to the SEEA ECT. Opening stock values of the account refer to 2010. The closing stock values are projections for 2020 based on the long-term trend for these variables (% per decade) assuming a linear trend. The short-term trend was used for gross water abstraction. For ecological status the closing stock refers to 2016 (see Box 2 on ecological status of rivers and lakes). The account reports averaged statistics for the EU28 as the accounting area. It also reports the percentage change per decade and adds a qualitative level of confidence to change estimate. Again, all data in Table 4 come from the *EU ecosystem assessment*.

While there are mixed messages across different water quality parameters presented in Table 4, the chemical quality of rivers and lakes is improving across the EU. Concentrations of key pollutants such as nitrogen and phosphorus are declining. Also biological oxygen demand, the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material, is decreasing. Gross water abstractions decreased by 2%.

The share of artificial area in floodplain linked to Europe's rivers is disproportionally high (7%), relative to the total land area under artificial land cover (5%). This share is also increasing with 7% over a decade, which means that construction in floodplains continues and at a rate higher than the EU average.

In 2010, the relative length of the EU's river network that was found in a good or excellent ecological status was 30%. This increased to 46% in 2016, although this increase is heavily biased due to a large number of unknown status data in 2010. When considering only the 51% of river water bodies that were assessed both in 2010 and 2016, ecological status declined slightly. For lakes, the total area under good or excellent status decreased from 58% to 52% and this decline is less influenced by unknown assessments (see Box 2 on ecological status for a more detailed analysis).

One condition variable comes without a trend; more than 60% of the river network has streamflow regulated by dams. Despite monitoring various taxa under the Water Framework Directive, data on the abundance of different freshwater species, which would be reported under composition, are not readily available.

Table 4: Condition variable account for rivers and lakes, EU28 (spatially averaged values)

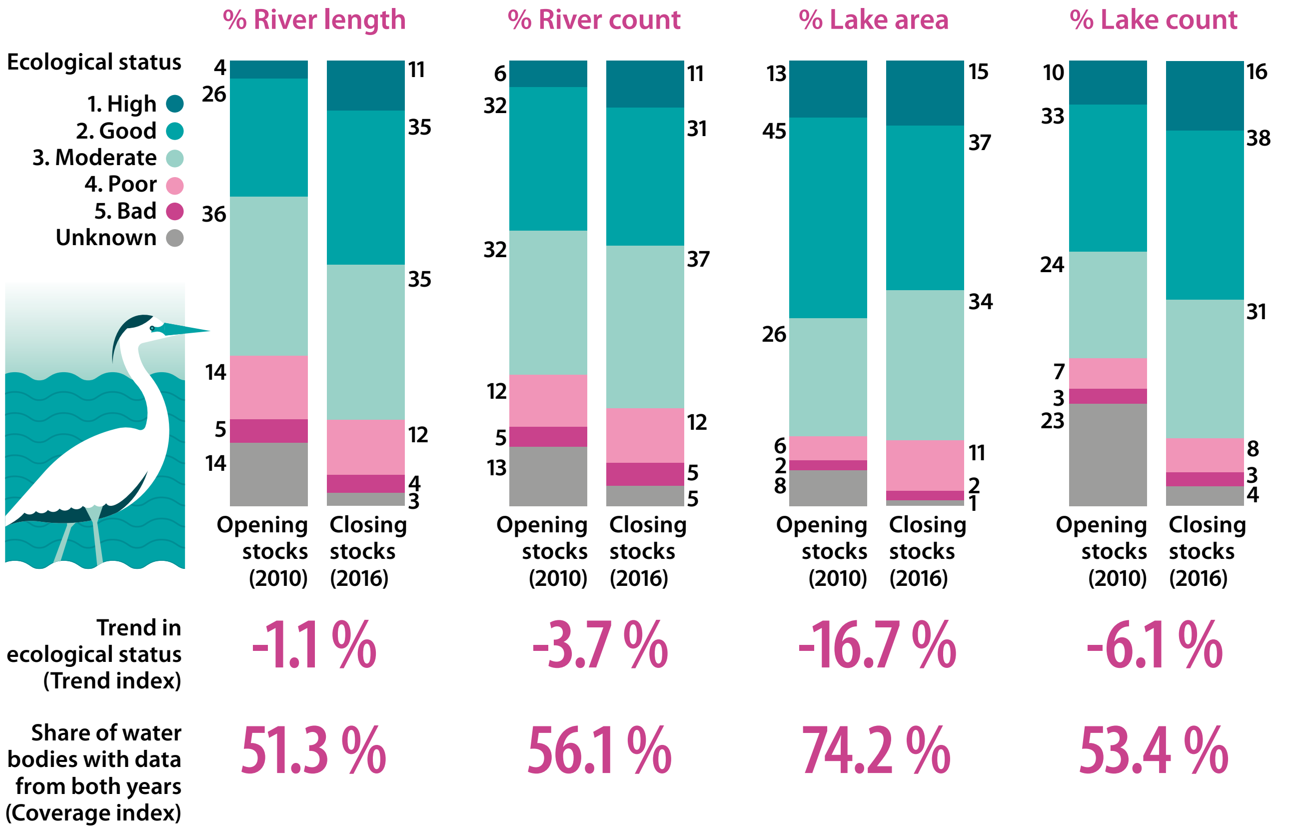
Condition class	Descriptor	Units	Opening stock (2010)	Closing stock (2020 - projected)	Change (% per decade)	Confidence
Physical state	Share of artificial areas in riparian land	%	7	7.5	7	high
	Gross water abstraction	million m3/y	204 489	204 448	-2	medium
Chemical state	Ammonia concentration	mg/l	0.131	0.034	-74	high
	Nitrate concentration	mg/l	1.87	1.7	-8	high
	Phosphate concentration	mg/l	0.07	0.05	-28	high
	Total phosphorus concentration	mg/l	0.103	0.059	-43	high
Composition	:	:	:	:	:	:
Structure	Length of rivers achieving good ecological status ([1])	%	30	46	44	low
	Area of lakes achieving good ecological status ([1])	%	58	52	-14	medium
Function	Biological oxygen demand	mg/l	2.09	1.55	-26	high
Landscape	Dam interception of streamflow	%	60.3	:	:	:

Source: tag00025, sdg_15_60, sdg_15_61, sdg_02_40, EU Ecosystem Assessment

Note: (:) not available

([1]) Closing stock for the 'length of rivers achieving good ecological status' and 'area of lakes achieving good ecological status' uses year 2016

Figure 5: Ecological status of rivers and lakes, EU28



Source: EEA

Note: The trend in ecological status is calculated as index across all five Water Framework Directive reporting categories. Data for Greece and Lithuania not available.

Box 2

Ecological status of rivers and lakes based on Water Framework Directive data

The Water Framework Directive[13] aims to bring Europe's surface waters to a good ecological status. Every six years, EU countries report the ecological status of freshwater (lakes and rivers), and transitional and coastal water bodies.

Ecological status expresses the quality of the structure and functioning of aquatic ecosystems associated with surface waters, classified on a 5-point scale from high (1) to bad (5). The ecological status for each water body is reported as a composite indicator based on biological, hydro-morphological and physio-chemical quality elements. Hence, the ecological status can be regarded as strong indication of ecosystem condition. Figure 5 presents the relative number (count) and length (km) or area (km^2) of EU rivers and lakes per status class for two reporting periods, 2010 and 2016.

Figure 5 illustrates how accounts can be used to monitor changes between the number of water bodies and their respective length or area between different ecological status categories (from poor to moderate, good to moderate, etc.). This gives an overall trend in ecological status (the 'trend index'). Figure 5 also includes data on the share of water bodies for which such a trend can be calculated (the 'coverage index') to show for what percentage of water bodies the trend index can currently be calculated.

The trend index shows that between 2010 and 2016, the overall score of ecological status declined by 6.1 % in relation to lake water body counts, and by 16.7 % when considering the surface area of these lake waterbodies. The overall score of ecological status for river water body counts reduced by 3.7% between 2010 and 2016. However, the same method applied to river length gave a decline of the trend index of 1.1 % (as river segments that declined less in ecological status had a greater length than those with stronger declines). It should be noted that the coverage index shows that a trend calculation could only be performed on between 51.3% and 74.2% of water bodies.

It is highlighted that due to the system of reporting for the Water Framework Directive by spatially explicit water body units, the EU-level results can be further broken down by country, river basin and other geographic entities. However, it should also be noted that some Member States updated their methodology between the two reporting periods, which may affect the trend for lakes in particular.

Ecosystem Services Accounts: Measuring how ecosystems provide benefits to our economy

What are ecosystem services and how can we record them in economic accounts?

Ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity. They underpin our economies and our well-being. How does our socio-economic system depend on ecosystems and their services? Forests provide us with timber but they also regulate water flows, control soil erosion, clean the air we breathe and withdraw vast amounts of carbon emissions from the atmosphere. Inland and coastal wetlands support commercial fisheries, provide protection against floods and purify water. Agro-ecosystems provide food or act as habitats for pollinating insects or pest-controlling species. Urban green spaces allow the infiltration of rainwater while also enhancing recreation opportunities that are essential to people. All these services delivered by natural and managed ecosystems result in benefits for people such as food, materials, clean air and water, protection from disasters and recreation.

Ecosystem services accounts estimate and track these flows or quantities that our society is using from nature as if it were transactions between two economic sectors. In the ecosystem accounting framework, ecosystem services are the connecting concept between ecosystems and the production and consumption activities of businesses, households and governments. Figure 6 illustrates this idea. As described previously, ecosystems can be characterised by their size (extent) and condition, which, in turn, defines their potential to deliver ecosystem services. The size of ecosystems matter (a large forest captures more carbon than a small forest) but the condition is important as well. Healthy ecosystems provide more services than degraded ecosystems. Drivers of change such as land take and pollution can reduce and degrade ecosystems and hence, their potential for ecosystem services. Information on extent and condition is not sufficient to record the transactions between ecosystems and the economy. Understanding and mapping the demand for ecosystem services is important, too.

When separately identifying, mapping and quantifying the supply and demand for ecosystem services we may be especially interested in (i) situations in which economic and societal needs for ecosystem services remain unsatisfied (there is an unmet demand) if ecosystems able to provide the required services are not present, and (ii) situations where ecosystem services are used beyond their sustainability levels (there is an 'ecosystem service overuse')(*). In accounting, it is however essential to quantify the amount of service actually used, which is known as 'actual flow of ecosystem services'. It is the actual flow of ecosystem services that is recorded in the accounting tables – supply and use tables – for ecosystem services.

Supply and use tables: An ecosystem services account consists in its essence of two tables: a supply table and a use table. The supply table measures how much of a service a specific ecosystem delivers, while the use table distributes this quantity over different economic sectors or households that benefit from it. Measuring the actual ecosystem service flows from nature to people and economic sectors is difficult. It is known that upstream forests protect downstream settlements from flooding during heavy rain events by retaining runoff water. However, there is no monitoring system in place that can measure these services in detail. Instead, we often rely on models that estimate these transactions between ecosystems and economic sectors. INCA developed an approach to do so at European scale (Figure 6). Instead of measuring or estimating directly the use of ecosystem services, the method relies on measuring two important drivers that affect the use: ecosystem service potential and ecosystem service demand.

The ecosystem service potential estimates what ecosystems can offer. A forest, wetland or grassland has a certain maximum capacity to produce timber, fish or hay. Equally so, there are limits to their potential to regulate water flows, absorb carbon from the atmosphere or remove excess nitrogen from the water. This ecosystem service potential can be mapped based on knowledge about the total surface area (provided by the ecosystem extent accounts) and the condition of ecosystems (provided by the ecosystem condition accounts) as well as based on other environmental and climatic data.

(*) In addition there are other situations, e.g. situations where ecosystem services are offered but not demanded (unused potential). For an in-depth analysis of ecosystem service overuse and unmet demand see: https://www.sciencedirect.com/science/article/pii/S2212041617307246

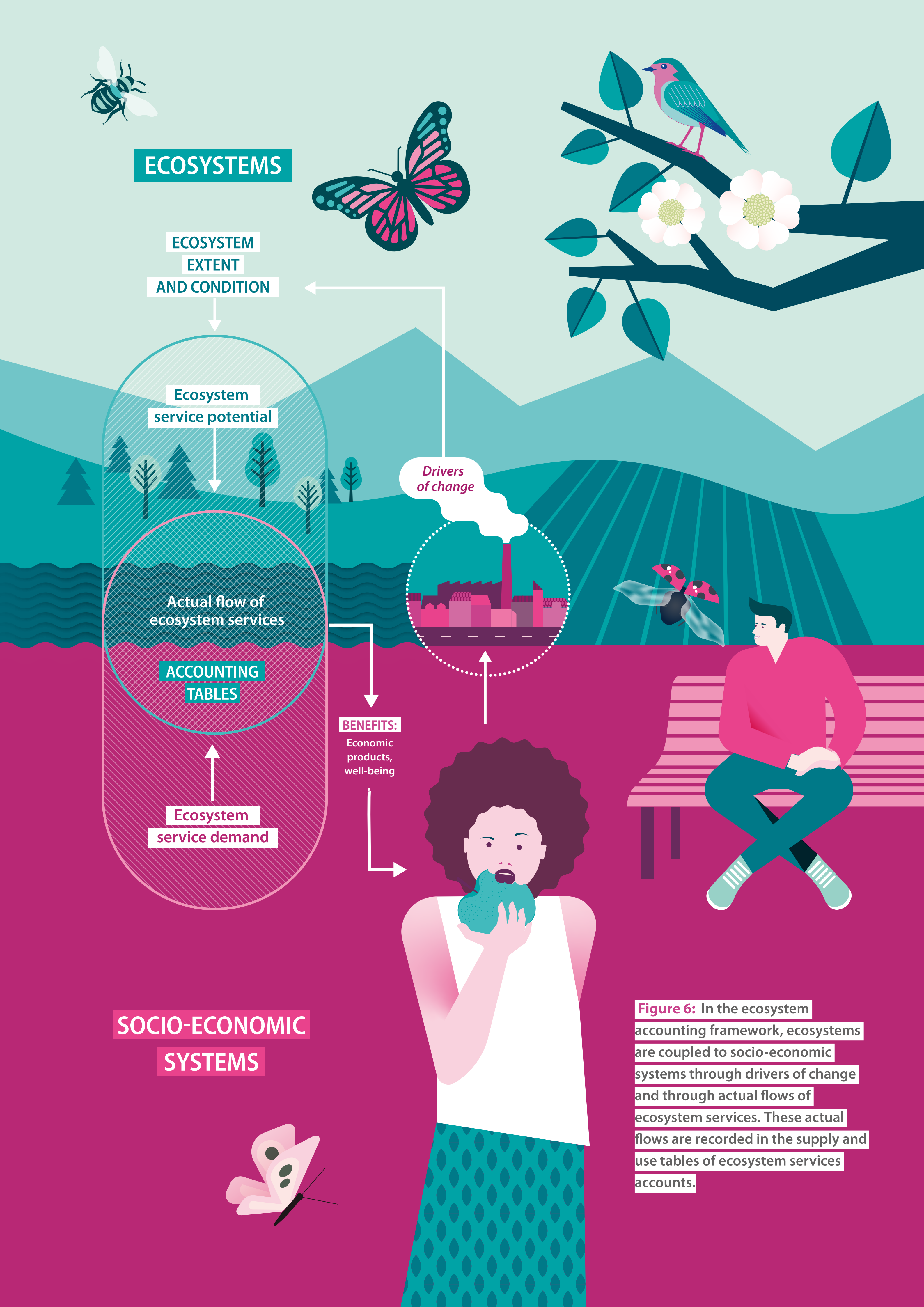


Figure 6: In the ecosystem accounting framework, ecosystems are coupled to socio-economic systems through drivers of change and through actual flows of ecosystem services. These actual flows are recorded in the supply and use tables of ecosystem services accounts.

