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JRC TECHNICAL REPORTS

# Ecosystem services accounting

## Part II Pilot accounts for crop and timber provision, global climate regulation and flood control

***KIP INCA Report*** *- contribution to the* ***K****nowledge and* ***I****nnovation* ***P****roject on an* ***I****ntegrated system of* ***N****atural* ***C****apital and ecosystem services* ***A****ccounting in the EU*

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## Contents

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## Executive summary

The Knowledge Innovation Project on an Integrated system of Natural Capital and ecosystem services Accounting (**KIP INCA**) aims to develop a set of experimental accounts at the EU level, following the United Nations System of Environmental-Economic Accounting - Experimental Ecosystem Accounts (**SEEA EEA**). The application of the SEEA EEA framework is useful to illustrate ecosystem accounts with clear examples, to further develop the methodology outlined in the United Nations Technical Recommendations, and to give guidance for Natural Capital Accounting.

This report assesses and accounts for four ecosystem services (ES): crop provision, timber provision, global climate regulation, and flood control. The methodology applied for the accounts of each ecosystem service depends on the nature of the service and on data availability. **Crop provision account** is based on official statistics on yield production. Here, we combine yield statistics with a novel approach to disentangle the yield generated by the ecosystem from what is generated by the human inputs (i.e., planting, irrigation, chemical products). **Timber provision account** follows a similar rationale, but the data to assess the ecosystem contribution is derived from economic aggregates. The **global climate regulation account** uses carbon sequestration as a proxy. The account is built on the ecosystem $CO_2$ uptake reported in the Land Use, Land-Use Changes, and Forestry (LULUCF) inventories at country level. Copernicus data (Dry Matter Productivity) have been also used to map $CO_2$ uptake by forest (the only ecosystem type acting across countries and over time, as reported in LULUCF inventories). Maps of $CO_2$ uptake are useful to make comparisons with other ecosystem services in a later stage of the project, in particular to assess synergies and trade-offs. Complementary, we also provide a thematic account for soil organic carbon based on data from Land Use/Cover Area frame Survey (LUCAS). However, this information is considered as an asset account in physical terms because it quantifies organic carbon stocks into the soil, and not flows. The valuation method used for crop and timber provision is based on market values and for global climate regulation is a proxy of market values. The **account of flood control by ecosystems** is the only service in this report based on biophysical modelling. Different components of the ecosystem service have been quantified: ES potential, ES demand, actual flow (or service use), and unmet demand. The actual flow, quantified as the hectares of demand benefiting from ecosystems in a given year, is also translated into monetary terms using as valuation technique the avoided damage cost.

Results of the accounts at the EU level for the **first period assessed (year 2000-2006)** show a decrease of the monetary value of the services for crop (-5%) and timber provision (-2%), and a very slight increase for global climate regulation (+0.4%). The account for flood control was not available for the first period because of the lack of data, which is a limiting factor for a regularly updated ecosystem service account. In contrast, for the

**second period assessed (year 2006-2012), all four service show an increase in their monetary value**: +34% for crop provision, +2% for timber provision, and +1.3% for global climate regulation and +1.14% for flood control. The use of spatially explicit models for the account of flood control provides very useful information to understand the drivers of changes in the value of this service. The increase of artificial areas benefiting from ecosystems controlling floods increases the value of flood control by ecosystems; however, its value per unit of economic asset decreases. This, together with an increase of the demand not covered by the ecosystem for artificial areas (i.e., unmet demand), show that there is a negative trend in the role of natural capital covering the need for flood control in these areas.

**So far, six ecosystem service accounts have been developed**: crop and timber provision, crop pollination, global climate regulation, flood control and nature-based recreation. The supply table at the EU level for all these six ecosystem services in 2012 shows woodland and forest as the ecosystem type with the highest absolute (~70 billion euro) and relative values (~44 thousand euro/$km^2$). In absolute terms, cropland appears as the second most important ecosystem given its large extent at the EU level; however, when it comes to relative values (value per square kilometre) cropland is among the ecosystem services with the lowest value. Complementarily, the use table shows households, followed by the agriculture sector, as the main beneficiaries of these ecosystem services; receiving an annual monetary flow of about ~62 billion euro and ~25 billion euro, respectively.

The experimental accounts shown for these ecosystem services, in a **consistent way with the SEEA EEA**, are useful to further develop the methodology applied for ecosystem services accounts. We also discuss about the advantaged and disadvantaged of the different data sources and methods used.

**Future releases of pilot ecosystem services accounts** will include water purification, habitat maintenance and soil erosion control. The final integrated assessment will be carried out at the end of the KIP INCA project, when a more comprehensive list of ecosystem services become available. The integration of ecosystem services accounts will be useful to make trade-offs in decision making more transparent, inform efficient use of resources, enhance resilience and sustainability, and avoid unintended negative consequences of policy actions.

# 1 Introduction

The 7th Environment Action Programme and the EU Biodiversity Strategy to 2020 include objectives to develop natural capital accounting in the EU, with a focus on ecosystems and their services. More concretely, the **Action 5 of the EU Biodiversity Strategy to 2020** requires Member States, with the assistance of the European Commission, to map and assess the state of ecosystems and their services (MAES). They must also assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020.

**Ecosystem services** (ES) are the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). ES are flows measured as the amount of ES that are actually mobilized (used) in a specific area and time: **actual flow** (Maes et al., 2013). Ecosystem services accounts focus on the actual flow of the service, considered as a 'transaction' from the ecosystem to the socio-economic system.

The Knowledge Innovation Project on an Integrated system of Natural Capital and ecosystem services Accounting (**KIP INCA**) aims to develop, in support to MAES, a set of experimental accounts at the EU level, following the United Nations **System of Environmental-Economic Accounting- Experimental Ecosystem Accounts** (SEEA EEA). The application of the SEEA EEA framework is useful to illustrate ecosystem accounts with clear examples, to further develop the methodology outlined in the Technical Recommendations, and to give guidance for Natural Capital Accounting.

In KIP INCA the **Common International Classification of Ecosystem Services** (CICES) is used as reference classification system of ecosystem services (Haines-Young & Potschin, 2018). However, we modify some of the concepts and definitions of ecosystem services to adapt them to what we really assess in the accounting approach developed.

Ecosystem services accounts are experimental can be developed using different methodologies, depending on data availability. Sometimes, ecosystem services accounts can be based on **official data and statistics** reported by countries, such as those provided by the European Statistical Office (Eurostat) or the Food and Agriculture Organization of the United Nations (FAO). These type of data are frequently used by national statistical offices as proxies for assessment of crop and timber provision (see for instance Office for UK National Statistics (2018)). Actually, **provisioning services** are the type of services more often quantified given the tangible products they generate, which are frequently reported by official statistics. The fact that these products are already part of the System of National Accounts (SNA) needs to be tackled to avoid misleading assessments that mix the ecosystem and human contribution to the growth of the product, and to avoid double counting. For this reason, we propose in this study a novel approach to account for the ecosystem contribution in the provision of these products, and disentangle it from human inputs. It is important to clearly separate the biomass growing (where ecosystem and human intervention interact) from the phase of resource harvesting and removal (that is part of the economic process, which is already in the SNA). This approach is one of the possible approaches that can be used. Other approaches might consider human inputs as a mean to enhance and access the ecological contribution, and thus not separable from it. Although we acknowledge that an alternative viewpoint exists, in the context of ES accounting there is no added value in considering the final output (as co-product of human input and ecosystem) since this item is already in the SNA.

The use of official statistics can be also used to account for **global climate regulation**. The European Union (EU), as a party to the United Nations Framework Convention on Climate Change (UNFCCC) reports annual inventories on greenhouse gas (GHG) emissions and removals within its territorial boundaries. In this report, we integrate the reported data into accounting tables to explore the feasibility of these data to produce regular accounts for global climate regulation.

However, statistics or reported data at national level are not available for most **regulating ecosystem services** such as crop pollination, flood control, water purification and soil erosion control, among others. There are still very few studies quantifying the actual flow of regulating ecosystem services and further research is still needed. This entails some difficulties to operationalize ecosystem service accounts for regulating services, which are usually underrepresented (Sutherland et al., 2018). In KIP INCA, we propose a framework to develop spatially explicit models and quantify the ecosystem service flow. This framework is based on **mapping different components of ES determining the actual flow** (Figure 1.1). On one hand, we have the ecosystems that can provide a given amount of the service (i.e., ES potential). It is usually assessed based on the ecosystem properties and condition that are recognised to be relevant to the service considered. Ecosystem service potential is the component of ecosystem services more frequently assessed in biophysical terms. However, quantification of the actual flow is still very challenging in the field of ES research (Hein et al., 2016; La Notte et al., 2019b). On the other hand, the actual flow is also determined by the demand of ecosystem services by the socio-economic system and importantly, by the spatial relationship between the areas providing the service (Service Providing Areas, SPA) and the areas demanding it (Service Demanding Areas, SDA). Consequently, an ES flow connects ecosystems to socio-economic systems to ultimately generate benefits. Therefore, when developing an ES model, the assessment of all these components, the spatial inter-connection of their spatial units (i.e., SPA and SBA) and their temporal dynamic, are essential to quantify the actual flow of the ecosystem service (Serna-Chavez et al., 2014; Syrbe et al., 2017; Wolff et al., 2015) and its integration into an accounting system (Sutherland et al., 2018).

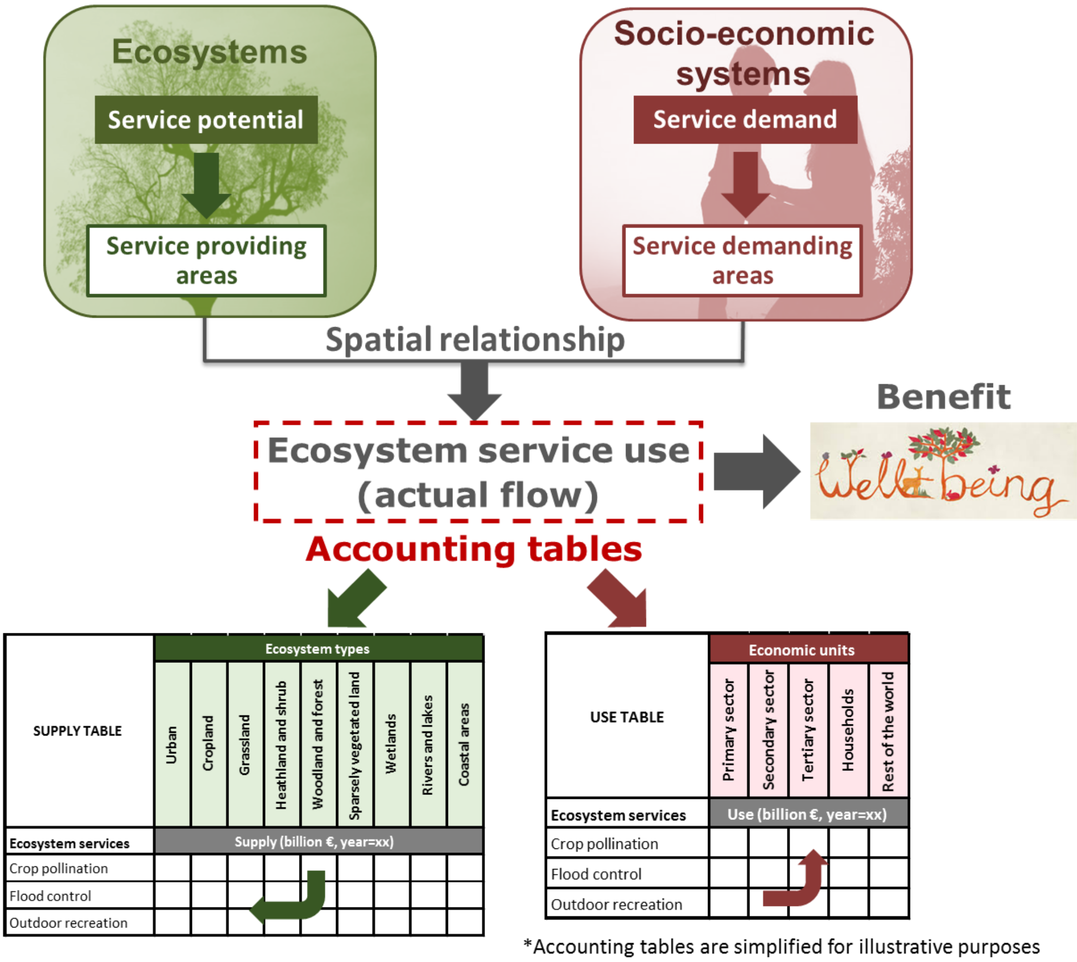



**Figure 1.1.** Scheme of the framework of ecosystem services accounts.

The adoption of this framework allows stablishing a direct **linkage with the accounting tables** (Figure 1.1). On one hand, quantification of ES potential provides the required information to estimate the contribution of each ecosystem type to the service flow, which is reported in the **supply table**. The ecosystem types are defined according to the ecosystem typology described under the Mapping and Assessment of Ecosystem Services initiative (Maes et al., 2013), (Annex 1). On the other hand, when quantifying the ES demand we should take into account the users and beneficiaries of the service flow to whom the actual flow is allocated in the **use table**. For a more detailed description of the accounting tables under the framework of the KIP INCA project see (La Notte et al., 2017).