The ecosystem service demand defines what and how much people or economic sectors need or want from ecosystems. We map demand by taking simple assumptions. For instance we take for granted that all people need a green space nearby to walk or recreate. Economic statistics such as harvested biomass from agriculture, forestry and fishery can be used to define the demand for provisioning ecosystem services. For other types of ecosystem services, assessing the demand requires modelling. An example is the demand for flood control which can be estimated by combining data on the geographical distribution of people and infrastructure that is exposed to flood risk.

Once ecosystem service potential and demand are mapped and aggregated over an accounting area (e.g., a region or a country), the actual use is then estimated as the share of demand that can be satisfied by the potential. This share is calculated for every ecosystem type which provides the service and subsequently recorded in the supply table.

The supply table thus shows for every ecosystem type that is present within an accounting area and for a given accounting period (usually one year) how much of every ecosystem service it provides. A supply table can store these values in physical units such as total volume of timber or water (m^3), total area that contributes to flood control (ha), or total number of visitors to nature areas (number). These numbers can be translated to monetary units (euro). Since most ecosystem services are not tradable on markets, economists use non-market valuation methods to estimate the economic worth of non-marketed ecosystem services. For instance, the costs associated to people traveling from home to a nature reserve are frequently used as an estimate to value recreational opportunities of natural areas. The advantage of using monetary units over physical units is that the supply values can be compared among different ecosystem services and ecosystems based on a common currency. In addition, monetary values can be summed across ecosystems or across services to understand either their relative contributions or to deliver estimates about the total aggregated contribution of ecosystems to the economy. The disadvantage is that monetary estimates are more uncertain than the physical estimates. Monetary estimates are context dependent and should always be interpreted with care.

The EU28-level supply and use tables for 2012: How much do ecosystems deliver to people?

The supply table estimates the total ecosystem service flow that each ecosystem type generates (Table 5). The table shows the aggregated supply of seven ecosystem services from nine ecosystem types for the EU for 2012.

The total supply of the seven considered ecosystem services amounts to EUR 172 billion. Forests deliver 47.5% of the total supply of these seven ecosystem services in the EU, croplands contribute 36% and urban ecosystems less than 1%. When we correct these percentages for the extent of each ecosystem type (forest being one of the dominant ecosystem types in terms of coverage in the EU), the combined value of these seven ecosystem services supplied by a unit of area of forests is almost 9 times more than by a unit of urban area.

It is important to keep in mind that the quantity of provided service depends on both what ecosystems can deliver (i.e. ecosystem service potential) and what is demanded by economy and society. For example, the presence of forests upstream protects downstream economic activities and human settlements only if these are effectively present, otherwise no flood control service is provided by the forest and recorded in the supply and use tables. On the other hand, if an urban area lacks vegetation, there is a demand for microclimate regulation by urban population, but this demand remains unmet and all residents will be exposed to the effects

Table 5: Economic value provided by ecosystem services in the EU (EU28, 2012, million EUR)[7]

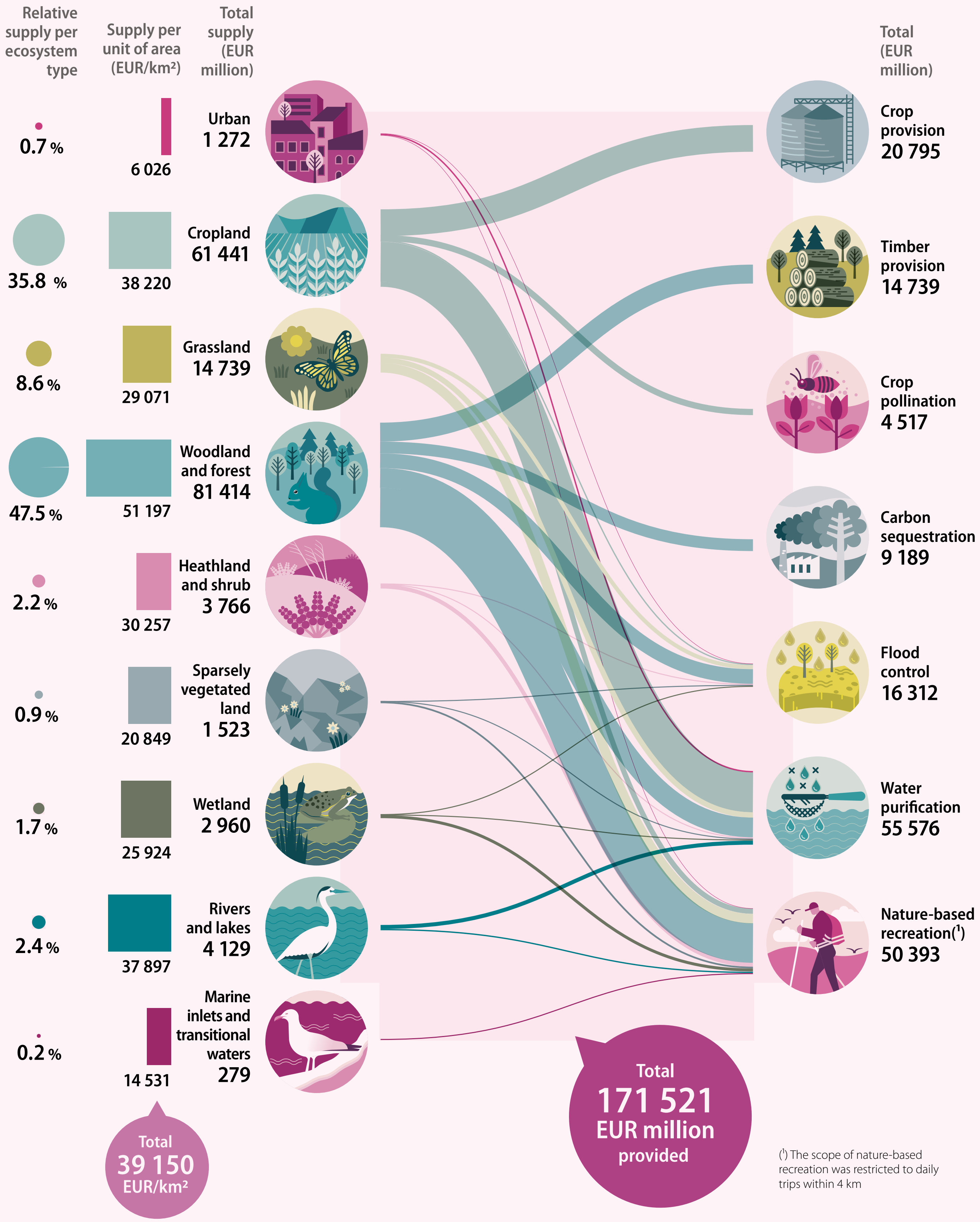
	Urban	Cropland	Grassland	Woodland and forest	Wetland	Heathland and shrub	Sparsely vegetated land	Rivers and lakes	Marine inlets and transitional waters
Crop provision	0	20 795	0	0	0	0	0	0	0
Timber provision	0	0	0	14 739	0	0	0	0	0
Crop pollination	:	4 517	:	:	0	:	0	0	0
Carbon sequestration	0	0	0	9 189	0	0	0	:	:
Flood control	89	1 015	3 129	11 388	333	357	1	:	:
Water purification	1 105	31 041	4 128	15 374	330	312	170	3 114	:
Nature-based recreation(¹)	77	4 073	7 482	30 723	22 96	3 097	1 351	1 015	279

Source: JRC

Note: (:) not available.

(¹) The scope of nature-based recreation was restricted to daily trips within 4 km from human settlements and the highest natural quality sites.

ECOSYSTEM SERVICES
ECONOMIC VALUE (EU28, 2012)



(1) The scope of nature-based recreation was restricted to daily trips within 4 km

of heatwaves. Under future climate scenarios, with increased frequency and intensity of heatwaves, the importance of the microclimate regulation ecosystem service will increase (provided there are green areas in cities to supply this service).

Water purification is the ecosystem service with the highest aggregated value (EUR 55.6 billion in 2012). This value is determined by the supply and the use of this ecosystem service and it would be even higher if there was more nitrogen pollution in the environment. This is a special feature of some ecosystem services that 'clean up' pollution – their quantity (and hence value) provided can be driven by the amount of pollution because the actual flow reported in accounting is not taking into account the consequences on the environment that the use of this service might cause. Ecosystems that clean up or remove pollution from the environment can do it at levels that are above their ecological limits (or capacity) that would assure the long-term good condition of the ecosystem that provides this service. After these limits had been exceeded, pollutants result in ecosystem degradation as a consequence of the overuse of the service (unsustainable use). A consequence of such overuse of one ecosystem service is that the potential for other ecosystem services is reduced. For example, high water pollution reduces the possibilities for recreation.

Water purification is followed by nature-based recreation – the ecosystem service with the second highest aggregate value in 2012 (EUR 50.4 billion). This represents daily recreation opportunities that people have in ecosystems with a high natural quality within 4 km from human settlements.

The value of crop provision is estimated at EUR 20.8 billion annually. This value reflects the contribution of ecosystem inputs to agricultural crop production in arable land but it leaves out human inputs such as fertilizers, machinery, or agro-chemicals that enhance production. The value of timber provision is estimated at EUR 14.7 billion annually, compared to a total size of the forestry sector of EUR 23 billion (gross value added, current price, 2012)([14]).

Flood control arises when ecosystems can reduce or retain runoff water and protect downstream infrastructure and residents from flooding. It has been assessed for terrestrial ecosystems only and has been valued at EUR 16.3 billion for 2012.

Some ecosystem services are delivered by one ecosystem type. This is the case for crop provision supplied by croplands and timber provision supplied by forests. Also crop pollination services are assigned to cropland, although the model that was used to map pollination considered the proximity to other ecosystem types such as grasslands and forests.

Carbon sequestration, flood control and nature-based recreation are accounted for by more than one ecosystem type. Carbon sequestration is based on reporting under the Land Use and Land Use Change and Forestry (LULUCF). This latter accounting system only considers the contribution of managed ecosystems and only forests are recorded as net sinks of atmospheric carbon. Therefore, other ecosystems have zero values in the table; however, some of them and wetland in particular, could act as sinks of carbon under a better management.

The use table estimates the total ecosystem service flow used by different sectors (Table 6). The use table is also compiled at EU28 level and allocates the aggregated use of seven ecosystem services to six sectors.

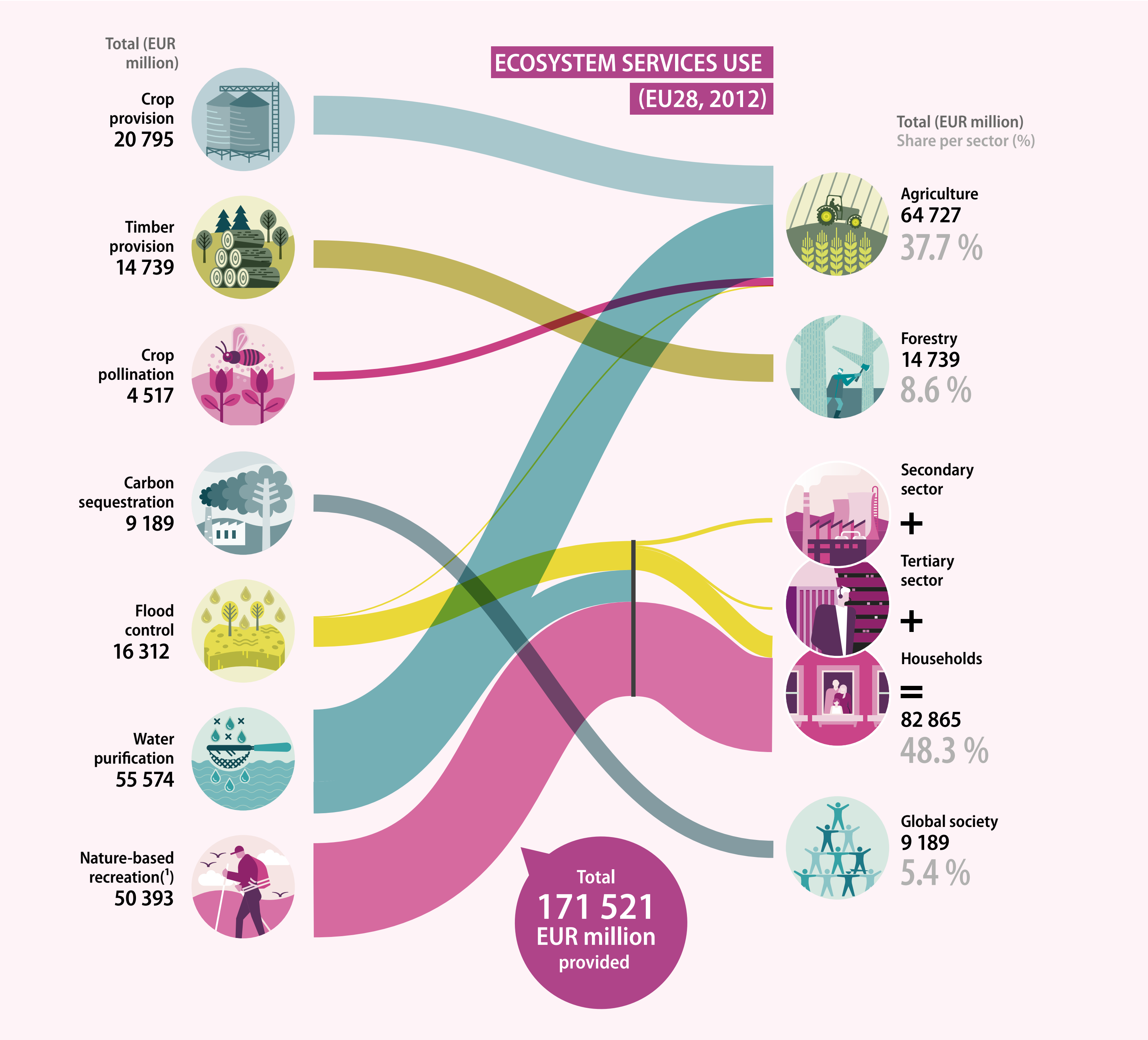
Almost half of the supply is used by households, the secondary sector and the tertiary sector. Agriculture uses 38% of the supply, forestry almost 9% through timber provision. Carbon sequestration is attributed to global society as a user. All carbon that is sequestered in the EU's forests benefits not only Europeans or particular sectors but is assumed to benefit the

Table 6: Ecosystem services use table (EU28, 2012, million EUR)([7])

<table>
<tr><th></th><th>Agriculture</th><th>Forestry</th><th>Secondary sector</th><th>Tertiary sector</th><th>Households</th><th>Global society</th></tr>
<tr><td>Crop provision</td><td>20 795</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Timber provision</td><td>0</td><td>14 739</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Crop pollination</td><td>4 517</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Carbon sequestration</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>9 189</td></tr>
<tr><td>Flood control</td><td>799</td><td>0</td><td>2 402</td><td>1 384</td><td>11 726</td><td>0</td></tr>
<tr><td>Water purification</td><td>38 615</td><td>0</td><td colspan="3">16 960</td><td>0</td></tr>
<tr><td>Nature-based recreation ([1])</td><td>0</td><td>0</td><td>0</td><td>0</td><td>50 393</td><td>0</td></tr>
</table>

Source: JRC

([1]) The scope of nature-based recreation was restricted to daily trips within 4 km from human settlements and the highest natural quality sites.



global population. This is because CO_2 is uniformly distributed in the global atmosphere.

By definition, in accounting the total supply of services by ecosystems equals the total use by different economic sectors (valued at EUR 172 billion in 2012). However, ecosystems have the potential to produce more than what is recorded in the supply and use tables. This situation can be found when there is no demand for the service (unused potential). For instance, when there are areas suitable for pollinators but no pollinator-dependent crops are grown there. At the same time, there is unmet demand for ecosystem services. Currently we estimate that about 50% of the demand for ecosystem services is not or only partially met. Consider pollination. The supply table only records the value of the service if it is actually used and results in yield of fruits and vegetables. However, in many areas where farmers grow pollinator dependent crops, there is a shortage of wild pollinators due to habitat loss or the use of chemicals that are harmful to insects. Simply put, if all the demand for pollinators would be met for instance by restoring pollinator habitats in farmlands and reducing the use harmful chemicals, the supply of the service, as well as its use, would double.