Once the ecosystem service is assessed in biophysical terms, the accounting workflow continues with the **translation of the output in monetary units**, by choosing the appropriate valuation technique. To ensure consistency of the whole accounting procedure, the valuation method is applied to the final output of the biophysical assessment, but it also integrates some of the key variables used for the service mapping (model).

In this context, ecosystem services accounting proves a very useful tool to **assess the role of ecosystems and socio-economics systems determining the ES flow and to**

**quantify the importance of the service in monetary terms**. The accounting framework provides the advantage of clearly presenting the service flow as the ecosystem contribution on the one hand, and the users or beneficiaries on the other hand.

This report is the Part II of a series of KIP INCA reports presenting an experimental EU wide ecosystem services accounts developed by JRC. In Part I of the pilot ecosystem services accounts, JRC presented outdoor recreation and crop pollination accounts (Vallecillo et al., 2018). In this second report, we develop pilot accounts for four ecosystem services: crop provision, timber provision, global climate regulation, and flood control. For each service, we use different type of input data and methods (Table 1.1).

**Table 1.1**. Ecosystem services accounts in this report.

| Ecosystem services | Main data source | Monetary valuation | Years assessed |
|---|---|---|---|
| **Crop provision** | Disentangling from official statistics on yield the ecosystem contribution | Market prices | 2000, 2006, 2012 |
| **Timber provision** | Disentangling from official statistics on timber the ecosystem contribution | Market prices | 2000, 2006, 2012 |
| **Global climate regulation** | $CO_2$ uptake from LULUCF inventories | Prices related to carbon emissions | 2000, 2006, 2012 |
| **Flood control** | Modelling ecosystem service components: potential, demand and flow | Avoided damage cost | 2006, 2012 |

The report introduces first the setting of the accounting framework adopted in this study (section 2); it then presents ecosystem services accounts for crop provision (section 3); timber provision (section 4); global climate regulation (section 5); and flood control (section 6). The last section presents the compilation of ecosystem service accounts carried out so far in KIP INCA with the main conclusions derived from this work.

# 2 Setting of the accounting framework

One of the main objectives of SEEA EEA is to provide relevant information on how economic activities and humans depend on ecosystem services and they may eventually reduce an ecosystem's capacity to continue generating ecosystem services (UN, 2017). This kind of information differs from the traditional datasets that feed national accounts and the SEEA CF. It is not about (direct or estimated) measurement of quantities and amounts (mass); it is about ecological processes (in some cases simulated by models, in other cases disentangled by existing datasets) that describe how different ecosystem types provide flows of services. The accounting structure and rules remain the basis that allows linking the SEEA EEA with the SNA and SEEA CF. However, some of the traditional accounting concepts need to be "enlarged" (Eigenraam & Obst, 2018; La Notte et al., 2019b) otherwise, no consistent representation of the ecological-economic interaction can be provided. Ecosystem types are considered as "producer units" and they play a key role in the supply table for ES accounts. Enlarged production boundaries also allow to record set of complementary information that otherwise would remain hidden in official accounting tables.

This issue is particularly relevant for provisioning services (in this report: crop and timber provision) where the biomass growth needs to be separated from the harvesting and removal that coms afterwards (section 2.1). Moreover, what ecosystems generate as "producer units" can be different from what is demanded by economic sectors and households (in this report flood control). This mismatch creates in some cases an unmet demand (i.e., demand that is not covered by the ecosystem) whose measurement and monitoring could provide useful information to complement ecosystem services accounts (section 2.2). Finally, some ecological processes become services because there is an economic activity that makes them needed (in this report global climate regulation) although the benefit generated flows into different (downstream) sectors. From a policy perspective, to identify actors that enable, activate, or modify the ES flow may offer a number of interesting applications (section 2.3). This enlargement of the accounting setting is facilitated when the role played by ecosystems in delivering the service is described (La Notte et al., 2019b). A simple visualization of the typology of delivering processes is presented in Annex 2. This can be helpful to understand few key features we are addressing throughout the report.

## 2.1 The contribution of provisioning services to the economy

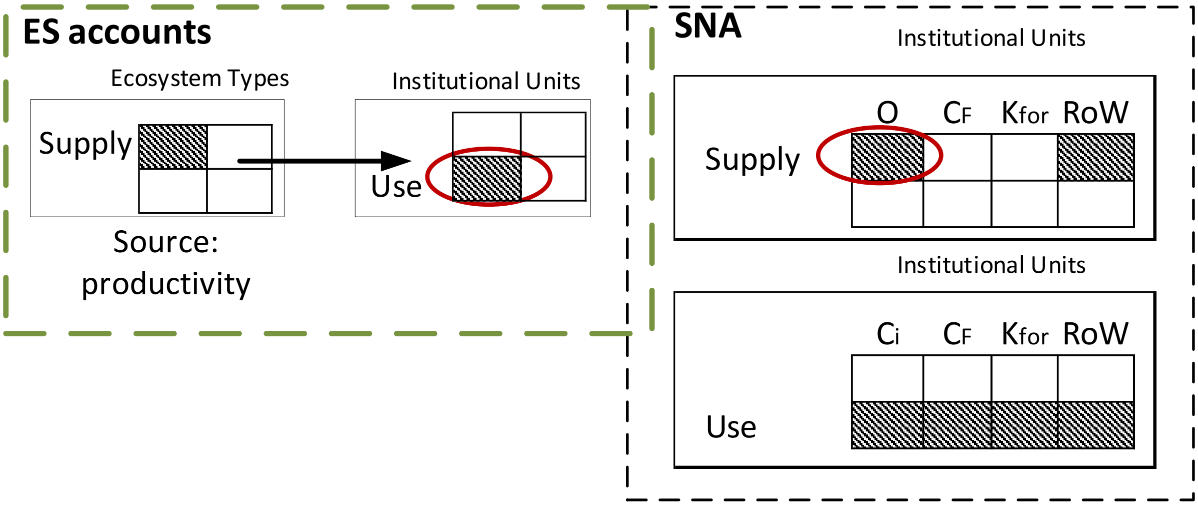
Provisioning services such as crop and timber provision represent a delivery of biomass leaving the ecosystem, which acts as a source of matter and energy. In this case, the ecosystem delivery process can be defined as "source: provision" (Annex 2).

The Supply and Use Tables (SUTs) of the SNA are structured to account for economic flows that can be transactions and other economic flows (Eurostat, 2013). "Transactions" include the market exchange in goods and services and (ref. Figure 2.1) describe (i) the supply of domestic output (O) and imports (Rest of the World, RoW) and (ii) the use as intermediate consumption ($C_i$), final consumption ($C_F$), capital formation ($K_{for}$) and exports (RoW). "Other economic flows" consider non-economic phenomena only recorded in accumulation accounts, such as natural disasters and political events. ES accounts focus on transactions: actual flow represents the transaction that takes place between ecosystem types and economic sectors and households. This transaction is reported in SUTs. Specifically for crop provision, we consider the flow of ecosystem contribution to the agricultural sector in terms of biomass growing. When looking at the Agriculture sector (according to NACE classification[1]), the ecosystem type "Cropland" delivers its flow to the economic sectors coded as A01.1 (growing of non-perennial crops) and A01.2 (growing of perennial crops). Other operations such as support activities to agriculture (which include harvesting) and post-harvest crop activities (coded all as A01.6) will not receive the ES flow, but will interact with A01.1 and A01.2. This interaction is already within the SNA and is not considered in ES accounts. The contribution of crop provision as ecosystem service to the economy is the flow from Cropland to A01.1 and A01.2. In the case of timber provision, the economic sector is Forestry, and the ecosystem type "Woodland and forest" (and specifically Forest Available for Wood Supply [FAWS]) delivers its flow to the economic sectors coded as A02.1 (Silviculture and other forestry activities). This sector (A02.1) will then interact with the sector A01.2 (Logging). This interaction is already within the SNA and is not affected by ES accounts. The contribution of crop provision as ecosystem service to the economy is the flow from FAWS to A02.1.

From a logic chain point of view, it is important to separate the "growing" stage from the resource "harvesting/removal" stage in order to avoid misleading overlapping and double counting between the ecosystem service and economic activities already captured by the economic accounts (Figure 2.1).

In the sections dedicated to crop provision (Section 3) and timber provision (Section 4) the actual ES flow is measured as ecosystem contribution to production (biomass growth), which is kept separated from the harvesting phase.

[1]Detailed classification available at https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC&IntCurrentPage=1




*Legend: Domestic output, O; Rest of the World (imports or exports), RoW; intermediate consumption, Ci; final consumption, CF; capital formation, Kfor*

**Figure 2.1.** Visual representation of provisioning services and their link with SNA.

## 2.2 Direct and indirect beneficiaries of ES flows

Some regulating services have the property of absorbing the negative effects of production and consumption activities: ecosystems can considered as sinks (Annex 2) to store and immobilise or they can absorb matter.

One important feature of sink services is that the amount of actual flow generated depends on the amount of pollutants, which can be considered as the ES demand (La Notte et al., 2019b). In the SEEA CF (UN et al., 2014a), there are *ad hoc* accounts that attribute emissions to polluting sectors. This information is linked to ES accounts (Figure 2.2) and provides the basis to connect ES to two kinds of beneficiaries: (i) direct beneficiaries enjoy the "cleaned" outcome of the sink process, (ii) indirect beneficiaries that contribute to environmental pollution through emissions of in particular non-persistent pollutants such as excess nitrogen and thus profit from ecosystems that clean up their pollution.

In this perspective polluters are benefitting from the role that ecosystems are playing in storing, absorbing or processing polluting substances. As pollution activates an ES flow, the sectors to which pollution can be ascribed are referred to as *enabling actors* (La Notte & Marques, 2017). The complementary allocation of actual flow to enabling actors allows performing a policy analysis based on indirect beneficiaries (Figure 2.2).