LINK TO SUSTAINABLE DEVELOPMENT GOALS: SDG 2 – Zero hunger: Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality: Indicator 2.4.1.: Proportion of agricultural area under productive and sustainable agriculture.

EUROPEAN GREEN DEAL: Farm to fork strategy([16]).

ECOSYSTEM SERVICE: CROP PROVISION([15])([7])

WHAT IS IT? In combination with the energy of the sun, soil ecosystems in croplands provide the substrate, the nutrients and the water that crops need to grow (referred to as 'ecosystem contribution'). This system is heavily supported with external human inputs such as the application of fertilisers and agrochemicals and irrigation to increase production as well as with fossil fuel that replaces human labour in terms of agricultural machinery needed to cultivate crops. Only the ecosystem contribution is considered as ecosystem service and quantified in the accounting table.

The physical accounts are based on reported yield statistics and on estimates of the ratio between natural and human inputs to crop production. The monetary accounts are based on market values for crops and corrected for the contribution of ecosystems to crop production.

PHYSICAL ACCOUNT: The ecosystem contribution to the total crop yield in the EU is, on average, 21% but there is considerable spatial variation (Figure 7). The remaining 79% of the crop yield can be attributed to human inputs (machinery, fossil fuels, agrochemicals, fertilizers, irrigation and human labour). The ecosystem contribution is higher in regions and countries with lower rates of irrigation and fertilizer application and with more extensive agriculture. The total yield derived from the ecosystem contribution to crop production in 2012 was 156 million tonnes (2.1 tonne/ha).

MONETARY ACCOUNT: The main users from the service provided by soil ecosystems in cropland are farmers. Their income is directly dependent on the condition of the farmland ecosystems. In the use table, the use is recorded under the primary sector (agriculture). The ecosystem contribution to crop production was estimated at EUR 20.8 billion in 2012.

POLICY RELEVANCE: Healthy soil systems are essential to maintain agricultural production in the long term. This account can be used in combination with accounts on crop pollination and soil retention to analyse the impact of nature-based solutions for natural pest control, increased pollination, water quality regulation, enhanced soil fertility and erosion control on total crop yields.

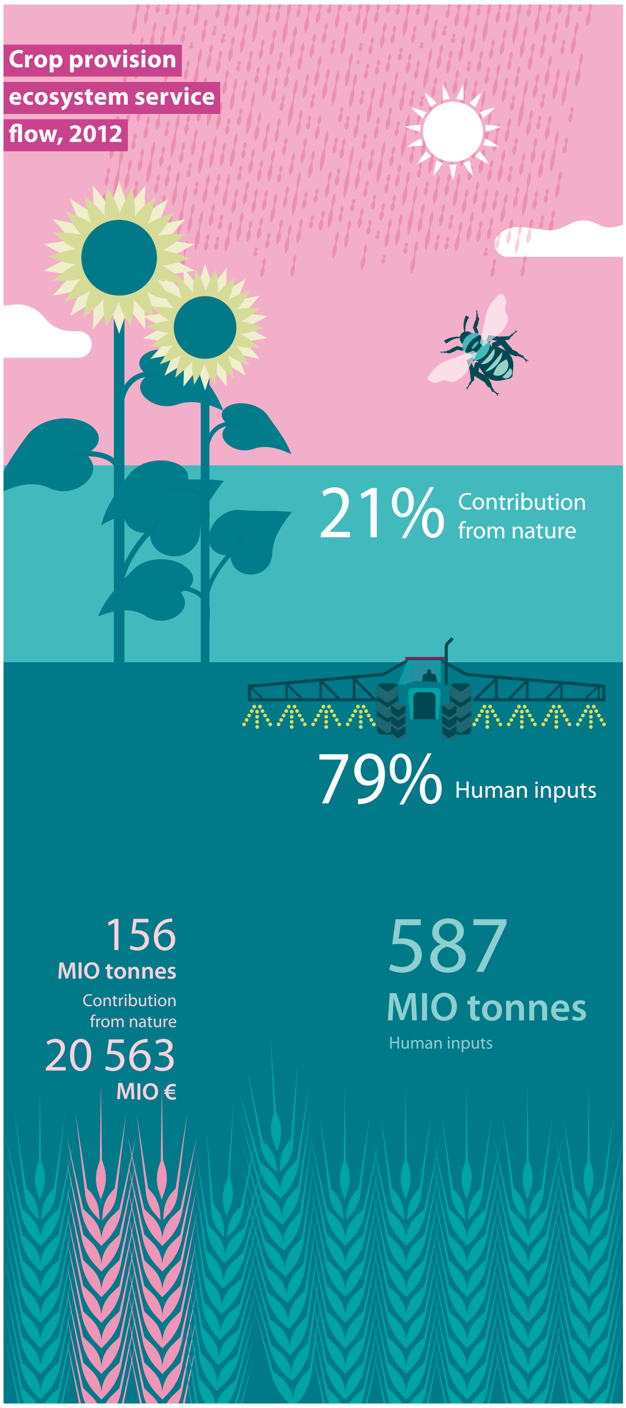
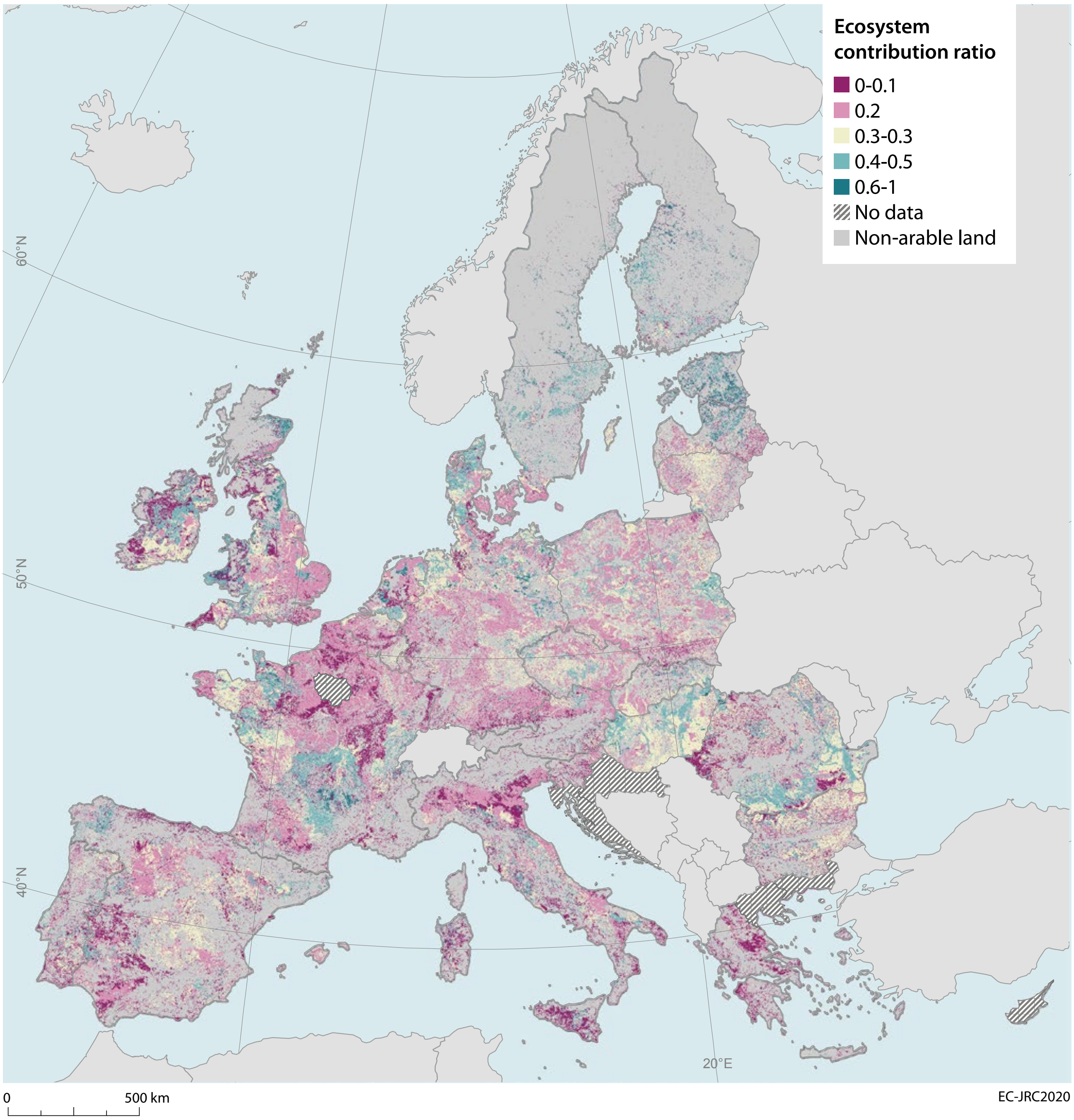


Figure 7: Ecosystem contribution to crop production as the ratio between natural capital inputs and human inputs in crop production in the EU and the UK



Note: Thirteen crop types assessed; Croatia, Malta and Cyprus not included.

ECOSYSTEM SERVICE: FLOOD CONTROL(17)(7)

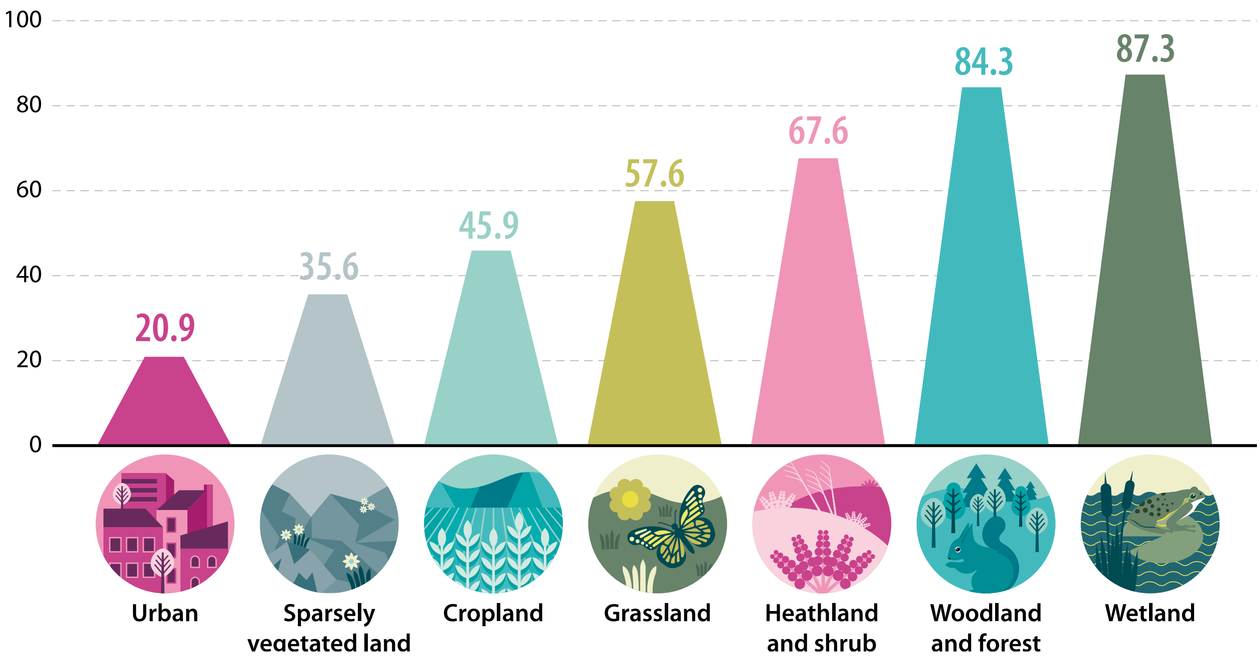
WHAT IS IT? Upstream ecosystems and wetlands protect cities, farmlands and infrastructure from flooding. Forests, wetlands and grasslands but also croplands and urban ecosystems regulate water flows. They reduce the speed of runoff water during heavy rain or they infiltrate and store water temporarily in the soil. Wetlands and riparian areas act as buffer zones and store excess waters. All these natural water retention functions reduce the risk of downstream flooding, protect people and infrastructure and avoid damage costs related to floods. Different ecosystem types differ in their ability to provide the flood control ecosystem service – forests and wetlands are particularly effective in holding water (Figure 8). In addition, urban areas and cropland can be managed to increase their potential to store water.

The physical accounts are based on a spatially explicit modelling of the water retention capacity of different ecosystem types and an assessment of the infrastructure and residential areas that are at risk. The monetary accounts are based on avoided damage costs – the costs that would have been made in absence of the protective functions of ecosystems.

PHYSICAL ACCOUNT: The total service providing area (the area with protective function) is as big as 2.4 million km^2 (about 3/5 of the EU territory; mostly forests and other vegetated lands that have flood controlling capacity regardless of the actual demand for it). Forests provide 70% of the service, followed by grasslands, providing 18%. In contrast, the service demanding area, i.e. the area with people and infrastructure subject to flood risk and needing the service of flood control, is much smaller and totals 142 037 km^2 of built land (12%) and agricultural land (88%). Of this area, only 41 696 km^2 is protected (the demand is met) leaving a large unmet demand of 95 111 km^2. Moreover, the results of the INCA project suggest that the extent of natural areas providing protection from floods to agriculture and urban areas decreased between 2006 and 2012 due to soil sealing in all Member States by 3 – 79% (Figure 9).

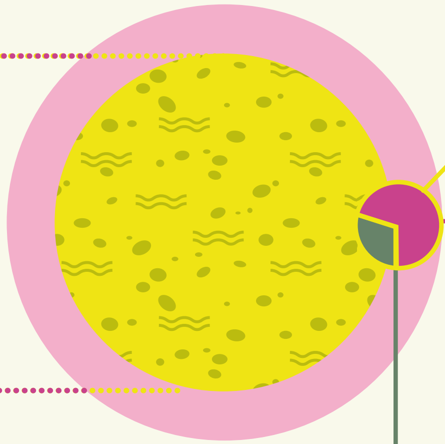
MONETARY ACCOUNT: Flood control ecosystem service is used throughout the economy but most of the value goes to households and the agricultural sector whose assets are to the greatest extent protected by ecosystems from flooding. The total value of this ecosystem service was estimated at EUR 16.3 billion in 2012.

Figure 8: Mean flood control potential for ecosystem types, 2012 (dimensionless indicator)



Flood control ecosystem service physical flow, 2012

2.4 million km²
of natural area of EU28 has a potential to provide flood control ecosystem service. This corresponds to 3/5 of EU28 area.



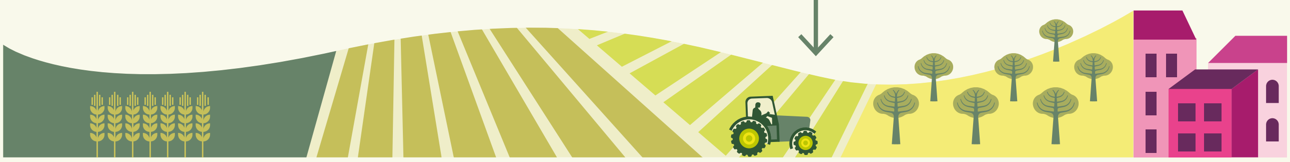
142 037 km² of the total area of EU28 need flood protection.

67% of this area is unprotected

29% of this area is protected by natural ecosystems. These are **41 696 km²** ....

This area is used as ...

(The remaining 4 % of this area is protected by man-made structures)



Agricultural land 88 %

built up land 12 %

Flood protection for this area is provided by the following natural ecostems...

Forests 70 %

Grassland 18 %

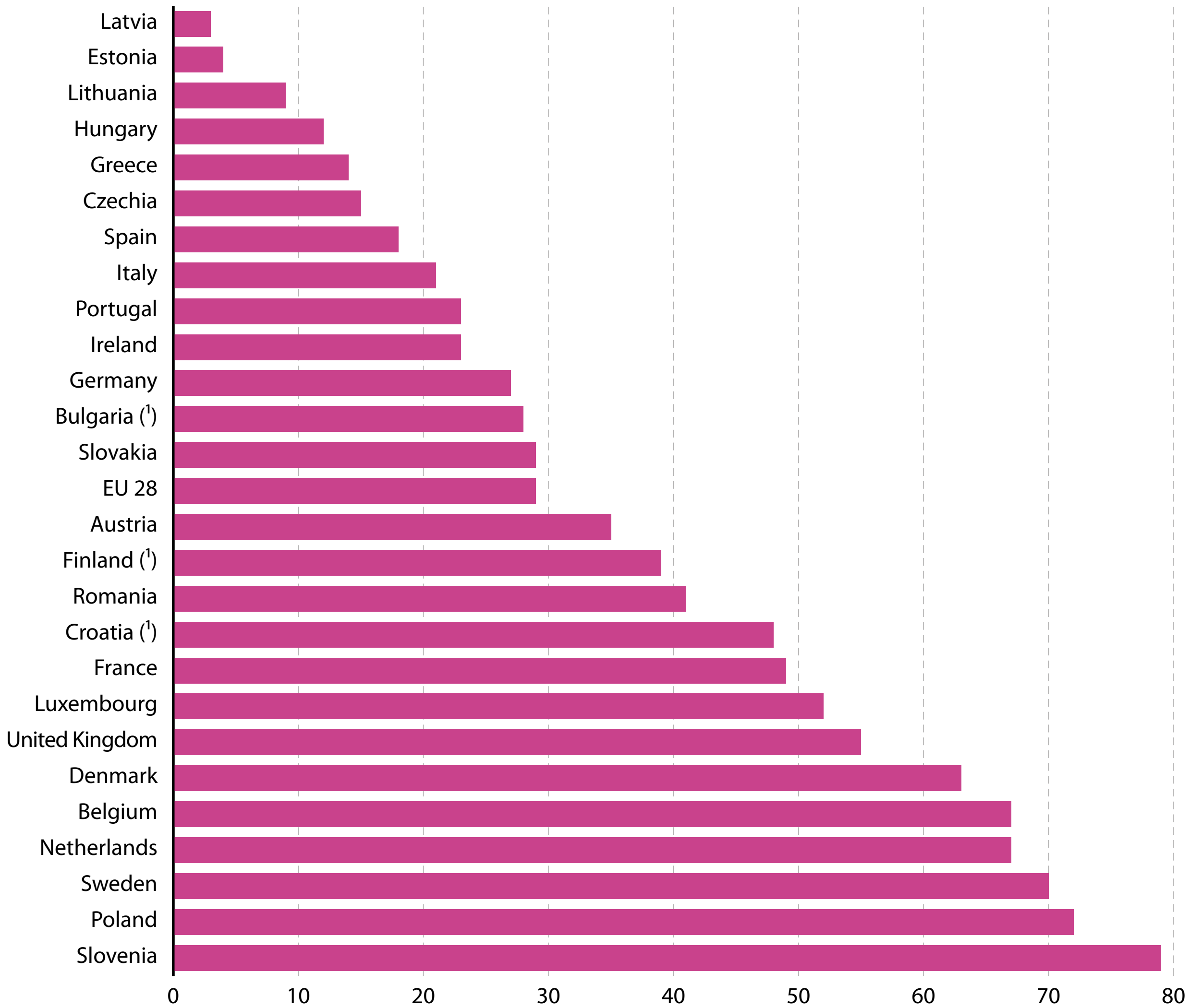
other 12 %

POLICY RELEVANCE: The high potential of ecosystems to protect people and infrastructure is heavily underutilized. Ecosystem accounts can be used to guide projects that restore ecosystems in upstream areas so that they reduce flood risk downstream. The flood control accounts highlight the need of integrating the role of ecosystems providing flood protection in the flood risk management and restoration plans.

LINK TO SUSTAINABLE DEVELOPMENT GOALS: SDG 11 – Sustainable cities and communities: Target 11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations. Target 11.5.2 Direct disaster economic loss in relation to global GDP, including disaster damage to critical infrastructure and disruption of basic services.

EUROPEAN GREEN DEAL: EU Biodiversity Strategy for 2030. Restoring ecosystems with high potential to protect against natural disasters.

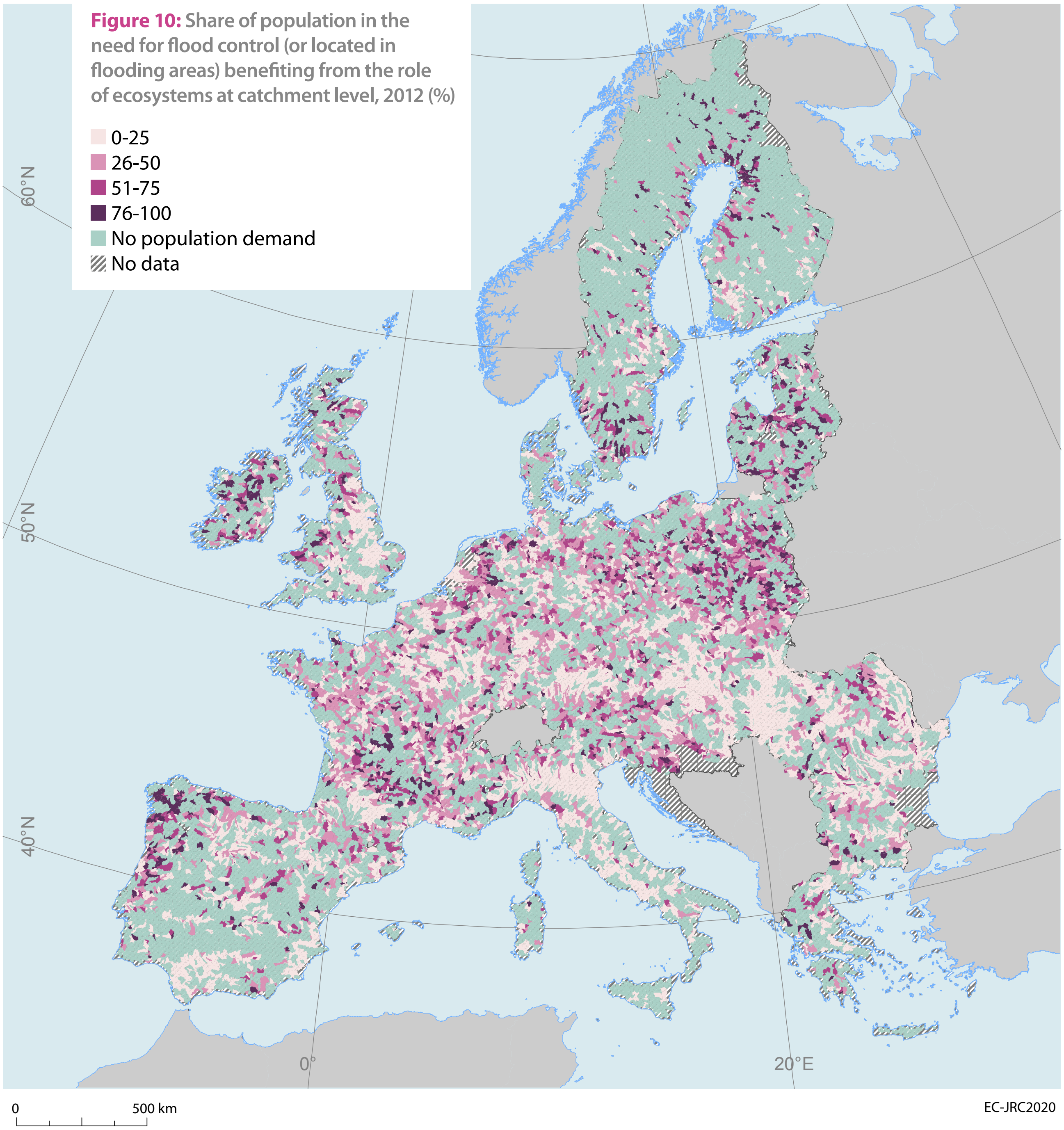
Figure 9: **Decrease in the extent of areas providing flood control ecosystem service due to the increase of imperviousness (soil sealing) between 2006 and 2012 (%)**



(¹) Data do not cover the whole country

Source: JRC

Figure 10: Share of population in the need for flood control (or located in flooding areas) benefiting from the role of ecosystems at catchment level, 2012 (%)



Where do people benefit most from nature-based solutions to flood protection and where are these solutions most needed?

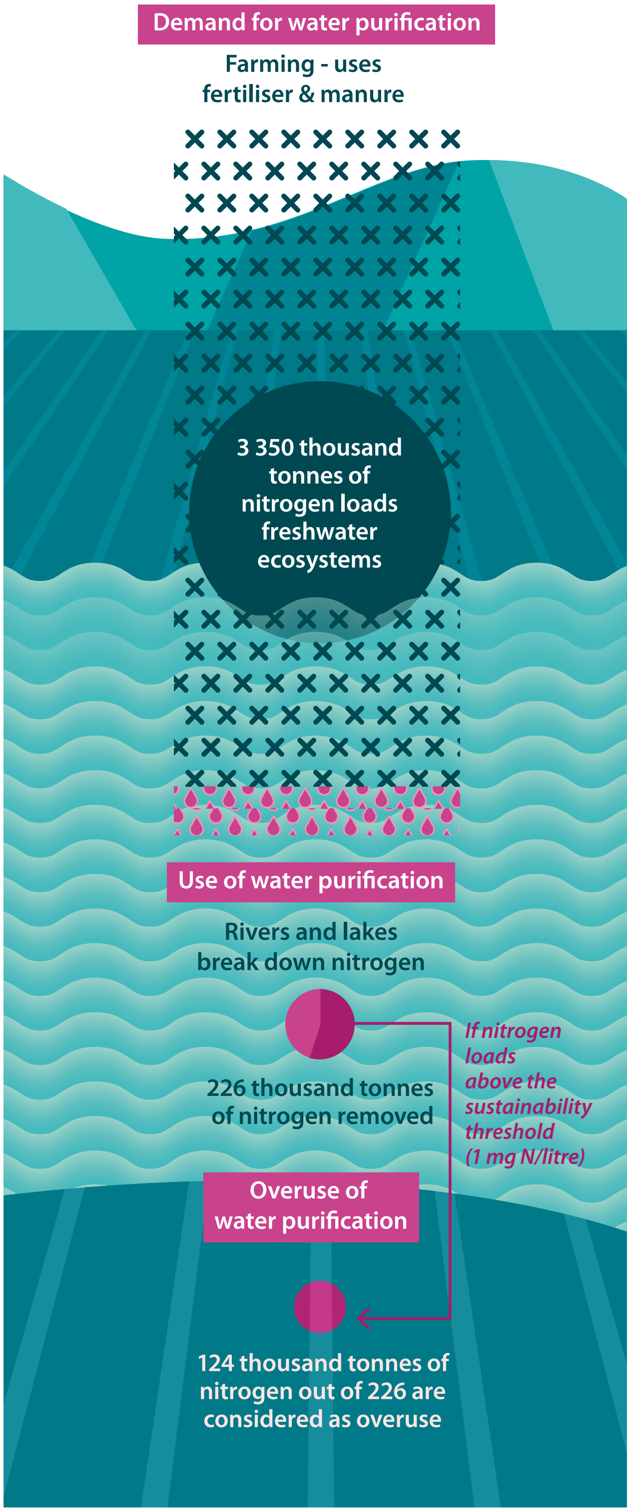
EU citizens benefit from flood control provided by ecosystems and the share of benefitting population varies across the EU28 (Figure 10). Ecosystem service accounts for flood control can support policies on the mitigation of flood effects through sustainable ecosystem management. Ecosystem management and nature-based solutions to enhance flood control should be prioritized in areas with lower share of population benefiting from flood control, as shown above. The share of unmet demand by the population is larger as a consequence of the absence of ecosystems with a high flood control potential (see Figure 8) or their poor condition. Flood damage mitigation through nature-based solutions and ecosystem restoration, especially in areas of unmet demand, are crucial under the expected increase of damages caused by floods in the EU due to climate change.

ECOSYSTEM SERVICE: WATER PURIFICATION(7)

WHAT IS IT? Rivers and lakes, wetlands and soils, and groundwater systems retain, immobilise and remove excess nutrients and other pollutants. This self-purifying capacity is essential in the water cycle as it reduces the downstream pollutant load and it results in improved water quality.

The physical accounts of water purification use nitrogen as an indicator for the need of water purification. Excess nitrogen in the environment caused by households, industry and in particular, agriculture, is a potent pollutant resulting in eutrophication and oxygen-poor zones in lakes and coastal areas. The physical account is based on a European model that calculates a nitrogen balance for watersheds. The monetary accounts are based on the cost of replacing water purification services by a comparable, technological solution (constructed wetlands). Water purification is a clear example of ecosystem service that can be overused when the amount of nitrogen to be removed from freshwater ecosystems exceeds their capacity to clean water affecting their ecological integrity (or deteriorating their condition), what is known as sustainability threshold. Sustainability thresholds can be defined under different criteria. For instance, maintaining nitrogen concentration of 2 mg of nitrogen per litre is considered a minimum standard to guarantee that rivers and lakes achieve good ecological status (according to the Water Framework Directive). A more restrictive threshold of 1 mg of nitrogen per litre can also be used to assess eutrophication issues, since at nitrogen concentrations above this threshold eutrophication is very likely to occur(*). In our example, we will refer to the threshold of 1 mg of nitrogen per litre as the eutrophication sustainability threshold (Figure 11).

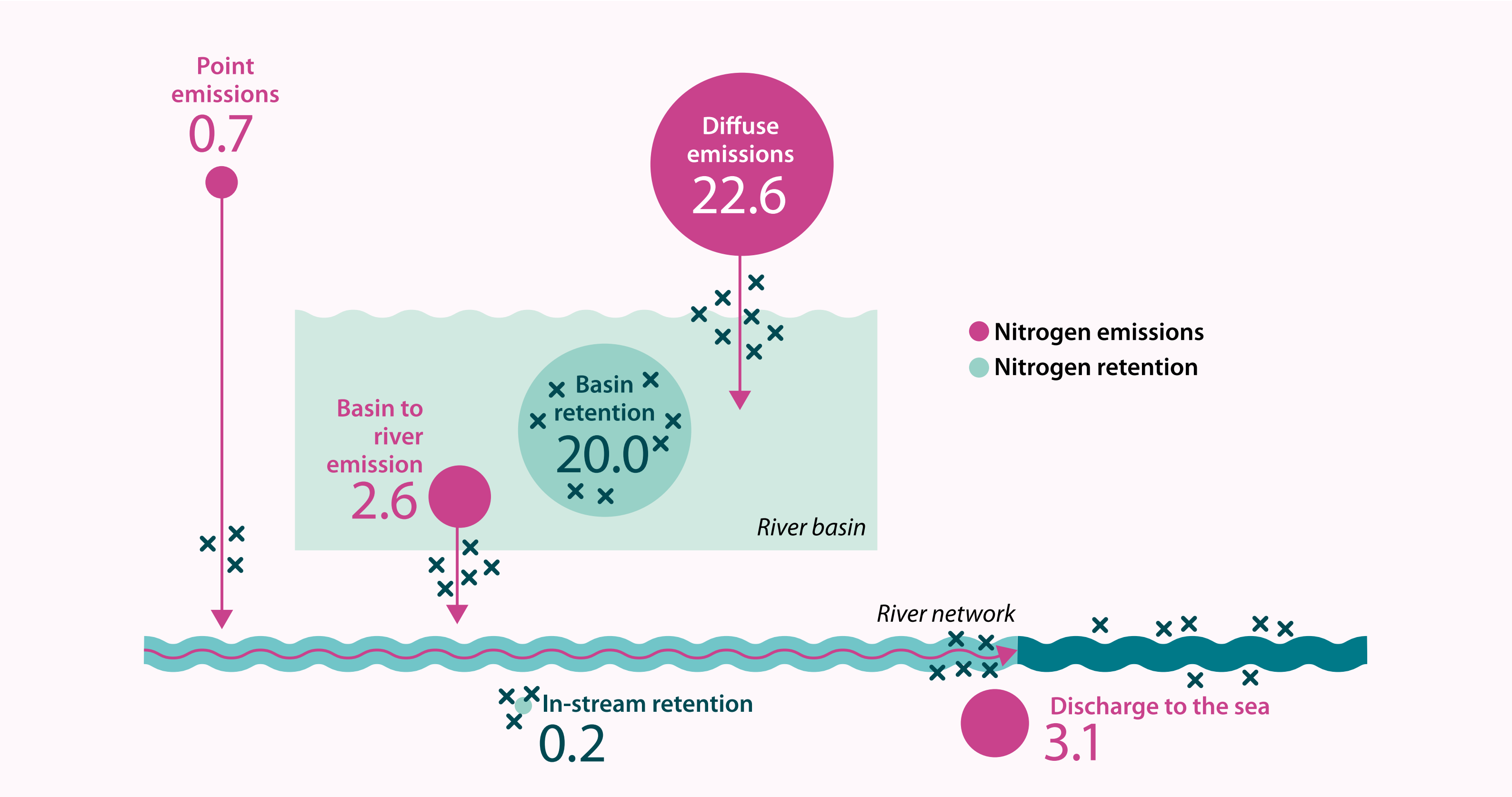
Figure 11: Water purification ecosystem services in the EU in 2012 using nitrogen removal as a proxy for water purification and the concentration of 1 mg of nitrogen per litre as a sustainability threshold



Source: JRC

(*) To establish the threshold level (i.e. the critical nitrogen concentration), we refer to https://www.nature.com/articles/s41598-017-00324-3, where with reference to nitrogen pressure in European rivers, the correlation with a good ecological status refers to a concentration of 2 mg/l and with a high ecological status refers to a concentration of 1 mg/l.