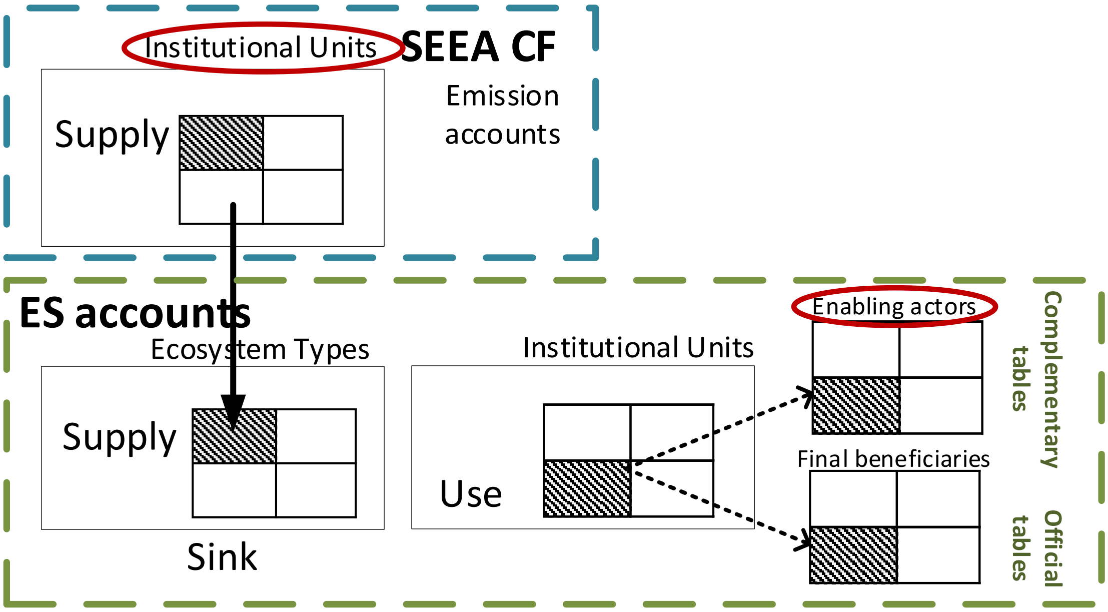



**Figure 2.2.** Visual representation of complementary and official ES accounts for sink services.

In the section dedicated to global climate regulation (section 5), an example can be found on how and why to allocate the sink service actual flow to its enabling actors. The case of global climate regulation is peculiar since the transformation process of $CO_2$ from the emitting sectors takes place in the atmosphere (that can be considered as a global transboundary asset). However mitigation and adaptation policies take place at national (and sub-national) level. The policy setting can thus justify the allocation, as performed.

## 2.3 When ecosystems do not satisfy the demand for the service

Some regulating services have the property of changing the magnitude of flows of matter flowing through ecosystems, which acts as transformers. In this case, the ecosystem delivery process can be defined as "buffer" (Annex 2).

An important advantage of considering ecosystem types as accounting units in SUTs, is the possibility to report complementary information, such as what ecosystem types are able to offer independently or how much of it will be used. The ecosystem's capacity to generate services (irrespective of the demand) is what we call ES potential. The actual flow is generated when the ES potential interacts with the ES demand. On the one hand, where we observe ES potential but no demand there is no actual flow. On the other hand, there can be ES demand where there is no ES potential: in this case, the demand remains unmet (and needs to be imported). SUTs only record the actual flow (UN, 2017), but the whole ES accounting framework offers the possibility to record and spatially represent the possible mismatch between ES potential and ES demand (La Notte et al., 2019a). As explained in La Notte et al. (2019b), the unmet demand occurs for three types or classes of ecosystem services: “source: suitability” (e.g., crop pollination), “information” (e.g., outdoor recreation) and “buffer” (e.g., flood control, Figure 2.3). Examples of unmet demand for crop pollination and outdoor recreation are available in a previous report and publications (La Notte et al., 2019b; Vallecillo et al., 2018; Vallecillo et al., 2019). An example for flood control is provided in this report (Section 6).

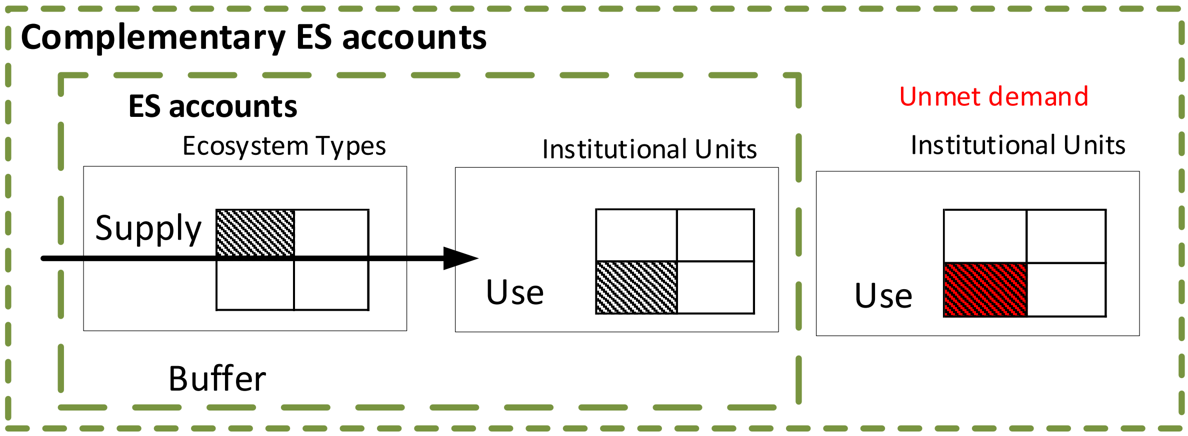



**Figure 2.3.** Visual representation of complementary and official ES accounts for buffer services

In the section dedicated to flood control (section 6) unmet demand is assessed and spatially located. This could be important information for policy makers, although complementary to SUTs.

# 3 Crop provision

Crop provision as an ecosystem service (ES) is defined as the ecological contribution to the growth of cultivated crops that can be harvested and used as raw material for the production of food, fibre and fuel (CICES V.5.1, Haines-Young and Potschin (2018)). Therefore, strictly speaking, crop provision understood as an ES should be disentangled from the total yield production, which is made possible by substantial human inputs invested for crop production (i.e., planting, irrigation, human labour, and chemical inputs).

Crop provision accounts are usually based on official data reporting yield production. In the approach we present here we use ESTAT data on crop production; however, we propose one of the first attempts to quantify, at the European scale and at fine-grained resolution (1 $km^2$), the ecosystem contribution to the growth of crops by clearly distinguishing natural and anthropic inputs.

## 3.1 Biophysical assessment

The biophysical assessment of crop provision builds on data derived from previous works focusing on the quantification of energy flows in agricultural systems (Pérez-Soba et al., 2019; Pérez-Soba et al., 2015). In particular, the latter study adopted an emergy-based approach in agroecosystems: emergy (from "embodied energy") of a product is defined as the total energy needed, directly and indirectly, to make that product. Pérez-Soba et al. (2019) considered all the inputs used in agricultural production to obtain the agricultural output for the whole EU25[2], including natural and anthropic inputs (Figure 3.1). Natural inputs were further subdivided in renewable input and non-renewable input:

Renewable natural input:

- Sunlight
- Wind, kinetic energy
- Evapotranspiration
- Rainfall

Non-renewable natural input:

- Soil loss (depletion of soil organic matter)

Anthropic inputs:

- Mineral fertilisers
- Manure
- Pesticides
- Irrigation water
- Seeds
- Diesel oil/fuel, gasoline, lubricants
- Machinery
- Human labour

[2] All EU countries except Croatia, Malta and Cyprus.

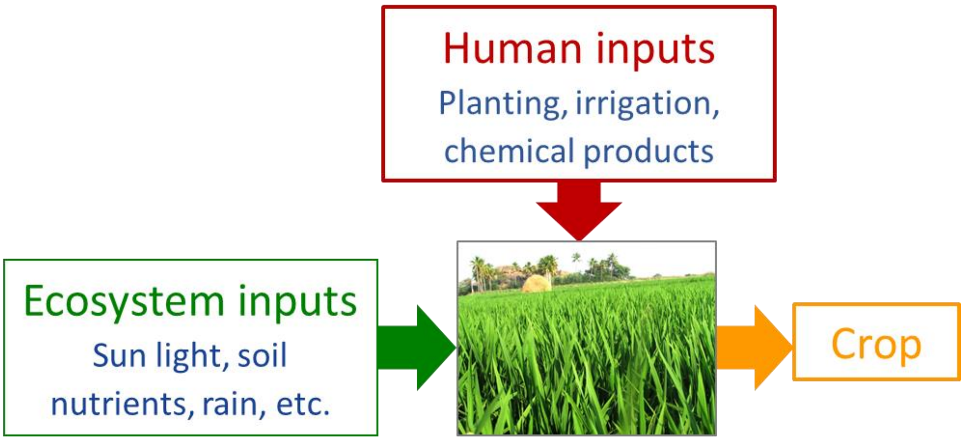



**Figure 3.1.** Simplified diagram of the main inputs and outputs in agroecosystem.

The studies of Pérez-Soba et al. (2015) and Pérez-Soba et al. (2019) are based on the Common Agricultural Policy Regionalised model (CAPRI), (Britz & Witzke, 2014; Leip et al., 2008). CAPRI is an agro-economical, partial equilibrium model with a focus on European regions, featuring a global market module and a supply module, iteratively linked. Statistical information on agricultural production from various sources (EUROSTAT, FAO, agricultural census) are periodically collected and made consistent through a standardised procedure to generate a so-called "baseline" (i.e., a coherent and consistent set of economic, agronomic and environmental indicators). The baseline used for this exercise refers to the year 2008 and it is a mean of data collected in the years 2007, 2008 and 2009. CAPRI data, by default, refer to single regions (NUTS2). They can be subsequently downscaled at a fine-grained spatial resolution on a 1 $km^2$ grid (see Kempen (2007) and Leip et al. (2008), for details on the method). The 2008 baseline covered the EU25 (i.e., all EU countries except Croatia, Malta and Cyprus).

CAPRI has also an energy module computing many of the energetic inputs listed above that was refined by Pérez-Soba et al. (2019) to better account all needed production factors. Through the downscaling process, all inputs per unit of produced output were calculated at grid level per hectare. These inputs were then converted from their original physical unit (e.g., kg of fertilisers per ha, or hours of human labour) into a common metric: solar equivalent Joule (seJ). To make such conversion, "transformity" coefficient were applied. Transformity is defined as the energy of one type (in this case solar energy), directly and indirectly required, to generate 1 J of another different sources. For example, the average transformity of Nitrogen mineral fertiliser is estimated to be 2.4 E10 seJ/g, meaning that a quantity of energy equal to 2.4 E10 J of solar energy are needed to produce 1 g of fertiliser. The transformity values used by Pérez-Soba et al. (2019) and the different literature sources are provided in Annex 3.

The quantification of inputs and outputs in agroecosystems in common units of energy allowed us estimating the percentage of the yield that is directly attributable to the ecosystem contribution ($EcoCon_{crops}$) according to the following equation:

$$EcoCon_{crops} = \frac{\text{Natural inputs}}{(\text{Natural inputs} + \text{Human inputs})} \qquad \text{(Equation 3.1)}$$

$EcoCon_{crops}$ varies in theory between 0, when yield is entirely derived from human inputs, and 1 when no human input is provided, although in practice both types of input are always present.

Data for the assessment of $EcoCon_{crops}$ were limited to 13 crop types: soft wheat, durum wheat, barley, oats, maize, other cereals, rape, sunflower, fodder maize, other fodder on arable land, pulses, potatoes, and sugar beet. All the analysis includes 13 crops that represent about 82% of the extent of all arable land in Europe. There were also available data for grasslands, but they were not considered here since they will be assessed as part of animal husbandry. Figure 3.2 shows the spatial distribution of ecosystem contribution aggregated for all crop types.