Figure 12: Nitrogen balance for the EU28 in million tonne, 2012



Source: JRC

PHYSICAL ACCOUNT: In 2012, 23 million tonne of nitrogen was emitted to the environment, most of it by agriculture (81%). Other sources were atmospheric deposition (16%) and point sources from industry or wastewater treatment plants (3%). Only a fraction (13%) of all the emitted nitrogen reaches the sea. Most of the nitrogen is retained in the soil and groundwater (86%). The remaining 1% is retained by rivers and lakes. So in 2012 the EU's ecosystems retained 20.2 million tonnes of nitrogen (Figure 12).

The total emission of nitrogen substantially overshoots the minimum and safe standards and suggests that the service is not used in a sustainable manner. Rivers and lakes receive too much nitrogen and have to go in overdrive to remove excess nitrogen from the water. This causes trade-offs with biodiversity and other ecosystem services, in particular water-related recreation.

MONETARY ACCOUNT. The economic value of nitrogen removal as ecosystem service is estimated based on replacement costs (the total costs of water purification through alternative means – constructed wetland – to replace this ecosystem service if ecosystems were not providing it). The total economic value of the services for the EU was EUR 55.7 billion in 2012.

POLICY RELEVANCE: The demand for natural water purification exceeds many times the capacity of freshwater ecosystems to clean water. Therefore, discharges of pollutants and nutrients to coastal areas remain far too high. Restoring and increasing the area of freshwater and coastal wetlands, riparian areas and floodplains (even if currently not accounted for in our models) is key to reduce the benefits gaps delivered through water purification.

LINK TO SUSTAINABLE DEVELOPMENT GOALS: SDG 6 – Clean water: Target 6.6. By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes. Target 6.6.1: Change in the extent of water-related ecosystems over time

EUROPEAN GREEN DEAL: Zero pollution action plan

ECOSYSTEM SERVICE: CARBON SEQUESTRATION(18)(7)

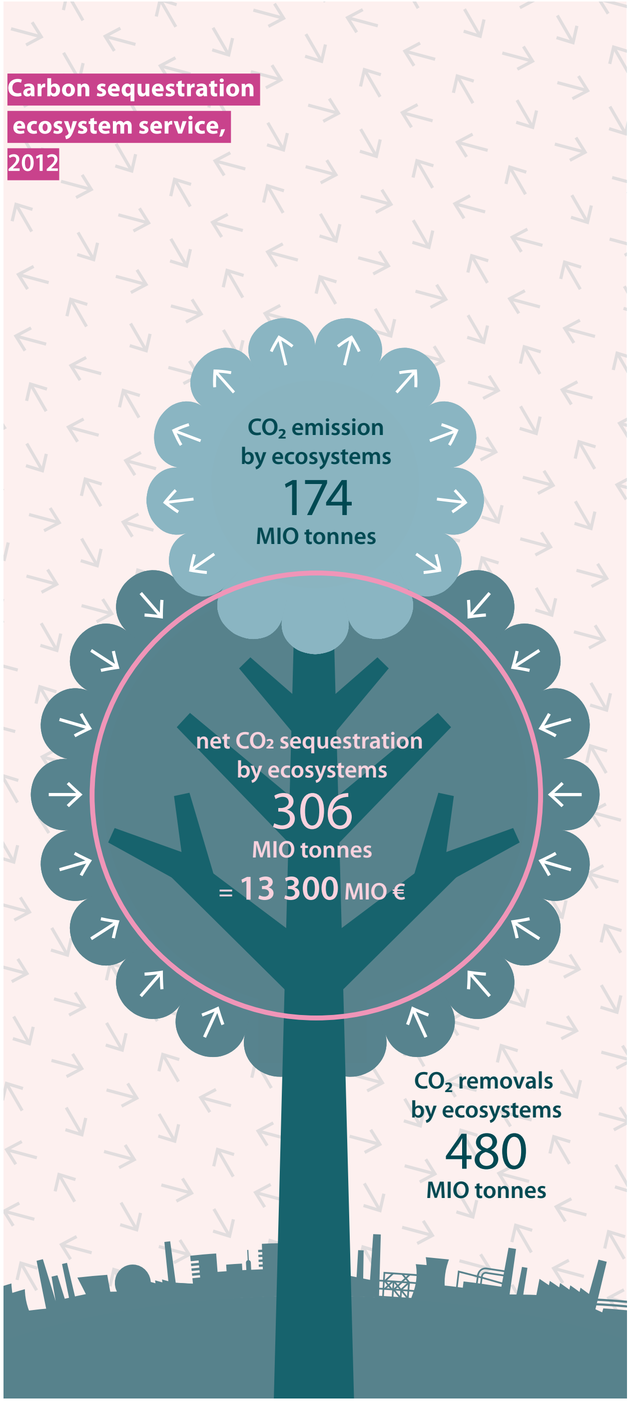
WHAT IS IT? Ecosystems absorb large quantities of CO_2 from the atmosphere, mainly through photosynthesis. As vegetation on land and algae in the oceans grow, they use solar energy and water to fix carbon dioxide hereby releasing oxygen. By so doing they mitigate the impacts of climate change occurring due to rising greenhouse gas emissions.

The physical accounts are simply based on the LULUCF reporting by countries for the United Nations Framework Convention on Climate Change. The monetary accounts are based on a market price for carbon.

PHYSICAL ACCOUNTS: In the EU, the net CO_2 uptake realised in 2012 was 306 million tonnes of CO_2. This number results from the balance between the net removals by forests (444 million tonne of CO_2) and the net emissions from other ecosystems (138 million tonne of CO_2). EU ecosystems, and in particular forests, mitigate ca 7% of all anthropogenic CO_2 emissions of the EU. In some countries, ecosystems emit additional CO_2 on top of human-induced emissions (shown as negative numbers in Figure 13). Ecosystems in Scandinavian EU countries mitigated >50% of their anthropogenic emissions.

MONETARY ACCOUNTS: The value of net CO_2 uptake is estimated at EUR 13.3 billion. Not only the EU economy benefits from this service. Instead, the benefits go the economic sector we refer to as 'global society'. This is because CO_2 is considered to be equally distributed over the global atmosphere.

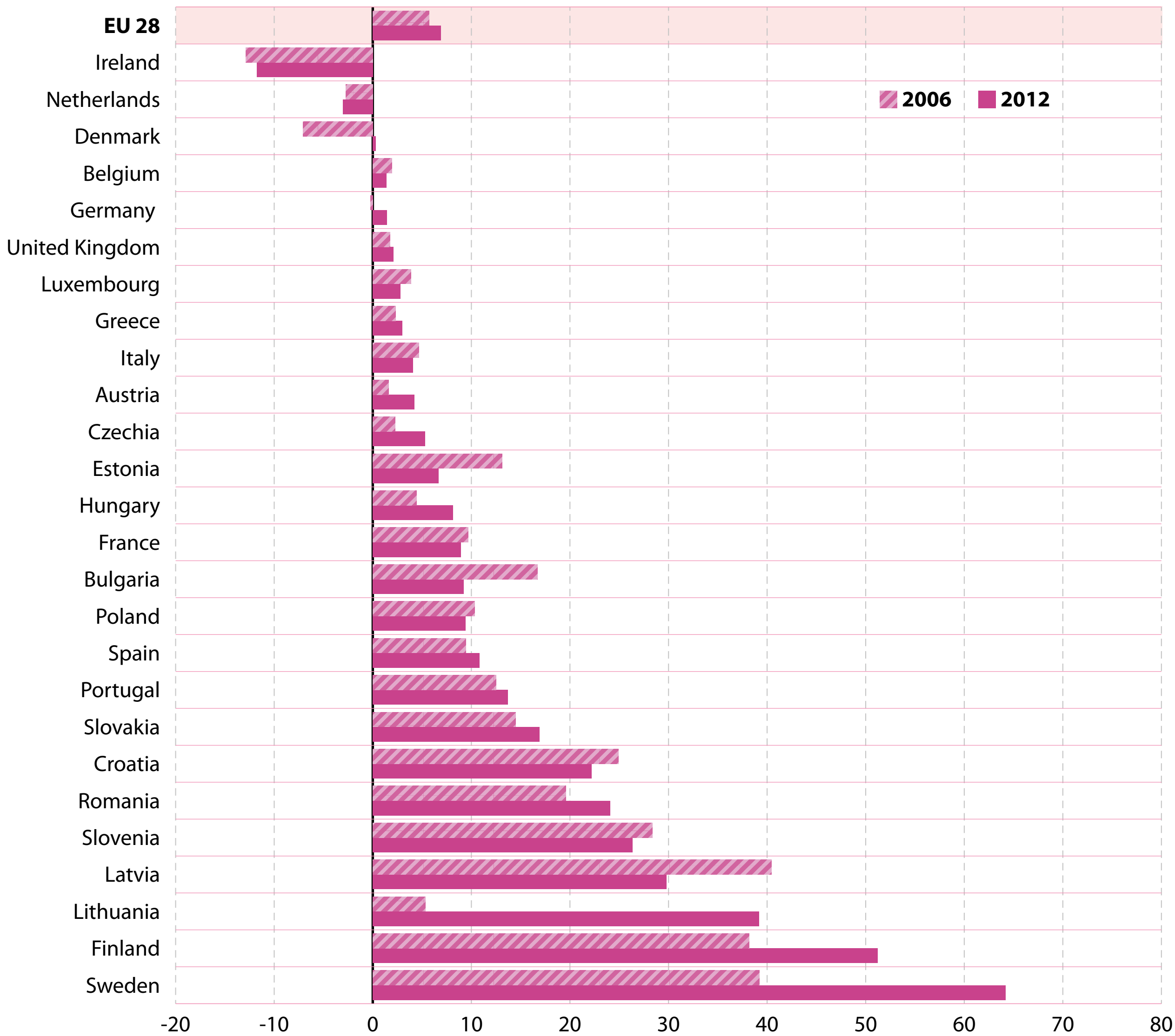
POLICY RELEVANCE: The capacity of healthy and resilient ecosystems to mitigate CO_2 is often overlooked. Emphasis goes to planting trees but this is only a small part of a solution to decrease atmospheric CO_2. Conserving natural ecosystems and restoring forests, grasslands and wetlands is expected to significantly reduce the CO_2 concentration (keeping everything else constant).



LINK TO SUSTAINABLE DEVELOPMENT GOALS: SDG 13 – Climate action: Target 13.2 Integrate climate change measures into national policies, strategies and planning

EUROPEAN GREEN DEAL: Increasing the EU's climate ambitions by 2030 and 2050.

Figure 13: Anthropogenic CO_2 emissions mitigated by ecosystems (thousand tonne)



Box 4:

Using SEEA EEA to inform land management for CO_2 sequestration: peatlands in the Netherlands([19])

Ecosystem accounts built following the SEEA EEA have been used in the Netherlands to inform public debate about the management of peatlands. Peatlands are very specific ecosystems playing a crucial role in the cycle of organic carbon on Earth and therefore having a potential to act as either carbon sink or carbon source depending on their management and on ecological conditions. Simply put, if drained (or drying out as a result of changing weather patterns), organic carbon stored in peat is exposed to oxygen and peatlands release CO_2. If wet, with water table close to or above the surface of the peat, plant matter accumulates in peatlands and organic carbon is stored. In densely populated areas, such as the Netherlands, peatlands have traditionally been drained and used for agriculture.

These pressures have a tendency to continue; however, there is a competing national interest of reducing CO_2 emissions and the relatively large potential of peatlands to contribute either to further emissions or sequestration. Ecosystem accounts in physical terms enabled the flows of carbon in the environment, including the emission of CO_2 from peatlands, to be quantified and clearly presented to stakeholders. The monetary accounts enabled all costs to be compared – the profits of farmers from drained land and the cost of draining to assure these profits, along with the monetized emissions of CO_2 resulting from draining, but also the cost of re-wetting the peatlands to restore the carbon sequestration ecosystem function and avoid further emissions.

A tentative estimate of EU ecosystem services value for 2019

This section presents an estimate of services provided by ecosystems to EU citizens and the economy in 2019. The estimate was produced using the data for year 2012 shown in Table 5 as a starting point and adjusting them for two elements. First, the 2019 estimate is more comprehensive – it aggregates values for ten ecosystem services and uses a broader scope of nature-based recreation. Second, the estimate provides more timely information – it presents results for all ecosystem services using the prices of 2019 and uses higher carbon prices.

The INCA project estimated the total value of the ten ecosystem services shown below in Table 7 to be EUR 234 billion in the EU28 in 2019. This value is comparable to the gross value added generated by agriculture and forestry combined (ca EUR 224 billion(*) for EU28). This value may be regarded as an initial estimate of the EU's 'gross ecosystem product', a concept being developed to mirror and complement the conventional measure of economic activity – the GDP.

How does this value compare to other estimates of the contribution of nature to the economy? Multiple methods have been used to estimate how much ecosystems contribute to the economy and society. Some methods considered natural inputs from both biotic (i.e. living) and abiotic (i.e. non-living) components of ecosystems, the latter including e.g. mineral resources or wind energy. Some considered both direct and indirect inputs from ecosystems, meaning that if a business uses natural inputs somewhere along the production chain, these inputs are counted (and a single input from ecosystems can be counted multiple times). Ecosystem accounting uses well-defined rules of measurement consistent with the ones used by national accounts. This way it aims to assure that produced values, both in physical and monetary units, are comparable and consistent across countries and over time, and that produced ecosystem accounts in monetary units can be viewed and analysed in a common context with standard economic accounts.

While the INCA project aimed to cover the economically most important ecosystem services, this estimate still comprises only a subset of all ecosystem services and it is based on a number of assumptions and limitations to what could be produced for the EU as a whole at the time the project was implemented. As a result, this number needs to be viewed as a 'proof of concept' rather than an actual value. It needs to be interpreted with great care and alongside physical ecosystem services accounts quantifying the supply and use of ecosystem services, their changes over time and distribution in space.

Table 7: Tentative estimate of ecosystem services values for EU28 in 2019 (EUR million)

Ecosystem service (valuation method)	Estimated value in 2019 (EUR million)
Crop provision (Share of crop market price)	23.145
Timber provision (Share of forestry output)	16.379
Pollination (Market value of increased output) (1)	4.977
Carbon sequestration (Social cost of carbon)	13.271
Flood control (Avoided damage cost)	18.016
Water purification (Replacement cost approach) (2)	61.882
Nature recreation (Travel cost method)	80.262
Water provision (Replacement cost approach) (2)	4.887
Air filtration of PM2.5 (Health care costs avoided)	10.446
Marine fish capture (Net profit)	1.042
Total	234.307

Source: Pilot aggregated EU ecosystem services accounts

Note: Values for 2019 were estimated based on the 2012 ecosystem services accounts of the INCA project using methods in the cited source. Input data for pollination and carbon sequestration (i.e. 2012 data) have been revised since 'Pilot aggregated EU ecosystem services accounts' was published, therefore, the 2019 estimates for these two services differ between this report and the cited source publication.

(1) Pollination and crop provision consider different types of crops, hence may be summed up without double counting.

(2) There might be some double counting between water purification and water provision.

The estimated EU28 gross ecosystem product presented for reference year 2019 has two components[20]. The first one are the seven ecosystem services accounts produced by the INCA project for reference year 2012 for the whole of EU28 as shown in earlier pages. These values were converted from 2012 prices to 2019 prices using the GDP deflator(**). In addition, further adjustments were made for the outdoor recreation and carbon sequestration ecosystem services. The scope of outdoor recreation in the estimate includes all recreation (i.e. not limited to the most valuable natural sites of the EU located within 4 km from human settlements) to give a better approximation of the 'gross ecosystem product'. Carbon sequestration in the estimate uses higher prices per tonne of greenhouse gasses sequestered than the original INCA account for 2012, to reflect the increasing importance of actions to combat climate change, as indicated by climate policies adopted since then.

The first component – the seven INCA ecosystem services – was further complemented with estimates for three additional ecosystem services – water provision, air filtration and marine fish capture – for which national ecosystem accounts had been produced by some countries. We scaled the Dutch data up to EU28 level to produce estimates of water purification and air filtration, and the UK data to produce an estimate of marine fish capture for EU28 for 2019.

(*) Value for 2018 presented for agriculture and forestry; data for 2019 were not available at the time this report was completed; see https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a64&lang=en.

(**) This means that the estimates did not consider the changes in the physical supply of ecosystem services as a result of e.g. improved/deteriorated condition of ecosystems or increase in the demand for ecosystem services by industries or the society.

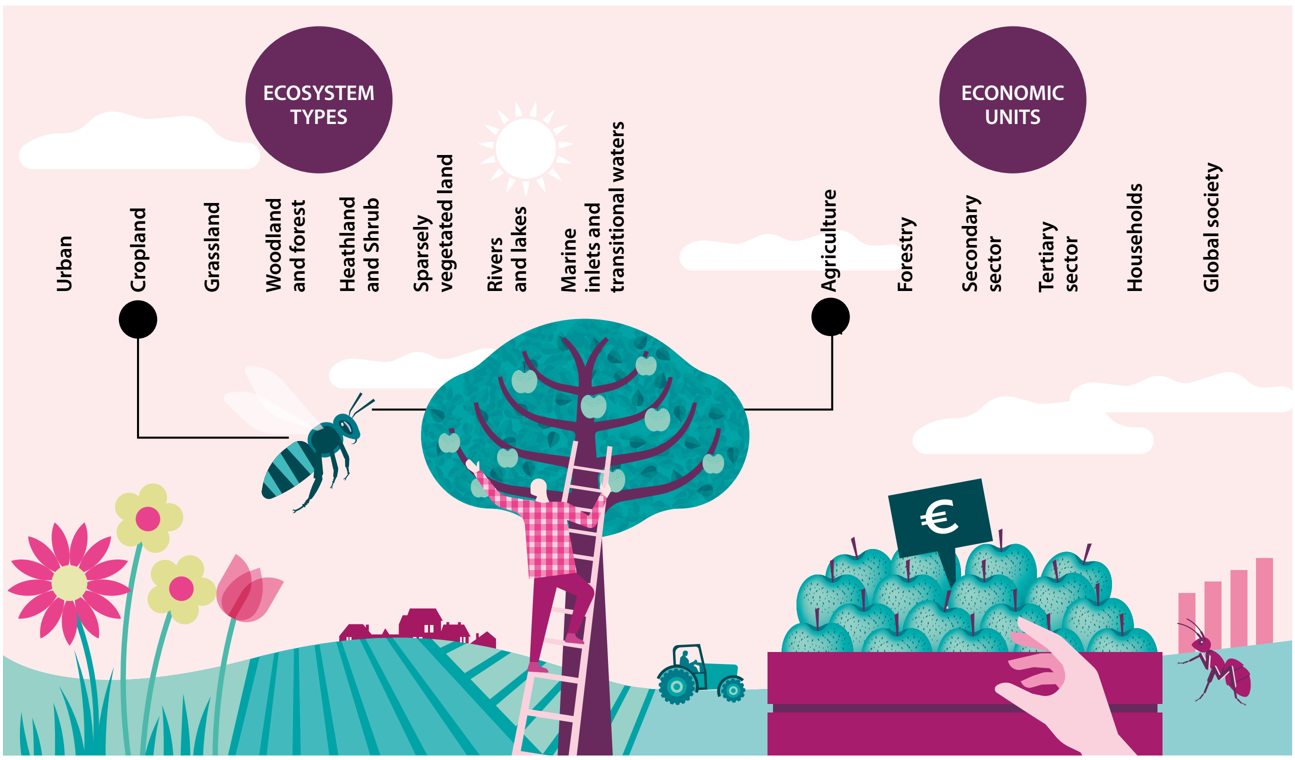
Possible uses of ecosystem accounts: Bridging ecology to economy([21])

How can ecosystem accounts be used and for which purpose?

Accounting follows strict rules, and economic accounting follows the rules of the *System of National Accounts* (SNA). The SNA is an international standard adopted at the UN level. National accounts compiled following these guidelines are used by European institutions, governments, central banks for economic analyses and forecasting, policy design and policymaking. Ecosystem accounts can be compiled as satellite accounts (as an 'add-on') to national accounts and be used in the same way for environmental-economic analysis and forecasting, policy design and policy making. This implies that we can measure relevant changes that occur in ecosystems in the economic domain with economic tools and figures.

The focus of this section is on ecosystem service accounts, and on the associated supply and use tables where the flows of ecosystem services provided by different ecosystem types (i.e. the supply) are allocated to the economic sectors (i.e. the use), mimicking the structure of the SNA (Figure 14). Concrete examples will show us how four policy questions are answered when supply and use tables for specific ecosystem services are linked ('bridged') with appropriate economic tools. Specifically: what drives the change in the supply of an ecosystem service? How sustainable are the main agricultural producers in EU? How much do agricultural products sold in one country affect ecosystem degradation in another country? Can the presence of invasive alien species have a material economic impact?

Figure 14: From ecosystems to economy: the linkage established by ecosystem services flows



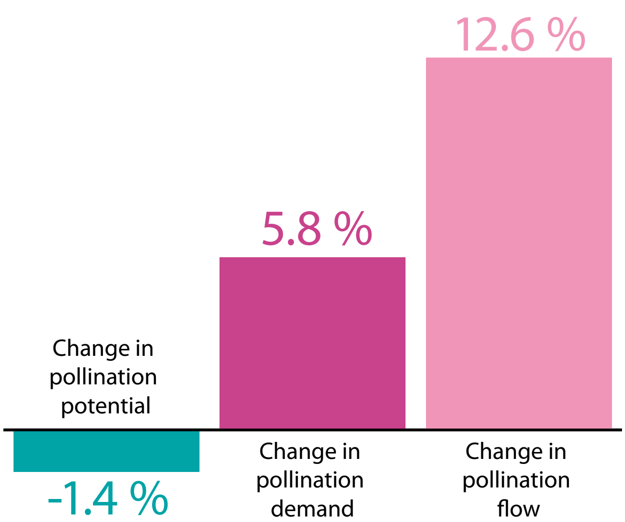
Source: JRC

There are many ways ecosystem services accounts can be used in economic analysis: (i) for descriptive statistics where data from accounts can be used directly without further processing; (ii) for developing scoreboards and indicators e.g. on sustainability; (iii) for the more complex processing required by the integration with economic tools; such as (a) multiregional input-output tables and (b) general equilibrium modelling.

Descriptive statistics to understand what is driving the change

The results of the INCA project suggested that the pollination ecosystem services increased from 2000 to 2012 by 12.6%. This seems at first glance to be a positive change. This increase could have been driven by the supply side of the account – improved conditions (habitat) for pollinators would result in more crops being pollinated. Under this scenario the accounts would show an increase in pollination potential. Or, the increase in pollination could be driven by the demand side – increased production of crops that require pollination. The increase might have also been caused by the combination of the two. In these results shown by INCA, there is more demand for pollinator-dependent crops in 2012 than in 2000 (by 5.8%) but no increase in the availability of suitable habitat for pollinators. In fact, habitat suitability for pollinators has decreased by 1.4% (Figure 15). Still, pollination increased notably by 12.6%, but this increase could have been even larger if habitat suitability for pollinators was enhanced. This is a strong message for policy makers, management of agricultural land and ecosystem restoration.

Figure 15: Changes in the pollination ecosystem service from 2000 to 2012



Source: JRC

The same applies to most ecosystem services: the identification of the driver of change (whether it is an ecological enhancement leading to increased potential supply or an increase of demand) is a crucial information for policy makers. To separately identify ecosystem service potential on the one hand and demand on the other hand before summing them up to quantify the flow of services is the novel approach proposed and developed by INCA with respect to ecosystem services accounting.

Scoreboards and indicators to analyse sustainability of management practices

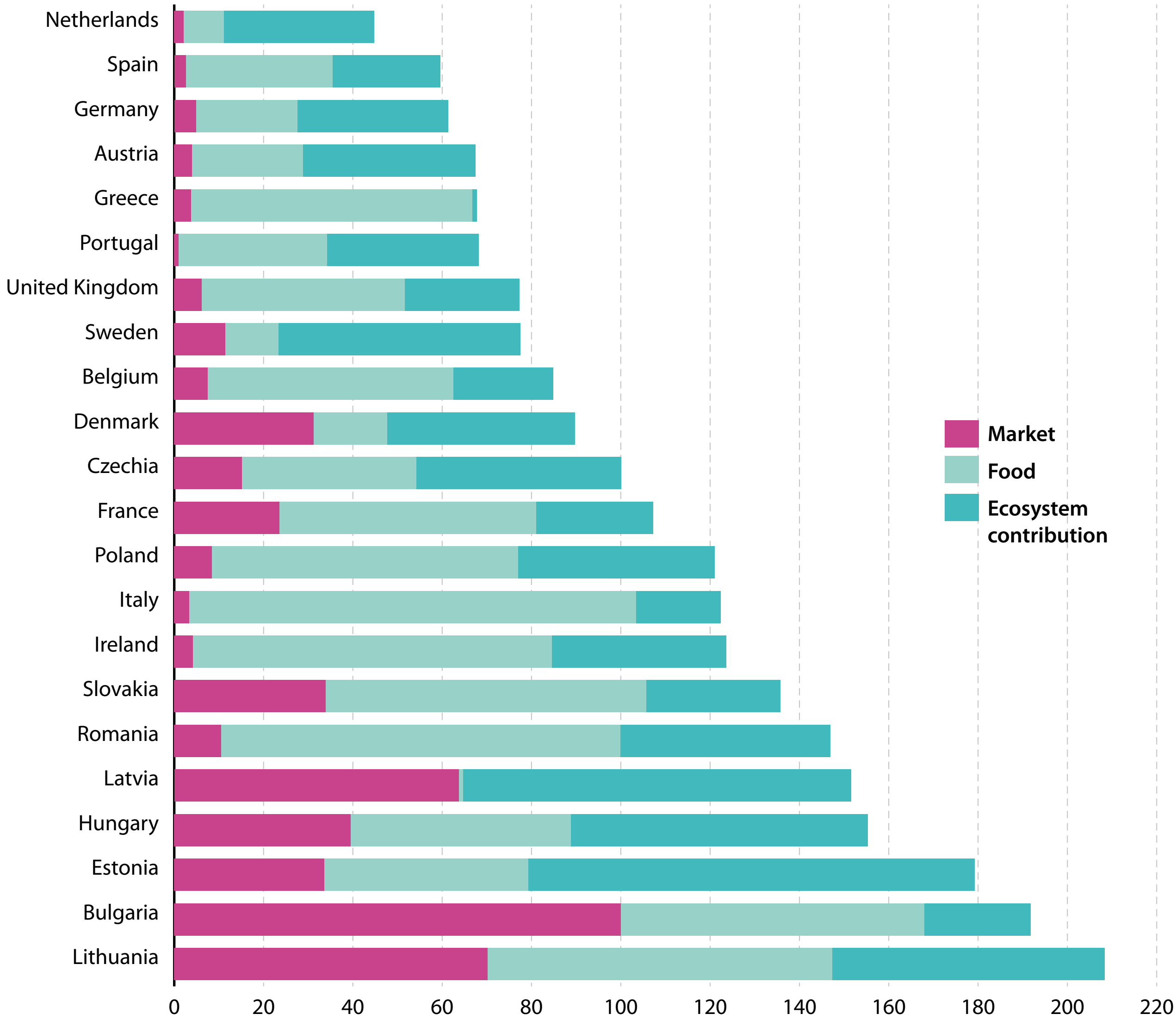
In 2012, France and Germany were the main producers of wheat, followed by the UK, Poland and Italy. These are important, traditional, agricultural statistics, and more or less the same ranking/results are seen regardless of the data source consulted. However, the measurement of wheat production can in fact be looked at from a number of different perspectives, to answer a number of different questions. To illustrate how such perspectives could then be combined, we have developed a simplified scoreboard on individual sustainability dimensions of wheat production per country below.

If we consider the role of ecosystem contribution(*) to produce wheat (as opposed to the human input), then do France and Germany still rank high up compared to other EU Member States? If we consider the importance of agricultural sector in relation to the total economy of the country (measured as the share of GDP), would the value of wheat retain the same weight within a market perspective? If we consider the domestic supply of wheat compared to domestic demand, which countries could be considered self-sufficient, and which as dependent on other countries? Building a scoreboard that is able to harmonize all these elements together through a combined presentation can provide some answers to these questions.

The sustainability scoreboard integrates information on the economic importance (Market), ecosystem contribution to agricultural production (Eco Con) quantified and translated into monetary terms using ecosystem accounting, and domestic availability (Food) of wheat production. When looking specifically at ecosystem contribution, Figure 16 suggests that eastern European countries such as Latvia and Estonia seem to adopt less intensive agricultural practices (i.e. higher ecological input) than France and Germany: the ecosystem contribution indicator (EcoCon) of the former two countries is very high, this explains why Latvia and Estonia score well in terms of the ecological component, and within the top five countries in terms of

(*) See chapter 'Ecosystem service: Crop provision' for more detail on ecosystem contribution.

Figure 16: Country ranking based on wheat sustainability scoreboard indicators, 2012



Source: JRC

Note: Croatia, Cyprus, Finland, Luxembourg, Malta and Slovenia not shown.

overall sustainability as measured by these three indicators. It should be noted that wheat is only one part of the overall agricultural production of each country and its relative importance will vary strongly from country to country. In addition, the purpose of the score is not to measure which country ranks the highest, but rather to examine the role of each sustainability component.