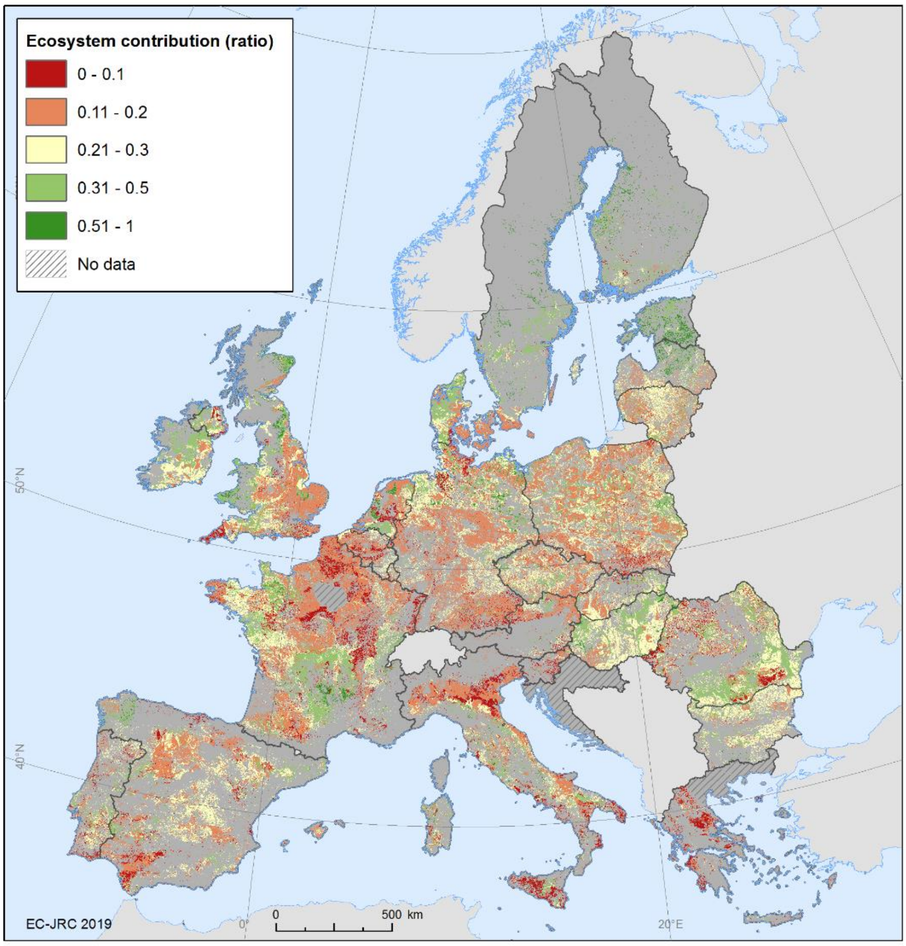



**Figure 3.2.** Map of the ecosystem contribution ratio for crop provision accounting.

Spatial patterns visible in Figure 3.2 are the consequence of different factors, including physical conditions, climate, historic patterns, and socio-economic aspects. However, some general considerations can be formulated: areas with intensive cereal production (e.g. the Po Plane in Italy, Bayern in Southern Germany, Eastern England) expectedly feature a low value, as anthropic input levels are high (mainly due to mechanization, mineral fertilizer, and pesticides). In the Mediterranean basin, a key role is played by irrigation, as in Southern Italy, plateaus of the Iberian Peninsula or Greece. In Eastern Europe, the combination of lower quantities of mineral fertilizers and higher levels of human labour contribute to increase the $EcoCon_{crops}$ values. Since data refers to 2008, however, possible recent intensifications processes in these countries are not captured.

The applied methodology is also able to account for substitution effects, a key aspect in energy-based accounts: for example, yields in Denmark are high, but a significant share of fertilization input there comes from animal manure instead of mineral fertilizers, the latter having of course a much higher transformity value. As a result, the overall ecosystem contribution in this country is relatively higher.

$EcoCon_{crops}$ is only available for 2008 and it is used to make spatially explicit estimates of crop provision derived only from the ecosystem contribution (see section 3.3.1). $EcoCon_{crops}$ values at national level (last column in Table 3.1) are based on the average $EcoCon$ values per crop type weighted by the crop extent at national level (Table 3.1).

$EcoCon_{crops}$ is then used to build the supply and use tables (SUTs) at national level by disentangling from the official statistics, specifically crop production in EU standard humidity (Ref. ESTAT [apro_cpsh1]), the component exclusively derived from the ecosystem contribution. The procedure is explained below. The correspondence between the crop code used in the $EcoCon_{crops}$ modelling and the ESTAT datasets is reported in Table 3.2.

The datasets downloaded refer to 1999, 2000, 2001 to average the production referring to year 2000; 2005, 2006, 2007 to average the production referring to year 2006; 2011, 2012, 2013 to average the production referring to year 2012. Multiple years were considered to avoid excessive fluctuations due to contingent events that happened in a specific year and thus would not help delineating a structural trend over time. However, datasets present some gaps in the time series retrieved for this application. To fill these gaps, most of the time a country average was taken for the available years; when this approach resulted not feasible, then the closest value in time was taken.

By confronting the availability of crop production with the coefficients reported in Table 3.1, for some crops where no coefficient is available but there is data on crop production, the EU average was applied (last row in Table 3.1). This happens especially for durum wheat and sugar beet.

**Table 3.1**. Ecosystem contribution values at country level per crop type.

| Country | Soft wheat | Durum wheat | Barley | Oats | Maize | Other cereals | Rape | Sunflower | Fodder maize | Other fodder on arable land | Pulses | Potatoes | Sugar beet | Average per country |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 0,191 | 0,183 | 0,258 | 0,262 | 0,079 | 0,245 | 0,223 | 0,227 | 0,25 | 0,109 | 0,027 | 0,014 | 0,083 | 0,165 |
| Bulgaria | 0,236 | 0,03 | 0,225 | 0,18 | 0,202 | 0,012 | 0,011 | 0,331 | 0,26 | 0,216 | 0,026 | 0,11 | 0,145 | 0,152 |
| Belgium/ Luxembourg | 0,128 | | 0,153 | 0,208 | 0,075 | 0,021 | 0,143 | | 0,284 | 0,117 | 0,187 | 0,13 | 0,105 | 0,141 |
| Czechia | 0,214 | | 0,27 | 0,376 | 0,114 | 0,258 | 0,378 | 0,317 | 0,293 | 0,015 | 0,06 | 0,02 | 0,17 | 0,207 |
| Germany | 0,172 | 0,167 | 0,215 | 0,266 | 0,106 | 0,199 | 0,204 | 0,317 | 0,291 | 0,097 | 0,228 | 0,181 | 0,165 | 0,200 |
| Denmark | 0,2 | | 0,296 | 0,301 | | 0,259 | 0,239 | | 0,01 | 0,247 | 0,185 | 0,222 | 0,211 | 0,217 |
| Estonia | 0,411 | | 0,415 | 0,481 | | 0,471 | 0,567 | | 0,214 | 0,643 | 0,163 | 0,151 | | 0,390 |
| Greece | 0,067 | 0,033 | 0,114 | 0,01 | 0,041 | 0,036 | 0,269 | 0,008 | 0,089 | 0,075 | 0,117 | 0,061 | 0,023 | 0,072 |
| Spain | 0,175 | 0,094 | 0,207 | 0,27 | 0,15 | 0,162 | 0,224 | 0,218 | 0,169 | 0,329 | 0,309 | 0,101 | 0,134 | 0,195 |
| Finland | 0,405 | | 0,295 | 0,251 | | 0,039 | 0,286 | 0,242 | | 0,59 | 0,163 | 0,099 | 0,145 | 0,251 |
| France | 0,151 | 0,132 | 0,187 | 0,234 | 0,086 | 0,001 | 0,157 | 0,266 | 0,272 | 0,328 | 0,213 | 0,112 | 0,103 | 0,172 |
| Hungary | 0,311 | 0,267 | 0,37 | 0,45 | 0,134 | 0,363 | 0,397 | 0,364 | 0,418 | 0,107 | 0,163 | 0,145 | 0,153 | 0,280 |
| Ireland | 0,189 | | 0,222 | 0,23 | 0,055 | | 0,253 | | 0,008 | 0,292 | 0,317 | 0,13 | 0,145 | 0,184 |
| Italy | 0,121 | 0,11 | 0,189 | 0,187 | 0,121 | 0,094 | 0,15 | 0,209 | 0,131 | 0,29 | 0,196 | 0,088 | 0,132 | 0,155 |
| Lithuania | 0,269 | | 0,325 | 0,44 | 0,024 | 0,381 | 0,443 | | 0,056 | 0,216 | 0,163 | 0,02 | 0,14 | 0,225 |
| Latvia | 0,363 | | 0,446 | 0,486 | | 0,487 | 0,458 | | 0,214 | 0,138 | 0,163 | 0,142 | 0,22 | 0,311 |
| Netherlands | 0,169 | | 0,308 | 0,322 | 0,117 | 0,086 | 0,244 | 0,021 | 0,34 | 0,072 | 0,308 | 0,139 | 0,21 | 0,194 |
| Poland | 0,207 | | 0,318 | 0,313 | 0,13 | 0,253 | 0,255 | 0,307 | 0,371 | 0,001 | 0,022 | 0,113 | 0,152 | 0,203 |
| Portugal | 0,208 | 0,132 | 0,258 | 0,244 | 0,191 | 0,01 | | 0,227 | 0,164 | 0,347 | 0,126 | 0,081 | 0,128 | 0,176 |
| Romania | 0,304 | 0,132 | 0,286 | 0,307 | 0,3 | 0,003 | 0,121 | 0,361 | 0,3 | 0,216 | 0,163 | 0,056 | 0,179 | 0,209 |
| Sweden | 0,244 | | 0,298 | 0,383 | 0,132 | 0,215 | 0,332 | | 0,214 | 0,387 | 0,163 | 0,027 | 0,047 | 0,222 |
| Slovenia | 0,164 | | 0,195 | 0,237 | 0,153 | 0,005 | 0,174 | 0,134 | 0,142 | 0,046 | 0,001 | 0,093 | 0,145 | 0,124 |
| Slovakia | 0,267 | 0,174 | 0,315 | 0,383 | 0,118 | 0,242 | 0,367 | 0,328 | 0,248 | 0,018 | 0,163 | 0,055 | 0,202 | 0,221 |
| United Kingdom | 0,148 | 0,132 | 0,195 | 0,251 | 0,329 | | 0,298 | 0,242 | 0,196 | 0,297 | 0,288 | 0,087 | 0,201 | 0,222 |
| **Average per crop type** | **0,221** | **0,132** | **0,265** | **0,295** | **0,132** | **0,174** | **0,269** | **0,242** | **0,214** | **0,216** | **0,163** | **0,099** | **0,145** | **0,197** |

In red, the EU average reported for the missing values.

**Table 3.2.** Correspondence between $EcoCon_{crops}$ codes and ESTAT datasets[3].

| EcoCon code | ESTAT code | Ref codes in physical terms [apro_cpnh1] | Ref codes in monetary terms [aact_uv01] |
|---|---|---|---|
| Soft and Durum Wheat | Wheat | C1100 | O1100 |
| Barley | Barley | C1300 | O1300 |
| Oats | Oats | C1400 | O1400 |
| Maize | Maize | C1500 | O1500 |
| Other cereals | Other cereals* | C1900 | O1900 |
| Rape | Rape | I1110 | O2110 |
| Sunflower | Sunflower | I1120 | O2120 |
| Fodder maize | Green maize | G3000 | O3100 |
| Other fodder | Other fodder on arable land** | G9100 and G9900 | O3100 and O3900 |
| Pulses | Protein crops *** | P0000 | O2200 |
| Potatoes | Potatoes | R1000 | O5000 |
| Sugar beet | Sugar beet | R2000 | O2400 |

** it includes buckwheat, millet, canary seeds, etc.; it does NOT include Triticale and Sorghum*

*** G9100 is "Other cereals harvested green" and G9900 is "Other plants harvested green from arable land"; it does NOT includes leguminous plants harvested green, lucerne, clover and mixture, green maize*

**** it includes Field pies [P1100], Broad and field beans [P1200], Sweet lupins [P1300] and other dry pulses [P9000]*

The equation applied to calculate the actual flow in physical terms is simply:

$$Actual\ flow\ crop\ (tonne) = crop\ pruduction\ (tonne) * \ EcoCon_{crop} \quad \text{(Equation 3.2)}$$

The results of the actual flow of crop provision in biophysical terms are reported in Table 3.3.