Multiregional input-output tables to quantify the 'footprint' of ecosystem services that are embedded in traded products

When an apple is exported from Italy to Germany, what is traded is more than the apple itself. Natural and human inputs are needed to produce the apple. And waste and pollution are unintentional by-products of the process. These natural inputs or pollution embedded in the apple can be considered to be the 'footprint'([22]) of the one consuming the apple. Agriculture, using natural and chemical fertilizers, is considered a major source of nitrogen enrichment in water bodies, leading to eutrophication, a major cause of poor water quality of inland waters. Nature has the ability to clean nitrogen-enriched runoff waters from agriculture – this is the water purification ecosystem service. The water purification service needed to clean the nitrogen emissions resulting from crop production is "embedded" in the agricultural product that is exported. The two sides of the story to consider are:

- water purification 'production accounts', that show where too much nitrogen enters freshwater systems beyond a sustainable level;

Figure 17: Flows of water purification ecosystem services embedded in crops traded across Europe, tonnes of nitrogen removed by ecosystems, year 2005. Only main flows are shown

Source: JRC

- water purification 'consumption accounts', that show to which countries the crops (for which fertilizers are used) – and hence the embedded water purification service – are exported.

From Figure 17 we see that, for example, the water purification ecosystem service (i.e. how much nitrogen freshwaters clean) in Italy is almost 2/3 higher than in Germany, i.e. 1 389 tonnes of nitrogen removed per year in Italy vs. 514 tonnes of nitrogen removed per year in Germany. The major source of nitrogen emissions is the agricultural sector.

Based on the water purification consumption accounts, in 2005, Italy exported to Germany agricultural products that embedded 673 tonnes of nitrogen removed by ecosystems in Italy. The water purification service embedded in those traded commodities becomes an important information to assess the causes of degradation of freshwater ecosystems.

General equilibrium models help understanding whether (and to what extent) changes in ecosystem services can have economic impacts

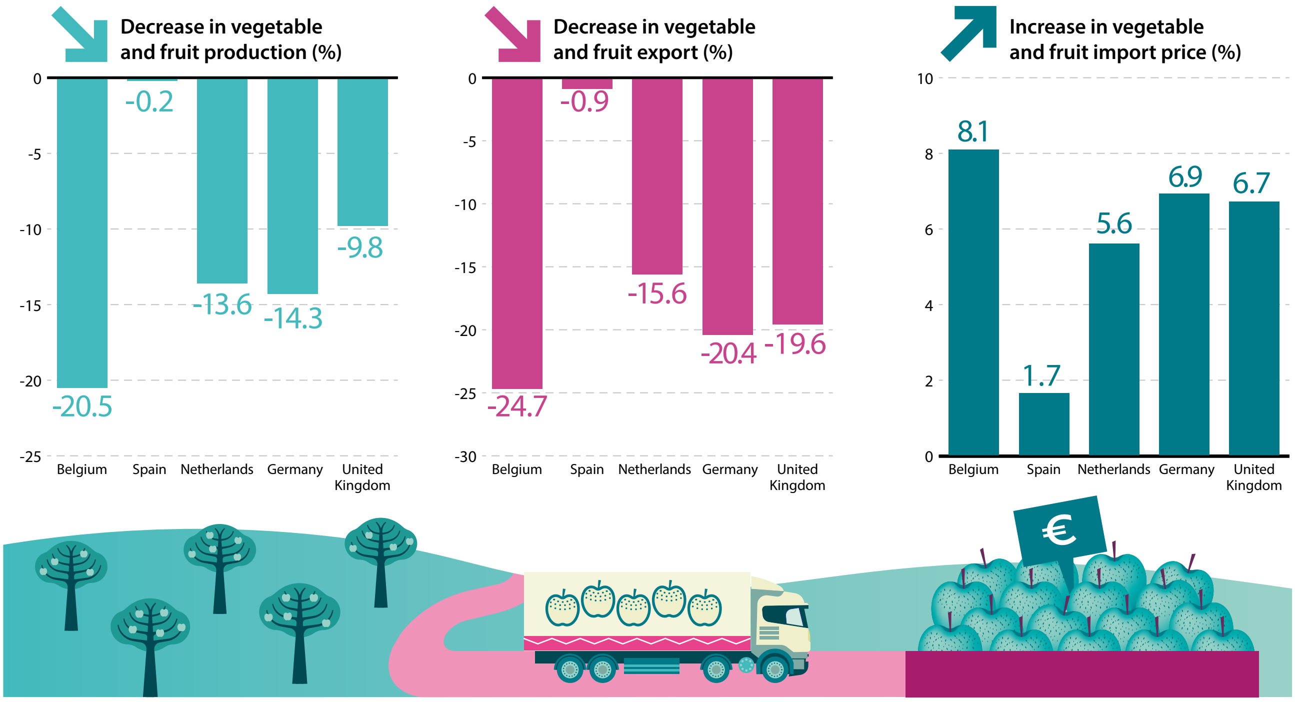
Invasive Alien Species (IAS) are animals and plants that are introduced accidentally or deliberately into a new natural environment where they are not normally found, and where these species prosper with often serious negative consequences for their new environment. They represent a major threat to native plants and animals in Europe, causing damage worth billions of euro to the European economy every year.

The Asian hornet was accidentally introduced in Europe from Asia. It was first observed in south-western France in 2004 and has since rapidly spread to Spain, Portugal, Belgium, the Netherlands, Germany, Italy and the UK. The Asian hornet is listed as an IAS of EU concern in the frame of the EU Regulation on IAS([23]) which means that EU countries have to take actions to eradicate this species.

Why are Asian hornets of such concern? They can devastate entire bee populations. Bees are important crop pollinators. Most fruits and vegetable crops are pollinated by honeybees and wild pollinating insects such as solitary bee species or bumblebees.

Here a scenario is simulated on the possible impact of a loss of pollinators on crop production, export and import in countries that are invaded by the Asian hornet. The scenario assumes that the Asian hornet spreads in all remaining regions within each affected country. In areas affected by the Asian hornet, there is a decrease of 35% in the production derived from pollinators. This exercise is undertaken by bridging the ecosystem accounting outcomes with a general equilibrium model, and specifically by running the tools developed by the Global Trade Analysis Project (GTAP)([24]).

Figure 18: **Simulated impacts of the effect of the invasion of the Asian hornet on the production, exports and import prices of certain pollinator-dependent crops in selected European countries, 2012(*)**



(*) France was not considered in the analysis. We presumed that the Asian hornet had already invaded all regions of France where conditions for its occurrence are favourable. As a result, no further loss in crop production and trade was expected in France.

Source: JRC

Policy use of ecosystem accounts

The INCA followed the SEEA EEA and developed the first comprehensive set of ecosystem accounts for the EU, including accounts in biophysical terms on ecosystem extent, initial ecosystem condition accounts and a range of ecosystem services. Ecosystem accounts in biophysical terms can greatly facilitate tracking changes in ecosystems (their condition and the services they supply), designing policies to prevent or reverse adverse changes in ecosystems and monitoring the responses of ecosystems once these policies have been implemented.

In monetary terms, INCA has produced a first estimate of gross ecosystem product for the EU. This needs to be further developed to be as comprehensive and accurate as possible but the results of the project demonstrate the feasibility of producing this aggregate. Being complementary (or 'satellite') accounts to national accounts, ecosystem accounts in monetary terms can help policy makers measure, and thus appreciate, the importance of ecosystems and their services for our economy and well-being.

The ecosystem accounting framework described in the SEEA EEA and the results of the INCA project have supported several concrete policy initiatives of the European Commission by 2020. These comprise:

- **Framework to Facilitate Sustainable Investment:** The SEEA EEA guidelines and related work, for example the CICES classifications([25]), have helped to frame the EU Regulation for helping identify and chose sustainable investments([26]). The aim is to help create the world's first-ever 'green list' – a classification system for sustainable economic activities – that will establish a common language that investors and businesses can use when investing in projects and economic activities that have a substantial positive impact on the climate and the environment.
- The first **EU Ecosystem Assessment,** which was released by the European Commission in close cooperation with the European Environment Agency on 21 October 2020. This landmark report is the result of 8 years of intense interactions between science and policy at EU and Member States' level. The report used an ecosystem accounting framework to analyse the trends in ecosystem extent, pressures, condition, and ecosystem services relative to the policy baseline 2010. The analysis of trends in ecosystem services concluded that the current potential of ecosystems to deliver timber, protection against floods, crop pollination, and nature-based recreation is equal to or lower than the baseline value for 2010. At the same time, the demand for these services provided by nature has significantly increased. A lower potential in combination with a higher demand risks to further decrease the condition of ecosystems and their potential to provide essential services for human well-being. The seven different ecosystem services quantified in INCA give clear pointers to where EU and national policies on land use and environmental protection need to focus for maintaining ecosystem condition and future ecosystem service flow. E.g. about 54% of the societal demand for regulating and cultural ecosystem services is not met by ecosystems, showing very significant ecosystem deficit. Closing this gap requires targeted ecosystem restoration, in particular in places where people need ecosystems for protection against floods, pollination or recreation.
- **EU Pollinators Initiative([27])** aims to improve scientific knowledge about insect pollinator decline, tackle its main known causes and strengthen collaboration between all the actors concerned. The development of a 'pollination account' was part of the Pollinators Initiative. The account shows that pollinator habitats inside croplands supply the pollination of crops valued at EUR 4.7 billion per year to the agricultural sector. More importantly, 50% of the demand for pollination services is not met. This means that about 50% of the areas where pollinator-dependent crops are grown in the EU (e.g. fruit trees) do not provide suitable condition for pollinators (e.g. nesting sites). Therefore, the pollination service cannot be provided where it is needed, leading to an unmet demand for this service. Restoring pollinator habitats in farmland therefore has the potential to double the benefit of pollination. As demonstrated in this report, the account can be used to assess how pollinator declines impact agricultural production, import and export.
- **EU nature restoration plan** of the EU Biodiversity Strategy for 2030 and legally binding restoration targets.

The accounting framework developed by INCA as well as the results of the *EU Ecosystem Assessment* can now be used to support this plan. Ecosystem accounts can be used to guide large-scale restoration efforts by mapping where ecosystems are degraded, monitoring of ecosystem condition following restoration, and by assessing the benefits of ecosystem restoration through ecosystem services. An example for the case of peat lands restoration is provided in Box 4 (chapter 'Ecosystem service: Carbon sequestration').

Although ecosystem accounts have been used in the initiatives mentioned above, overall, the uptake of the results of ecosystem accounting in key policy areas such as trade, agriculture, economy or finance, is still limited.

The experimental nature of ecosystem accounting, the (currently) laborious production of these accounts, as well as the uncertainty surrounding the physical and monetary estimates of ecosystem services (and even more so ecosystem assets), remain an obstacle for the mainstreaming of ecosystem accounts into other policy areas. However, it is now widely recognized that business as usual, which ignores the values of nature and ecosystems, is no longer an option. The EU-level ecosystem accounts presented in this report provide a basis for assessing the benefits of ecosystem restoration and the costs of ecosystem degradation. They are essential for assessing the impacts of existing and forthcoming policy initiatives under the European Green Deal.

Making ecosystem accounts operational

The previous chapters have shown the results of INCA work to produce a pilot for an integrated system of ecosystem accounting for the EU, comprising accounts for ecosystem extent, ecosystem condition and ecosystem services, and demonstrated how ecosystem accounts can inform policy decisions. This chapter reviews key aspects of making ecosystem accounts operational. It briefly discusses the data foundation, developing an accounting infrastructure, rolling out ecosystem accounts at Member State level and the involvement of the research community.

Data foundation

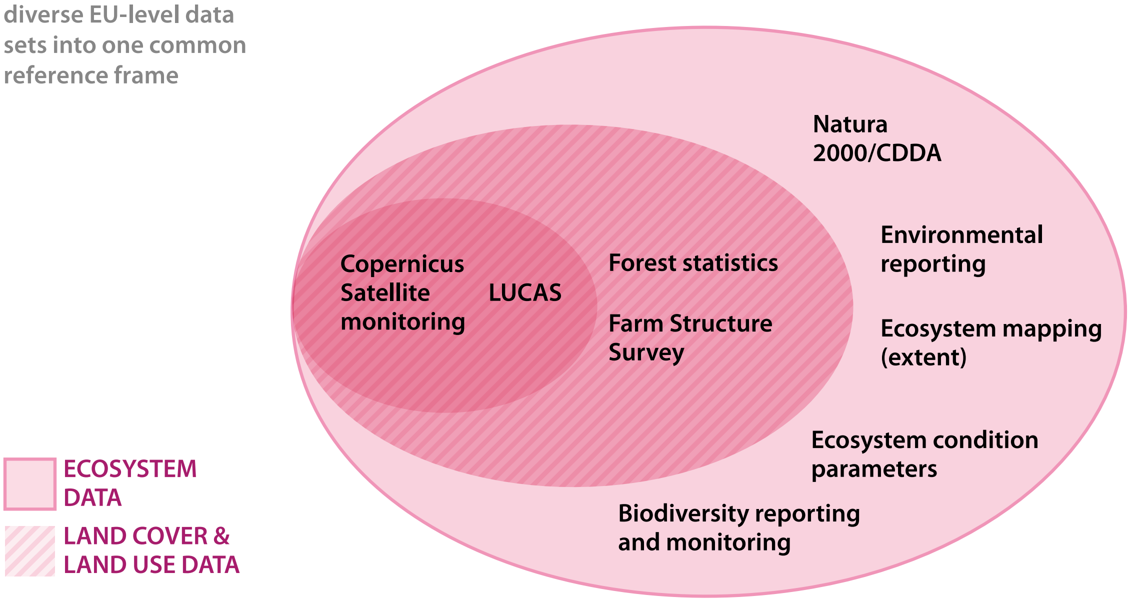
Ecosystem accounting requires the integration of different types of data on ecosystems and the economy. As ecosystems form a spatial patchwork across countries, geospatial data are needed that accurately describe their distribution and condition. These data also underpin the modelling of ecosystem services flow.

Three steps are necessary for establishing the data foundation for ecosystem accounting:

a) Identify the essential ecosystem and other parameters for ecosystem accounting
b) Determine the spatial resolution and data collection frequency required
c) Compare available data to the needs identified under point a) and data characteristics under point b)

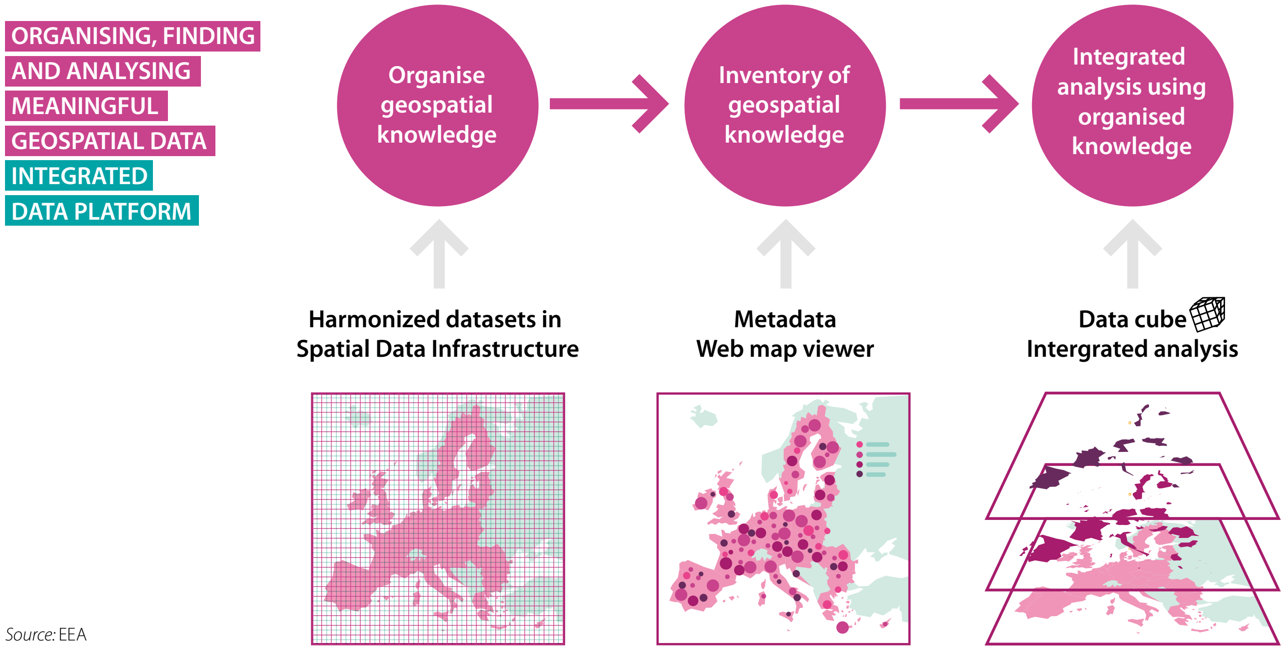
This approach has been tested on data sets suggested as input to MAES and INCA ecosystem condition analysis. The review tested whether trends in MAES or INCA condition parameters can be tracked on the basis of regular data collection exercises that will continue into the future. This showed that of the EU data sets available in 2018 to underpin ecosystem condition indicators, about only 50% were collected regularly enough to enable accounts to be developed[28].