## 3.2 Monetary valuation

Monetary valuation is also based on ESTAT datasets. Specifically, the "Unit values at basic prices" (Ref ESTAT [aact_uv01]). For each crop, the corresponding unit value was chosen per country -per crop -per year. Once again, the datasets downloaded refer to 2000, 2001 to average the crop price referring to year 2000 (1999 is not available); 2005, 2006, 2007 to average the crop price referring to year 2006; 2011, 2012, 2013 to average the crop

[3] The first coding refer to the dataset "Crop production in national humidity [apro_cpnh1]" in physical terms; the second coding refers to the dataset "Unit values at basic prices [aact_uv01]" in monetary terms

price referring to year 2012. In this case we adopt three different averages for three different years. This choice opens the methodological issue of applying different prices over time versus applying the same price as "fixed" and eventually process inflation and other factors ex-post.

Once again, dataset presents some gaps in the time series retrieved for this application. To fill the gap, most of the time a country average was taken for the available years; when this approach resulted not feasible, then the closest value in time was taken.

The equation applied to calculate the monetary values is simply:

$$Actual\ flow\ crop\ (EUR) = actual\ flow\ (tonne) * \ EUR/tonne \qquad \text{(Equation 3.3)}$$

The results of the actual flow of crop provision in monetary terms are reported in Table 3.4.

## 3.3 Crop provision results

### 3.3.1 Biophysical maps

The biophysical assessment of crop provision allows us to make comparisons between total yield production for the 13 crop types considered (which is usually considered as a proxy of crop provision) and the yield derived exclusively from the ecosystem contribution for 2008 (Figure 3.3). Total yield in Figure 3.3 shows the highest values in central Europe, South of the United Kingdom and North of Italy. However, the ecosystem contribution map shows the highest value in more specific regions such as at the borders between Germany, the Netherland and Belgium, Denmark and West of France.

### 3.3.2 Accounting tables

For crop provision, the allocation of actual flow in SUTs is straightforward. Cropland is the Ecosystem type that supplies the service; "Agriculture" is the economic sector that uses the service: the sum over all the flows into crops provided within "Agriculture" equals the flow provided by "Cropland". Through "Agriculture" crop provision enters the economic system and the market for further processing, transformation and trading. For what concerns ecosystem accounting we only consider the "entry point" to the sector "Agriculture".

Tables 3.3 and 3.4 show aggregated values for the EU 25 in absolute terms. Table 3.3 shows a decrease from 2000 to 2006 and an increase from 2006 to 2012. This happens in both physical and monetary terms, although in the Use table few crops (such as durum wheat, other forage, sugar beet and other cereals) suffer a continuous decrease both in physical and monetary terms. This decrease is compensated both in quantitative physical terms and higher per unit values by other group of crops such as soft wheat. Ad hoc per country analysis (see Annex 4) would be more appropriate, since some countries are specialized in selected crops and enjoy/suffer more than others ES flow increase/decrease.

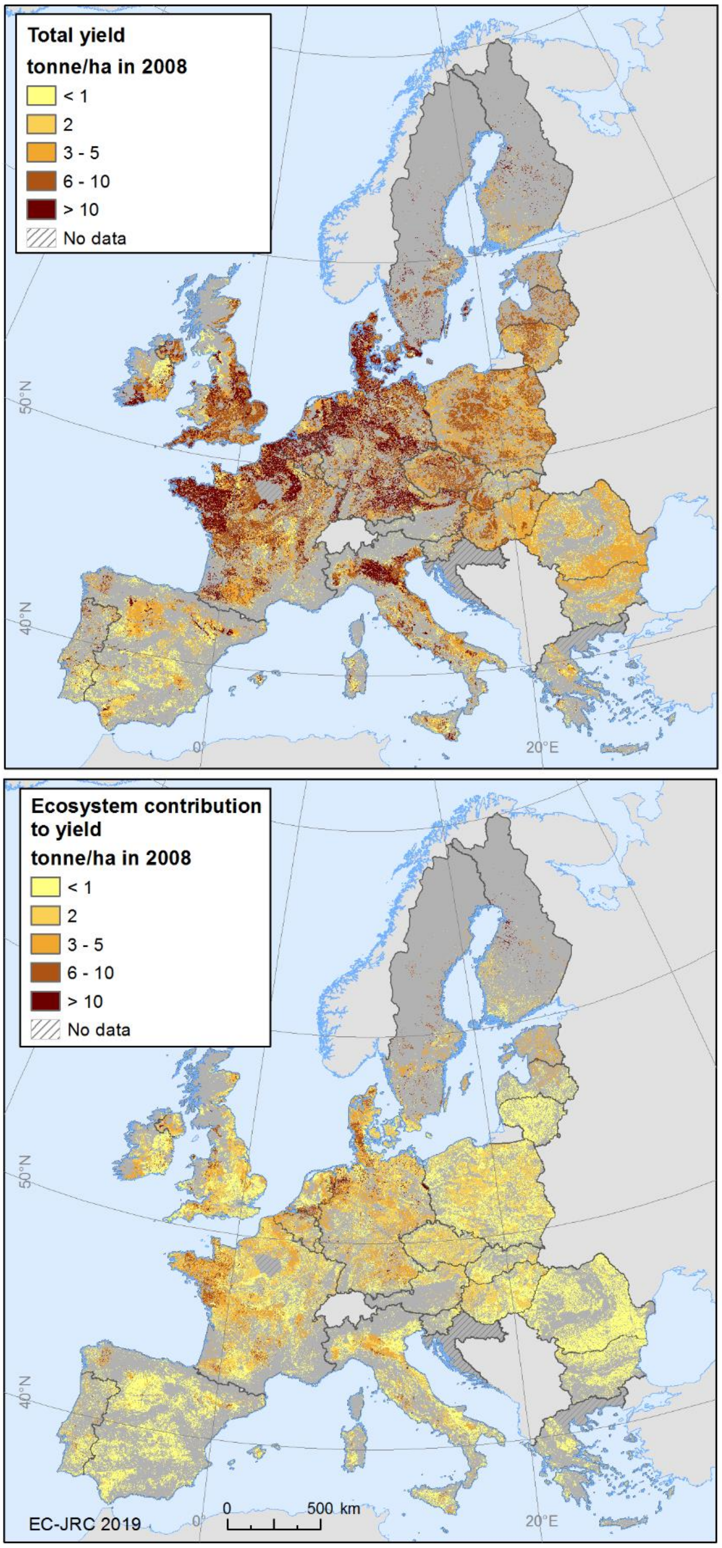



**Figure 3.3.** Maps of total yield and yield derived from the ecosystem contribution.

**Table 3.3**. Supply and use tables for crop provision in physical terms.

| | Institutional sectors | | | | | | | | | | | | | | | | | | Ecosystem types | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | | | | | | | | |
| Million tonne | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | Fisheries | Secondary sector | Tertiary sector | Households | Rest of the world | Cropland | Grassland | Other ecosystem types |
| *Supply table* | | | | | | | | | | | | | | | | | | | | | |
| 2000 | | | | | | | | | | | | | | | | | | | 144 | | |
| 2006 | | | | | | | | | | | | | | | | | | | 138 | | |
| 2012 | | | | | | | | | | | | | | | | | | | 156 | | |
| *Use table* | | | | | | | | | | | | | | | | | | | | | |
| 2000 | 22.50 | 0.92 | 13.97 | 3.77 | 7.74 | 0.12 | 2.63 | 1.22 | 1.04 | 18.54 | 44.60 | 18.38 | 9.25 | | | | | | | | |
| 2006 | 22.06 | 0.91 | 13.29 | 3.66 | 7.88 | 0.13 | 3.92 | 1.46 | 0.76 | 17.22 | 47.99 | 11.97 | 7.25 | | | | | | | | |
| 2012 | 24.84 | 0.88 | 13.07 | 3.46 | 9.22 | 0.09 | 4.70 | 2.06 | 0.64 | 16.78 | 64.07 | 9.57 | 6.90 | | | | | | | | |

**Table 3.4**. Supply and use tables for crop provision in monetary terms.

| | Institutional sectors | | | | | | | | | | | | | | | | | | Ecosystem types | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | | | | | | | | |
| Million EUR | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | Fisheries | Secondary sector | Tertiary sector | Households | Rest of the world | Cropland | Grassland | Other ecosystem types |
| *Supply table* | | | | | | | | | | | | | | | | | | | | | |
| 2000 | | | | | | | | | | | | | | | | | | | 15,604 | | |
| 2006 | | | | | | | | | | | | | | | | | | | 15,353 | | |
| 2012 | | | | | | | | | | | | | | | | | | | 20,563 | | |
| *Use table* | | | | | | | | | | | | | | | | | | | | | |
| 2000 | 3,793 | 223 | 2,367 | 535 | 1,180 | 17 | 776 | 475 | 281 | 1,342 | 1,810 | 905 | 1,902 | | | | | | | | |
| 2006 | 3,724 | 162 | 2,214 | 547 | 1,225 | 20 | 1,112 | 512 | 159 | 1,243 | 1,848 | 552 | 2,033 | | | | | | | | |
| 2012 | 5,465 | 183 | 2,600 | 592 | 1,970 | 18 | 2,053 | 984 | 172 | 1,171 | 2,476 | 417 | 2,462 | | | | | | | | |

## 3.4 Trend analysis

Since the Ecosystem Contribution coefficient was not calculated for the different years because data were only available for 2008, the analysis of changes over time reflect the changes in the total production, and not the real actual flow of crop provision, i.e. the ecosystem contribution remained the same while the total amount of yield increases or decreases. However, the trend analysis is useful to show that few changes occurred over time: the decrease for the first period (2000-2006) compared to the second (2006-2012) can be explained by the collapse of the socialist regimes in Eastern countries[4]. In fact, countries such as Czechia, Hungary, Slovakia, Romania, Poland, Slovenia, Lithuania, and Estonia experience a continuous increase considering all the crops aggregated (Figure 3.4).

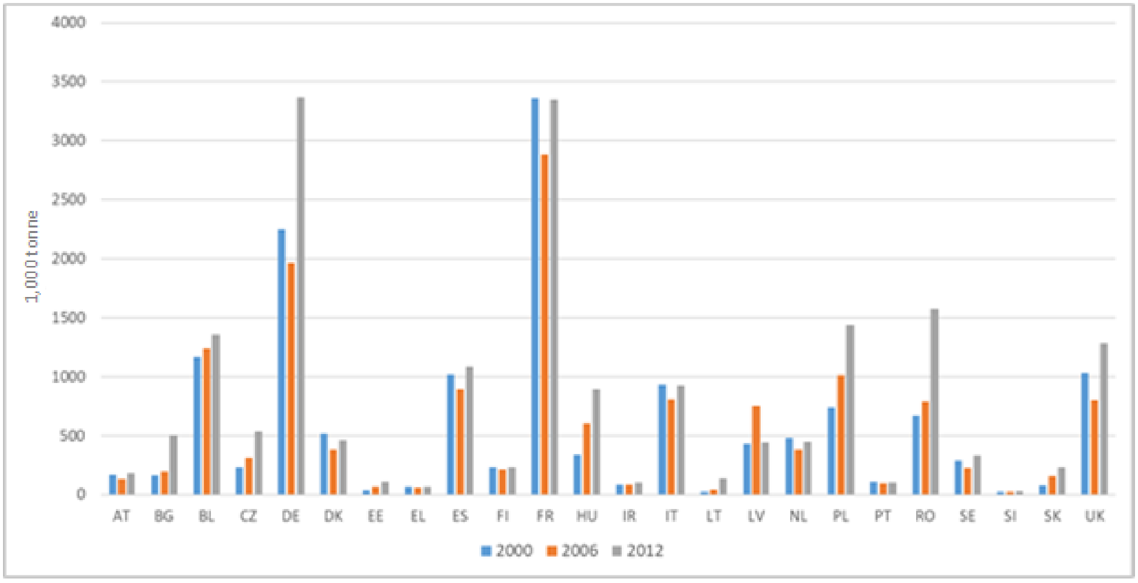



**Figure 3.4.** Actual flow of crop provision for 13 crop types per country.

It is interesting to consider how the individual trends per crop and per country changes when the former (Figure 3.4) or the latter (Annex 4) are aggregated. Specific policy directions cannot disregard the level of disaggregation of different components of the same information block, e.g., in Figure 3.4 for Italy we see a general increase from 2006 to 2012, while in Annex 4 Italy records decreases in many crops such as durum wheat, barley, oats, and maize.