Figure 19: Bringing diverse EU-level data sets into one common reference frame



Source: EEA

Figure 20: Structure and purpose of the Integrated Data Platform of EEA



Source: EEA

This is not very surprising as existing data collection systems were not designed for the monitoring of trends in ecosystem condition. Where ecosystem-related variables are being collected, the spatial referencing of existing reporting systems, e.g. under Natura 2000 reporting, is only adequate to report on national-level trends in many cases. This makes it necessary to develop better spatial referencing for many ecosystem data sets required for ecosystem accounting, or to set up new, dedicated monitoring schemes which collect such data at the spatial scale of the ecosystems to be investigated.

Figure 19 shows the many different types of data that need to be brought together in one common spatial frame, ranging from biodiversity monitoring data to agricultural statistics. This requires the development of a shared data processing infrastructure to support accounting and other types of analyses.

Developing an infrastructure for geo-spatial analysis and accounting

An efficient implementation of ecosystem accounting requires a processing infrastructure that can facilitate the production of accounts using geospatial datasets. One example of such an approach is the EEA Integrated Data Platform (EEA IDP), which was developed to enable integrated geo-spatial data analytics. The EEA IDP underpins the calculation of ecosystem extent accounts but also other accounting outputs of the EEA([29]).

Figure 20 shows the three main functions provided by the EEA IDP, which are: bringing data together in one system, reviewing the analytical utility of these data and running different research and accounting queries.

The IDP also enables an efficient creation of interactive dashboards which allow the user to explore and derive statistics, e.g. on the area of various land cover and land use categories and their changes. The ecosystem extent account dashboard([30]) gives users the possibility to explore the time series of INCA ecosystem extent accounts in various dimensions (e.g. tier, country or NUTS level, focus on Natura 2000 areas) or extract data for other analyses.

Implementing ecosystem accounting at Member State level

The level of development of ecosystem accounting varies greatly across EU Member States and other European countries. Some European countries are relatively advanced in ecosystem accounting or even world leaders, experimenting with and producing a range of ecosystem accounts at national level. Other European countries have minimum experience. INCA partners have been supporting the development of ecosystem accounts in EU Member States, e.g. via the Eurostat grants or the Horizon research programme. Table 8 shows examples of ecosystem accounts produced by European countries.

Table 8: Examples of work on ecosystem accounts in EU Member States

	Bulgaria	Germany	Denmark	Estonia	Spain	Finland	Hungary	Italy	Luxembourg	Netherlands	Sweden	France
Ecosystem extent accounts	X	X		X	X	X	X			X		
Land accounts									X		X	
Ecosystem services accounts												
Crop provisioning			X							X		
Provisioning of fodder				X						X		
Provisioning of medical plants				X								
Provisioning of biomass				X								
Pollination				X			X	X		X		
Timber provisioning			X							X		
Provisioning of non-wood forest products	X											
Provisioning of game animals	X		X	X								
Habitat for species				X								
Water purification					X							
Water filtration (provisioning)										X		
Flood regulation								X				
Water regulation					X				X			
Water provisioning			X			X		X		X		
Erosion control					X							
Air filtration										X		
Carbon sequestration						X				X		
Climate regulation, etc.				X								
Provisioning of marine fish						X						
Outdoor recreation			X	X		X		X		X		
Cultural services					X							
Amenity values										X		
Other types of accounts												
Biodiversity					X					X		
Marine (biodiversity, condition and provisioning of marine fish)						X				X		
Carbon accounts										X		X

Box 5:

Horizon 2020 – Research and Innovation programme – supports the development and mainstreaming of ecosystem accounting

The MAIA([31]) project (Mapping and Assessment for Integrated ecosystem Accounting) running from 2018 to 2022 aims to promote the mainstreaming of natural capital accounting in 10 EU Member States and Norway. Partner countries have worked together to assess policy priorities and produce initial or more advanced ecosystem accounts using innovative approaches. The project has identified a number of common priority policy areas, namely urban areas, water management/regulation, climate/carbon-related and biodiversity policy.

However, there are also a number of challenges: the uptake and use of ecosystem accounts has been limited as they are novel and not well known or understood; only a small number of use cases are available to demonstrate policy uses of ecosystem accounts. Furthermore, produced accounts are often pilot accounts or not yet formally published.

We Value Nature([32]) project running from 2018 to 2021 supports businesses and the natural capital community to make valuing nature the new normal for businesses across Europe. The project shares research, resources and best practice; helps businesses improve their risk management, communication with investors, stakeholder engagement and anticipation of future legislation.

The EuropaBON([33]) project (Europa Biodiversity Observation Network) aims to design an EU-wide framework for monitoring biodiversity and ecosystem services, including remote sensing, citizen science and institutional monitoring frameworks. It will identify user and policy needs for biodiversity monitoring, identify data gaps and investigate the feasibility of setting up a center to coordinate monitoring activities across Europe. The monitoring framework is envisaged as a direct contribution to the knowledge base for informing EU environmental policy objectives and could support the further development of ecosystem condition accounts in particular.

Annex 1: Ecosystem typology for EU ecosystem extent accounts

Table 9: Correspondence between tier I to III ecosystem types used for ecosystem extent accounts

Corine Land Cover - Level 3 Classes	Tier III	Tier II	Tier I (MAES)
1.1.1 Continuous urban fabric	URB 1.1.1 Dense urban area	URB 1.1 Dense urban area	1 - Urban
1.1.2 Discontinuous urban fabric			
1.2.1 Industrial or commercial units			
1.2.2 Road and rail networks and associated land			
1.2.3 Port Areas			
1.2.4 Airports			
1.3.2 Dump sites			
1.3.3 Construction sites			
1.3.1 Mineral extraction sites	URB 1.2.1 Mineral extraction sites	URB 1.2 Dispersed urban area	
1.4.1 Green urban areas	URB 1.2.2 Open green space		
1.4.2 Sport and leisure facilities			
2.1.1 Non-irrigated arable land	AGR 2.1.1 Arable land	AGR 2.1 Arable land	2 - Cropland
2.1.2 Permanently irrigated land			
2.1.3 Rice fields	AGR 2.2.1 Rice fields	AGR 2.2 Rice fields	
2.2.1 Vineyards	AGR 2.3.1 Other permanent crops	AGR 2.3 Permanent crops	
2.2.2 Fruit trees and berry plantations			
2.4.1 Annual crops associated with permanent crops			
2.2.3 Olive groves	AGR 2.3.2 Olive groves		
2.4.2 Complex cultivation patterns	AGR 2.4.1 Mosaic farmland	AGR 2.4 Mixed farmland	
2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation			
2.4.4 Agro-forestry areas	AGR 2.4.2 Agro-forestry areas		
2.3.1 Pastures [Modified grassland]	GRA 3.1.X	GRA 3.1 Modified grassland	3 - Grassland
3.2.1 Natural grassland [Semi-natural grassland]	GRA 3.1.X	GRA 3.2 Semi-natural grassland	

Corine Land Cover - Level 3 Classes	Tier III	Tier II	Tier I (MAES)
3.1.1 Broad-leaved forest	FOR 4.1.1	FOR 4.1 Broad-leaved forest	4 - Forest and woodland
	FOR 4.1.X.		
3.1.2 Coniferous forest	FOR 4.2.1 Coniferous forest	FOR 4.2 Coniferous forest	
3.1.3 Mixed forest	FOR 4.3.1	FOR 4.3 Mixed forest	
	FOR 4.3.X		
3.2.4 Transitional woodland/shrub	FOR 4.4.1 Transitional woodland/shrub	FOR 4.4 Transitional woodland/shrub	
3.2.3 Sclerophyllous vegetation	SMN 5.1.1 Sclerophyllous vegetation	SMN 5.1 Sclerophyllous vegetation	5 - Heathland and shrub
3.2.2 Moors and heathland	SMN 5.2.1 Moors and heathland	SMN 5.2 Moors and heathland	
3.3.1 Beaches, dunes, sands	OSP 6.1.1 Beaches, dunes, sands	OSP 6.1 Sparsely vegetated habitats	6 - Sparsely vegetated land
3.3.2 Bare rocks	OSP 6.1.2 Bare rocks		
3.3.3 Sparsely vegetated areas	OSP 6.1.3 Sparsely vegetated areas		
3.3.5 Glaciers and perpetual snow	OSP 6.2.1 Glaciers and perpetual snow	OSP 6.2 Glaciers and perpetual snow	
4.1.1 Inland marshes	IWL 7.1.1 Inland marshes	IWL 7.1 Inland marshes	7 - Inland wetlands
4.1.2 Peat bogs	IWL 7.2.1 Peat bogs	IWL 7.2 Peat bogs	
4.2.1 Salt marshes	CWL 9.1.1 Salt marshes	CWL 9.1 Salt marshes	9 - Marine inlets and transitional waters
4.2.2 Salines	CWL 9.2.1 Salines	CWL 9.2 Salines and intertidal areas	
4.2.3 Intertidal flats	CWL 9.2.2 Intertidal flats		
5.2.1 Coastal lagoons	CWL 9.3.1 Coastal lagoons	CWL 9.3 Coastal waters	
5.2.2 Estuaries	CWL 9.3.2 Estuaries		
5.1.1 Water courses	WBO 8.1.1 Water courses	WBO 8.1 Water courses	8 - Rivers and lakes
5.1.2 Water bodies	WBO 8.2.1 Water bodies	WBO 8.2 Water bodies	
3.3.4 Burnt areas			Not considered terrestrial ecosystems
5.2.3 Sea and ocean			

Source: EEA

List of figures

List of tables

List of acronyms

CAPRI:	Common Agricultural Policy Regional Impact Model
CLC:	Corine Land Cover
EEA:	European Environment Agency
EEA IDP:	Integrated Data Platform of the European Environment Agency
IAS:	Invasive Alien Species
JRC:	Joint Research Centre of the European Commission
LISBETH:	LInking accounts for ecosystem Services and Benefits to the Economy THrough bridging
LULUCF:	Land Use, Land-Use Change and Forestry
MAES:	Mapping and Assessment or Ecosystems and their Services
NUTS:	Nomenclature of territorial units for statistics
SEEA EEA:	System of Environmental-Economic Accounting – Experimental Ecosystem Accounting
SEEA EA:	System of Environmental-Economic Accounting – Ecosystem Accounting
SEEA ECT:	Ecosystem Condition Typology proposed by the SEEA EA
SNA:	System of National Accounts

List of INCA publications

Implementing an EU system of accounting for ecosystems and their services (2017)

Ecosystem services accounting - Part I. Outdoor recreation and crop pollination (2018)

Ecosystem services accounting - Part II. Pilot accounts for crop and timber provision, global climate regulation and flood control (2019)

Linking accounts for ecosystem services and benefits to the economy through bridging (LISBETH) (2020)

Natural capital accounting in support of policymaking in Europe – A review based on EEA ecosystem accounting work (2020)

Pilot aggregated EU ecosystem services accounts (2020)

End notes

Endnotes
(1) https://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf
(2) https://seea.un.org/
(3) https://ec.europa.eu/environment/action-programme/; the 8th Environment Action Programme was under preparation at the time of writing this publication
(4) https://eur-lex.europa.eu/resource.html?uri=cellar:a3c806a6-9ab3-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF
(5) The technical report of the EU Ecosystem Assessment is available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC120383. The Summary for policy makers is available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC123783.
(6) https://unstats.un.org/unsd/statcom/52nd-session/documents/decisions/Draft-Decisions-3March2021.pdf
(7) For further details on the data and maps see the INCA website: https://ecosystem-accounts.jrc.ec.europa.eu/
(8) https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers
(9) https://www.eea.europa.eu/data-and-maps/data/data-viewers/ecosystem-extent-accounts?portal_status_message=Changes%20saved
(10) For further details see https://tableau.discomap.eea.europa.eu/t/Landonline/views/Ecosystemextentaccounts/Ecosystemextentaccounts?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link&:isGuestRedirectFromVizportal=y&:embed=y
(11) https://publications.jrc.ec.europa.eu/repository/handle/JRC120383
(12) For further detail see https://biodiversity.europa.eu/ecosystems/ecosystem-accounting
(13) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060
(14) See https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a64&lang=en
(15) For details of the INCA crop provision ecosystem service account see http://publications.jrc.ec.europa.eu/repository/handle/JRC116334
(16) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590404602495&uri=CELEX%3A52020DC0381
(17) For details of the INCA flood control ecosystem service account see http://publications.jrc.ec.europa.eu/repository/handle/JRC116334
(18) For details of the INCA carbon sequestration ecosystem service account see http://publications.jrc.ec.europa.eu/repository/handle/JRC116334
(19) For details see https://seea.un.org/ar/node/2286
(20) For details on methods see technical report Pilot aggregated EU ecosystem services accounts (2020) produced by eftec under a contract for Eurostat.
(21) This section reports one example for each potential use. More details on each kind of analytic tool can be found in: EU Ecosystem Assessment (ref. chapter 5 on ecosystem services), available at https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/mapping-and-assessment-ecosystems-and-their-services-eu-ecosystem-assessment, and LISBETH report, available at https://publications.jrc.ec.europa.eu/repository/bitstream/JRC120571/jrc_report_lisbeth_final_1.pdf
(22) Eurostat produces and publishes air emission footprints, material footprints and domestic energy footprints. Work is ongoing to develop land footprint estimates.
(23) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014R1143
(24) Database and software used for this simulation is available at https://www.gtap.agecon.purdue.edu/databases/default.asp
(25) https://cices.eu/
(26) (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088
(27) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1528213737113&uri=CELEX:52018DC0395
(28) For further details see: https://www.eea.europa.eu/publications/natural-capital-accounting-in-support
(29) For further details see: https://www.eionet.europa.eu/etcs/etc-uls/products/etc-uls-report-02-2020-land-and-ecosystem-accounts-for-europe-towards-geospatial-environmental-accounting-1/@@download/file/ETC-ULS-02-2020_Land_and_ecosystem_accounts_for_Europe.pdf.pdf
(30) https://www.eea.europa.eu/data-and-maps/data/data-viewers/ecosystem-extent-accounts
(31) https://maiaportal.eu/about
(32) https://wevaluenature.eu/
(33) https://europabon.org/
(34) For further detail see https://biodiversity.europa.eu/ecosystems/ecosystem-accounting

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Accounting for ecosystems and their services in the European Union (INCA)

Final report from phase II of the INCA project aiming to develop a pilot for an integrated system of ecosystem accounts for the EU

KS-FT-20-002-EN-N

This report summarises key results of the INCA project. INCA delivered an integrated system of ecosystem accounts for the EU. The report provides an introduction to ecosystem accounting and presents ecosystem extent accounts, initial ecosystem condition accounts and ecosystem services accounts for EU28, before the withdrawal of the UK. The report shows practical examples of possible uses of ecosystem services accounts and existing policy applications. The report is intended for a broad audience – policy makers, researchers, compilers of ecosystem accounts and other expert and non-expert users who wish to learn how ecosystems and their services support our society, what changes in ecosystems and ecosystem services took place in the EU in the past couple of decades and how all this can be measured in a standardised and comparable way.

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