[4] Having 2000 as the benchmark year.

## 3.5 Model limitations

In this experimental crop provision accounts, we have made one of the first attempt to disentangle the ecosystem contribution from total yield to properly assess the ecosystem service. In this way, human inputs into the agriculture are not integrated in this account. The main limitation of the approach here proposed is that $EcoCon_{crops}$ here calculated is static and, therefore, does not show changes over time. This is an important limitation since changes in management practices in cropland result in changes in ecosystem contribution to provide the service.

Further developments of crop provision account could be focused on estimating the ecosystem contribution dynamic over time. The study of Pérez-Soba et al. (2015) and Pérez-Soba et al. (2019) are very demanding in terms of data needed, which makes it really difficult to calculate the $EcoCon_{crops}$ in a dynamic way.

It is however worth to explore the possible correlation between $EcoCon_{crops}$ (average for all crops at country level) and some relevant agri-environmental indicators (Eurostat, 2018). Exploratory analyses at country level show negative correlation of $EcoCon_{crops}$ with irrigation, mineral fertiliser consumption, agricultural area managed under high intensity and gross nitrogen balance (Table 3.5). $EcoCon_{crops}$ is higher with higher share of agricultural area managed under low intensity, under organic farming and under agri-environmental commitments (Table 3.5, positive sign of the correlation coefficient).

These analyses are useful to validate and provide contrasted support to the $EcoCon_{crops}$ used in this study, showing a decrease of the ecosystem contribution when agricultural practices are intensified. Further analysis could be carried out at a more detailed spatial resolution and find alternative ways to calculate the $EcoCon_{crops}$ based on agri-environmental indicator or ecosystem indicators.

In monetary terms, agricultural statistics (ref. ESTAT [agr]) potentially offer several possibilities to attribute monetary values to crop provision. Apart from the simple methodology explained throughout the chapter, Economic accounts for agriculture - values at current prices (Ref. ESTAT [aact_eaa01]) could be used to extrapolate the ecosystem contribution directly in monetary terms. ESTAT [aact_eaa01] offers information aggregated for all crops and services, also on gross and net value added, gross and net fixed capital formation.

If we considered the agricultural output (that includes: crop, animal and services output) and deducted total intermediate consumption and fixed capital consumption, we face the following situation: i) negative ratios for two countries in 2012 (Luxembourg and Finland) one country in 2000 (Slovakia), and (ii) overall very low values (average for all countries over the three year equals 0.24). The 0.24 of final Agricultural Output should then be multiplied by the ecosystem contribution coefficient that on average is 0.28. We believe that the (on average) 0.07 is not a fair coefficient to attribute the monetary value. If we consider the relationship between the Gross and Net Value Added, specifically (NVA/GVA), the average across years and countries is 0.64 that is much higher than the 0.24 of the previous option. However, we need to keep in mind that both options consider all agricultural output together, while ecosystem coefficients are applied to each of the 13 individual crops. In this case the specificity gained for individual crop gets lost in the aggregation on the monetary side. For this reasons and for the sake of having full consistency between SUTs in physical and monetary terms we finally opted for methodology described in section 1.2, nevertheless acknowledging the need of having a reference resource rent procedure to calculate monetary values.

**Table 3.5**. Ecosystem contribution values at country level per crop type.

| Agri-environmental indicator | | Year | Correlation coefficient |
|---|---|---|---|
| Share of area under agri-environmental commitments on total UAA (%) | | 2013 | 0.21 |
| Percentage of UAA under organic farming (%) | | 2008 | 0.34 |
| Mineral fertiliser consumption | Nitrogen/Fertilised UAA (kg N/ha) | 2006 | -0.48 |
| | Phosphorus/Fertilised UAA (kg P/ha) | 2006 | -0.57 |
| Consumption of pesticides | Sold pesticides (tonne) | 2011 | -0.21 |
| Irrigation | Share of irrigated areas in UAA (%) | 2007 | -0.60 |
| Energy use | Energy supplied to agriculture for all energy uses (kgOE/ha) | 2008 | -0.19 |
| Intensification / extensification | Share of agricultural area managed under high intensity (%) | 2008 | -0.48 |
| | Share of agricultural area managed under low intensity (%) | 2008 | 0.44 |
| Gross nitrogen balance | kg N per ha UAA | 2008 | -0.36 |

UAA: utilised agricultural area

## 3.6 Summary of crop provision accounts

**Box 1.** Crop provision accounts: main outcomes

Crop provision accounts can be disentangled from data already reported in official statistics.

It is important to disentangle the ecosystem contribution from the human input and not to take crop production as a proxy for the ecosystem service, because a high total crop production can include a significant enhancement by fertilizers and mechanization.

At the EU level, ecosystem contribution to crop provision is about 21% of the total yield value. The rest is due to human inputs.

The value of crop provision as ecosystem service is about 20.6 billion EUR in 2012, which increased in 32% since 2000. However, these changes are due to changes in agriculture production and not to changes in the ecosystem contribution ratio.

Few comments on the accounting outcomes:

— Ecosystem contribution is very different per crop type and also per country: aggregated values can provide different trends whether considering each individual crop or each individual country;

— Monetary values differ crop by crop; any analysis undertaken for conjoined changes in physical and monetary terms should consider the role played by the market price of individual crops.

Limitations of the approach are mainly due to the lack of data to assess change over time in the Ecosystem Contribution coefficient. There is also an issue to make this coefficient replicable as undertaken in the original study, given the large amount of data required to estimate this coefficient. There are ways to overcome the problem, but they need to be probed. Another limitation lies in the coverage of crops. Although important crops have been considered, still many other crops have not been included. Data availability remains a problem in official statistics both in physical and monetary terms.

# 4 Timber provision

Timber provision as an ecosystem service is defined as the ecological contribution to the production of timber that can be harvested and used as raw material (modified from CICES V.5.1., Haines-Young and Potschin (2018)).

As most of European forests are managed, timber provision is partially driven by human action. On the one hand, there are features beyond the control of forest management, such as biophysical site conditions and climate. On the other hand, tree species composition, tree growth, and shape are influenced by silvicultural operations such as thinning, clear cut or selective cutting, plantation, seeding or natural regeneration. Therefore, one way of interpreting timber provision as ES is meant to disentangle the ecosystem contribution (as the ecological side of biomass growth) from all human inputs invested in the co-production process.

Timber provision accounts represent an example of ecosystem service where the account of the actual service flow in biophysical and monetary terms can be based on official statistics. In fact, forest accounts based on the SEEA CF guidelines combined with the use table of national accounts would provide all the information needed to compile timber provision supply and use tables (SUTs) in both physical and monetary terms. Using data from forest accounts as starting point, we can estimate the actual flow of ES that results from the functioning of the ecosystem and separate it from the human contribution. Having the SEEA CF forest accounts would guarantee the possibility to easily compile this ecosystem service account in a very simplified way. However, due to data gaps for the time series the study aims to assess (year 2000, 2006, and 2012), we have to find alternative solutions. Complementarily, a methodology of spatial disaggregation of timber provision accounts at country level is used to map the actual flow of timber provision. The map of the actual flow will be useful for further analysis and integration with spatially explicit data for other ecosystem services.

In conventional forest account tables we find information on timber biomass that is the outcome of ecosystem and human inputs. In the approach we present here, we propose a first attempt to quantify the actual flow of timber provision as generated by ecosystem input only, i.e., the assessment of the ecological contribution to be separated from human inputs. In this way, we assess more accurately the ecosystem service suiting the ecosystem service definition.

## 4.1 Biophysical assessment

Since timber provision specifically refers to the production of woody biomass undertaken by the forestry sector, only forest land designated available for wood supply will be considered to determine the actual flow. This implies that the estimates here reported do not include woody biomass in general, but only the woody biomass in Forest Available for Wood Supply (FAWS). Specifically the Gross Annual Increment is “the average annual volume of increment over the reference period of all trees with no minimum diameter”

(UN-ECE & FAO, 2000). Once the losses due to the natural mortality of trees are subtracted, we obtain the Net Annual Increment of timber (NAI, as shown in Figure 4.1), which in our assessment represents the starting point to calculate the actual flow, following the SEEA CF guidelines (UN et al., 2014a). Based on SEEA CF, the European Forest Accounts (EFA) will constitute a precious source of information, directly employable in all estimates needed to build the account of timber provision as ecosystem service.

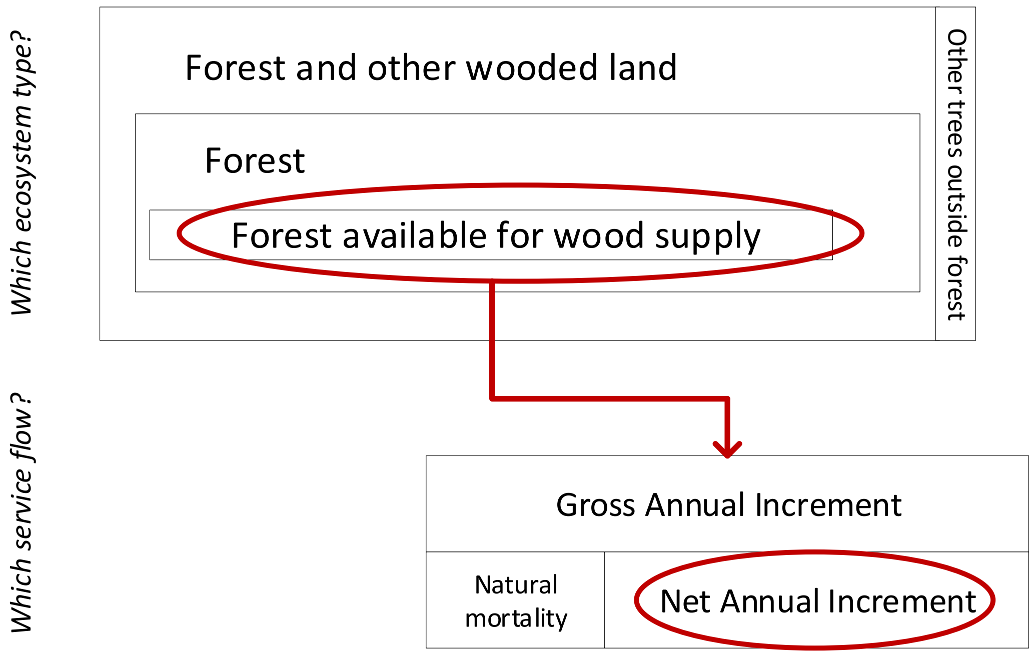



**Figure 4.1.** Identification of the target variable to be assessed as actual flow (adapted from Camia et al. (2018))

However, NAI is the product of ecosystem and human inputs. Similarly to crop provision, we aim at calculating a coefficient to disentangle the ecosystem contribution from the total production. Figure 4.2 shows in a simple way the logical process by showing that different set of inputs contribute to generate the benefit (i.e., timber) that will eventually enter the economy system through the forestry sector. One set of inputs is human driven (management activities such as selective logging), another set of inputs is based on ecosystem inputs (i.e., sun light, soil nutrients, and water).

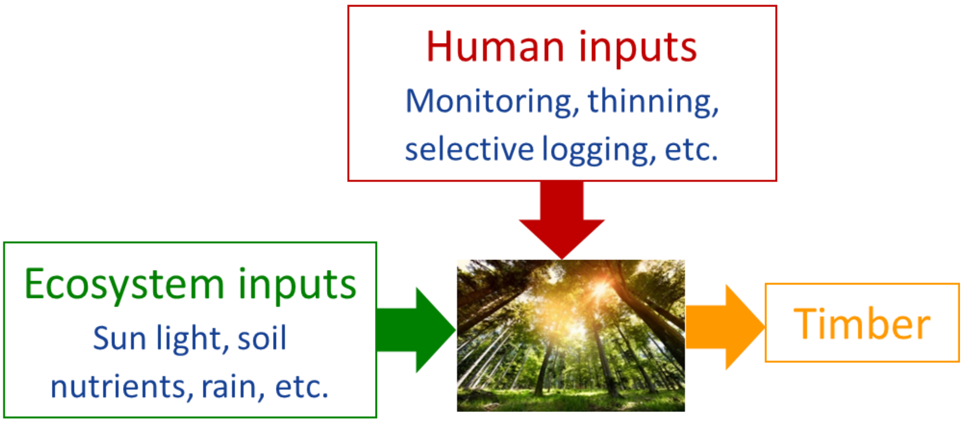



**Figure 4.2.** Simplified diagram of the main inputs and outputs in forest ecosystems.

Starting from the NAI estimates that we extract from forest statistics and accounts, we need to identify human inputs in order to isolate what remains as ecosystem contribution ($EcoCon_{timber}$). Unlike crop provision, we do not use modelling to disentangle the ecosystem contribution. Instead, we proceed as follows:

1. Identify which human inputs play a role in the management of forest resources for production purposes based on the literature;
2. Find proxies of these inputs in the national accounts and extract them;
3. Calculate the ecosystem contribution coefficient ($EcoCon_{timber}$);
4. Calculate the actual flow of timber provision by multiplying the coefficient with NAI (in physical terms).

The different steps are described below:

**Step 1** – traditionally, the classification of forest management systems was based on an economic perspective based on production factor utilization and monetary returns (e.g., Arano and Munn (2006)) or on an ecological perspective based on the degree of modification of natural conditions (e.g., Kruger and Volin (2006)). Duncker et al. (2012) demonstrated that the variety of silvicultural systems goes beyond these separated classifications, by identifying an intensity scale of five categories based on 12 management decision criteria. Among the management selection criteria reported in Duncker et al. (2012), we selected: 1) type of regeneration (that include not only natural regeneration but also planting, seeding and coppice); 2) fertilization and application of chemical agents; and 3) machine operation.

We also considered the categories acknowledged in forest accounts as "forest trees nursery services" and "support services to forestry", and specifically: forestry inventories; tree removals; forest management consulting services; timber evaluation; forest fire prevention and fighting and protection; and forest pest control.

These operations link to specific silvicultural operations (i.e., human input) that are: stand establishment (management of natural regeneration or plantation and forest tree nursery services), possible amelioration to increase yield (fertilization) and pest control (application of chemical agents), thinning (tree removal) and finally use of machinery that is cross sectional to all the operation that requires driving on forest soils (e.g., tree removal).

**Step 2** - we use SUTs available in National Accounts to find the proxies of human inputs (Eurostat, 2013) and consider individually the relevant inputs that represent human contribution in timber provision defined in the previous step. We used the ESTAT dataset "Use table at purchasers' prices" (ref. [naio_10_cp16]) in million EUR as source data, from which we selected[5]:

1. Products of agriculture, hunting and related services ($CPA_{A01}$), selected as proxies for planting material with reference to tree improvement and type of regeneration;
2. Chemicals and chemical products ($CPA_{C20}$), selected as proxy for fertilization and application of chemical agents;
3. Coke and refined petroleum products ($CPA_{C19}$), selected as proxy for machine operation (i.e., fuel);
4. Products of forestry, logging and related services ($CPA_{A02}$), selected as proxies for tree nursery and "forestry services" explained in the previous paragraph.

For the calculation of the coefficient, we also extracted the total Output to the forestry sector (P1), as shown in the following step.

**Step 3** - we calculate $EcoCon_{timber}$ at country level based on economic data (i.e., aggregates) according to Equation 4.1:

$$EcoCon_{timber} = 1 - \frac{(\mathrm{CPA_{A01}} + \mathrm{CPA_{A02}} + \mathrm{CPA_{C19}} + \mathrm{CPA_{C20}})}{\mathrm{P1}} \qquad \text{(Equation 4.1)}$$

Where $CPA_{A01}$ is the proxy for planting material, $CPA_{A02}$ is the proxy for nursery and forestry services, $CPA_{C19}$ is the proxy for machine operation, $CPA_{C20}$ is the proxy for fertilization and chemical agents, $P_1$ is the total output of the forestry sector.

Due to constraints in data availability, we could only calculate an average of the coefficient at country level from 2010 to 2014. The lack of data for more years forces this coefficient to be static. Having a complete time series would allow to measure how $EcoCon_{timber}$ changes over time. Please note that $EcoCon_{timber}$ is dimensionless.

[5] We kept data coding (i.e. CPA02, CPA_19, etc.) to facilitate the reader in case of crosschecking.

Table 4.1 shows the results of $EcoCon_{timber}$ at country level. Since Malta has no FAWS (and no forestry activities), we do not calculate the coefficient for this country. It might be interesting to note (please refer to Annex 6) that the country where the input is the highest for agricultural products is Germany (followed by France); the country where the input is the highest for forestry services is France (followed by Germany and Austria); the country where the input is the highest for the use of chemical products is Finland; finally, Finland and Sweden are the countries where Forestry uses the highest input in terms of coke and refined petroleum products (not surprisingly because in these countries harvest is highly mechanized). Please refer to Annex 6 for supporting material.

**Table 4.1**. Ecosystem contribution coefficient for timber provision at country level.

| Country | *EcoCon* timber | Country | *EcoCon* timber |
|---|---|---|---|
| **United Kingdom** | 0.52 | **Ireland*** | 0.73 |
| **France** | 0.55 | ***EU average*** | 0.73 |
| **Latvia** | 0.57 | **Romania** | 0.75 |
| **Austria** | 0.57 | **Luxembourg** | 0.77 |
| **Belgium** | 0.58 | **Czechia** | 0.78 |
| **Slovakia** | 0.63 | **Slovenia** | 0.8 |
| **Denmark** | 0.67 | **Finland** | 0.8 |
| **Croatia** | 0.67 | **Greece** | 0.82 |
| **Lithuania** | 0.67 | **Netherlands** | 0.83 |
| **Hungary** | 0.68 | **Portugal** | 0.84 |
| **Poland** | 0.68 | **Spain** | 0.9 |
| **Bulgaria** | 0.71 | **Sweden** | 0.92 |
| **Germany** | 0.71 | **Italy** | 0.97 |
| **Estonia** | 0.73 | **Cyprus** | 0.97 |

*Data missing for Ireland. The reported coefficient is the average calculated at the EU-27 level

Source: processed from "Use table at purchasers' prices" [naio_10_cp16]

**Step 4** - $EcoCon_{timber}$ is applied to the NAI available at country level in physical terms to obtain the actual flow of timber provision (in $m^3$/year) understood as ecosystem service (Equation 4.2).

$$Actual\ flow\ timber\ provision\ (m^3/year) = NAI\ (m^3/year) * \ EcoCon_{timber}$$

(Equation 4.2)

In this study, data on NAI are obtained from official statistics, specifically the Forest resources tables (ref. ESTAT dataset [for_sfm]). Within this data it is possible to find: volume of timber over bark (source: EFA [for_vol_efa]) and volume of timber (source: FAO - FE [for_vol]). To assess the volume of timber in physical terms we used FAO-FE [for_vol] because it covers all European countries for most of the years we refer to. However, FAO-FE [for-vol] does not include any monetary measurement. On the other hand EFA [for_vol_efa] includes other accounting data we need (opening stock, net annual increment, removals, etc.) but only for few countries and only for few years.

Mapping of the actual flow is needed for further analyses on synergies and trade-offs between the different ecosystem services mapped in INCA. To do this, the actual flow of timber provision obtained with Equation 4.2[6] was then spatially disaggregated using Dry Matter Productivity (DMP) as a proxy to generate a map of the actual service flow. DMP is derived from the Copernicus service information data (© European Space Agency) at 1 km x 1 km grid cell size. DMP is a measure of the overall growth rate or dry biomass increase of the vegetation expressed in kilograms of dry matter per hectare over a period of time (Copernicus Global Land Operations, 2018). The spatial disaggregation was performed on the forest CLC, that do not exactly match with the definition of Woodland and forest of the MAES ecosystem types (transitional woodland and shrub are not included) (see Annex 1 on the Correspondence between CORINE Land cover classes and MAES ecosystem types).

The actual flow is assessed through data allowing the calculation of the ecosystem contribution to the timber growth in FAWS. Forest in CLC includes all forests, available and not available for wood supply. We explored an alternative to map FAWS by setting different spatial constraints such as slope or protected areas, however identification of common thresholds across Europe to define FAWS is still very challenging, and delineation of FAWS could be misleading (Alberdi et al., 2016). See a further discussion on the model limitations section.

## 4.2 Monetary valuation

The overall approach implemented for the monetary valuation of the actual flow consists of applying a unit market price to the estimated quantity in physical terms. Ideally, the best procedure to follow would be to multiply the NAI with the $EcoCon_{timber}$ coefficient to obtain the actual flow in $m^3$ and then to multiply it by EUR/$m^3$, and to reach full consistency between SUTs in physical and monetary terms (as done for crop provision). However, many data gaps from official statistics complicate what would otherwise be a suitable procedure.

Therefore, an alternative approach was chosen: the primary source of information is the EFA dataset (ref. to ESTAT dataset [for_vol_efa]), from which we can calculate the value

[6] Equation 4.2 is calculated by using data retrieved from ESTAT dataset [for_vol_efa].

of the actual flow in EUR per $m^3$ of timber, but data are at the moment available only for 11 countries. As an alternative, we use the available information from EFA (ref. to ESTAT dataset [for_vol_efa]) and combine it with the total Output of forestry (in monetary terms) obtained from the dataset on economic aggregates of forestry (ref. to ESTAT dataset [for_eco_cp]). The latter does cover all EU 28 countries[7] and can thus be used to approximate missing values.

Specifically, we proceed as follows:

1. From the EFA dataset in monetary terms we calculate the ratio of NAI to the total Output of forestry per country, where available (Table 4.2, third column);
2. The average ratio at EU level (0.43) is then applied to all other countries with no data in EFA (ref. to ESTAT dataset [for_vol_efa]) to estimate the NAI (Table 4.2, second column in red);
3. We apply $EcoCon_{timber}$ to the monetary NAI derived from Table 4.2, as shown in Equation 4.3:

$$Actual\ flow\ timber\ provision\ (EUR) = NAI\ (EUR) * \ EcoCon_{timber}$$

(Equation 4.3)

4. We divide the monetary supply and use tables for reference year 2012 by physical supply and use table and obtain a unit value (EUR/$m^3$) as reference price;
5. We multiply the unit value (EUR/$m^3$) by 2000 and 2006 physical supply and use tables to provide a monetary valuation for the missing years.

The best way to assess supply and use table in both physical and monetary terms would be to use the information contained in EFA (ref. to ESTAT dataset [for_vol_efa]) for all countries. Because of data gaps we had to find alternative solutions that involve:

- Using a set of data (ref. ESTAT datasets [for_vol]) to compile a supply and use table in physical terms;
- Combining different sets of data (ref. ESTAT dataset [for_vol_efa]) and ESTAT dataset [for_eco_cp]) to compile a supply and use table in monetary terms.

Table 4.3 summarizes the datasets used in the chosen approach as well as the desirable ones.

[7] In the for_eco_cp dataset data for 8 or so countries are estimated from nama national accounts (NACE 02) (flagged with e) in the original dataset).

**Table 4.2.** From the Output of forestry to the value of the Net Annual Increment.

| Countries | Output (million EUR) | NAI (million EUR) | Ratio Output/NAI |
|---|---|---|---|
| *Closest years available* | *Year 2013* | *Year 2014* | |
| **Belgium** | 439 | 188 | |
| **Bulgaria** | 578 | 327 | 0.57 |
| **Czechia** | 2,308 | 986 | |
| **Denmark** | 680 | 291 | |
| **Germany** | 8,780 | 3,535 | 0.40 |
| **Estonia** | 542 | 232 | |
| **Ireland** | 358 | 153 | |
| **Greece** | 79 | 34 | |
| **Spain** | 1,317 | 563 | |
| **France** | 4,591 | 2,585 | 0.56 |
| **Croatia** | 299 | 128 | |
| **Italy** | 1,563 | 668 | |
| **Cyprus** | 5 | 3 | 0.57 |
| **Latvia** | 1,020 | 436 | |
| **Lithuania** | 1,344 | 575 | |
| **Luxembourg** | 93 | 31 | 0.33 |
| **Hungary** | 451 | 193 | |
| **Malta** | 0 | 0 | |
| **Netherlands** | 267 | 114 | |
| **Austria** | 2,533 | 839 | 0.33 |
| **Poland** | 4,663 | 2,339 | 0.50 |
| **Portugal** | 1,175 | 502 | |
| **Romania** | 1,522 | 640 | 0.42 |
| **Slovenia** | 385 | 124 | 0.32 |
| **Slovakia** | 720 | 265 | 0.37 |
| **Finland** | 4,655 | 1,989 | |
| **Sweden** | 4,712 | 2,014 | |
| **United Kingdom** | 1,149 | 369 | 0.32 |
| **EU average** | | | 0.43 |

Source: Output data were extracted from Economic aggregates of forestry [for_eco_cp], NAI data in black were extracted from Volume of timber over bark (source: EFA questionnaire) [for_vol_efa], NAI data in red were estimated.

**Table 4.3**. Summary table reporting current and desirable source of data.

| | Current | Desirable |
|---|---|---|
| ***Ecosystem contribution*** | [naio-io-cp16]<br>ESA 2010 | *Ad-hoc*<br>*modelling* |
| ***Actual flow (m³)*** | [for_vol]<br>FAO –FE | [for_vol_efa]<br>EFA |
| ***Actual flow (EUR)*** | [for_eco_cp] and [for_vol_efa]<br>For_EAF EFA | [for_vol_efa] only<br>EFA |

## 4.3 Timber provision results

### 4.3.1 Biophysical maps

Figure 4.3 shows the map of the actual flow of timber provision, where only the ecosystem contribution is assessed. Areas with higher actual flow of timber provision can be found in central Europe, but also Portugal. Lowest values appear in the North of Sweden and Finland, where the short growing season limits the timber growth; but also in some Mediterranean countries such as Greece, Cyprus, and some areas Spain where drought is the main limiting factor of growth.


**Figure 4.3.** Map of the actual flow of timber provisioning.

### 4.3.2 Accounting tables

For timber provision, the allocation of actual flow in SUTs is straightforward. FAWS is the share of "Woodland and forest" that supplies the service; forestry is the economic sector that uses the service. Through forestry timber provision enters the economic system and the market for further processing, transformation, and trading. For what concerns ecosystem accounting, we only consider the "entry point" to the forestry sector.

Tables 4.4 and 4.5 show aggregated values for EU 28 in absolute terms (please consider that Malta has no FAWS and thus no timber provisioning service). Table 2.4 shows a decrease from 2000 to 2006 and an increase from 2006 to 2012. Table 2.4 (in physical terms) is not fully in line with Table 2.5 (in monetary terms) when aggregated at EU level. This is due to the different prices among countries: some countries with high price record a decrease (see Annex 5 for details on timber provision accounts at national level) or do not increase enough to compensate the decrease in other countries.

**Table 4.4**. Supply and use tables for timber provision in physical terms in EU 28.

| | Type of economic unit | | | | Type of ecosystem unit | | |
|---|---|---|---|---|---|---|---|
| *million m³* | Forestry | Other primary sectors | Secondary and tertiary sectors | Households | FAWS | Woodland and other forest | Other ecosystem types |
| *Supply table* | | | | | | | |
| Years | | | | | | | |
| *2000* | | | | | 526 | | |
| *2006* | | | | | 516 | | |
| *2012* | | | | | 532 | | |
| *Use table* | | | | | | | |
| Years | | | | | | | |
| *2000* | 526 | | | | | | |
| *2006* | 516 | | | | | | |
| *2012* | 532 | | | | | | |

**Table 4.5**. Supply and use tables for timber provision in monetary terms in EU 28.

| | Type of economic unit | | | | Type of ecosystem unit | | |
|---|---|---|---|---|---|---|---|
| | Forestry | Other primary sectors | Secondary and tertiary sectors | Households | FAWS | Woodland and other forest | Other ecosystem types |
| *million EUR* | | | | | | | |
| *Supply table* | | | | | | | |
| Year | | | | | | | |
| *2000* | | | | | 14,560 | | |
| *2006* | | | | | 14,210 | | |
| *2012* | | | | | 14,544 | | |
| *Use table* | | | | | | | |
| Year | | | | | | | |
| *2000* | 14,560 | | | | | | |
| *2006* | 14,210 | | | | | | |
| *2012* | 14,544 | | | | | | |

When comparing absolute and relative values (i.e., per hectare) the country ranking changes as reported in Figure 4.4. A few countries, e.g., Germany, few countries have a high ranking both in absolute and per hectare values. Other countries, such as Sweden, Finland, Denmark, and Cyprus, have completely different records in absolute and per hectare values. This can be mostly explained by the net primary productivity that is strongly affected by bioclimatic conditions. In northern European countries it takes a larger FAWS area to generate high actual flow, compared to central European countries. Other variations in the actual flow might depend on different typologies of species (coniferous, broadleaves, mixed). Access to national forest inventories would be needed in order to undertake this kind of detailed analysis.

There are also variations when comparing relative values in physical and monetary terms (Figure 4.5). Different tree species and growing conditions affect the quality of wood and thus its market value and all the supply chain (e.g. used for firewood or luxury furniture), but also, countries in which human intervention is efficient to take benefits of the environmental and climate conditions are likely to invest more and rely less on the pure functioning of the ecosystems. Considering we have no information on the vegetation types of FAWS, we cannot explain such differences in detail.

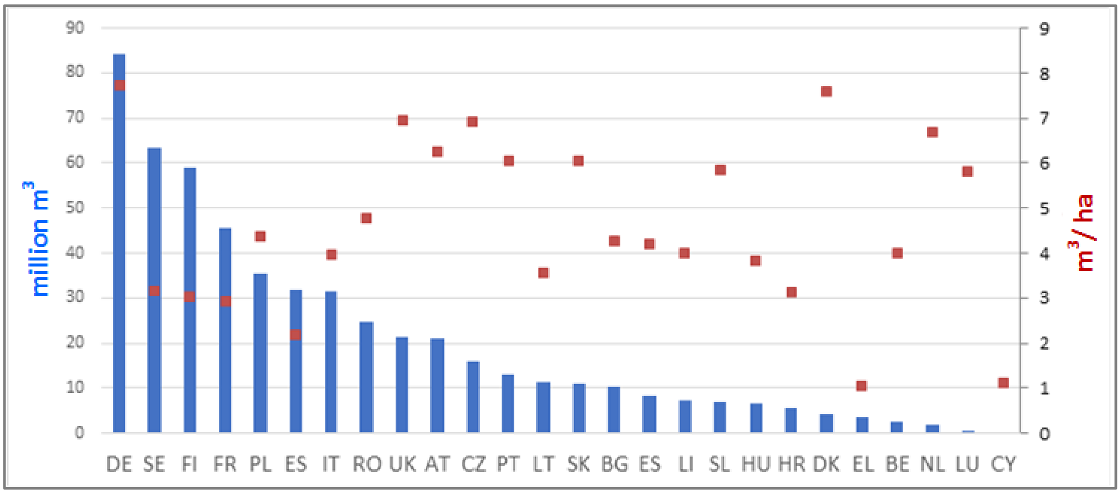



**Figure 4.4.** Timber provision actual flow in relative and absolute terms (year 2012).

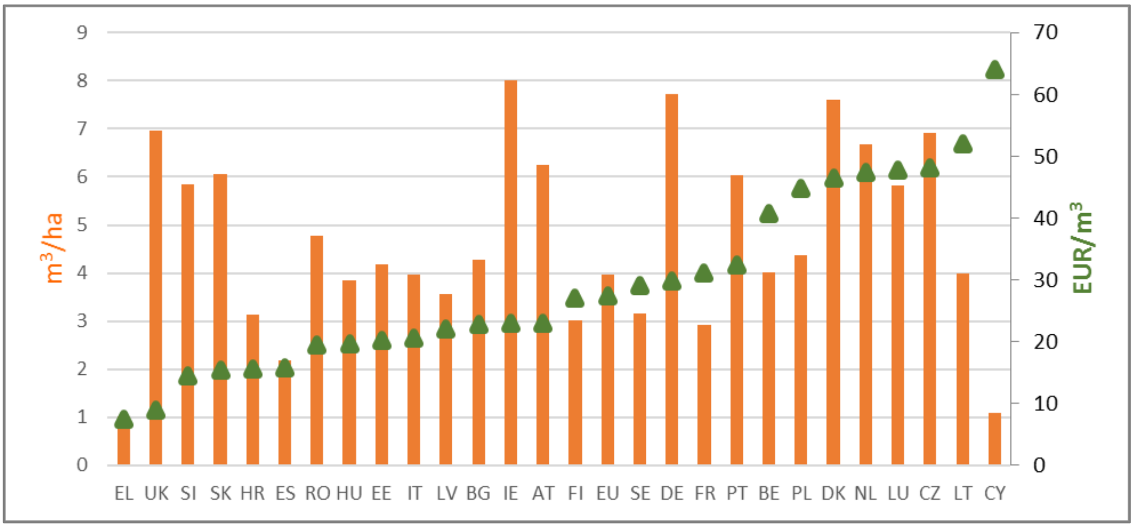



**Figure 4.5.** Timber provision actual flow in relative terms: physical and monetary estimates (year 2012).

## 4.4 Trend analysis

Since the ecosystem contribution coefficient was not calculated for different years because of the lack of data, the analysis of changes over time reflect the changes in the total production, and not the real actual flow of timber provision. However, the trend analysis is useful to show that at EU level there is a slight decrease for the first period (2000-2006) by 1.94% and an increase for the second period (2006-2012) by 3.1%.

Trend analyses per country is shown in Figure 4.6 and only regarding the changes between 2006 and 2012 because of the high degree of uncertainty or non-comparability resulting from break in time series concerning the data populating year 2000, especially for some major contributing countries, such as France that shows the most impacting changes (for country details, refer to Annex 6).

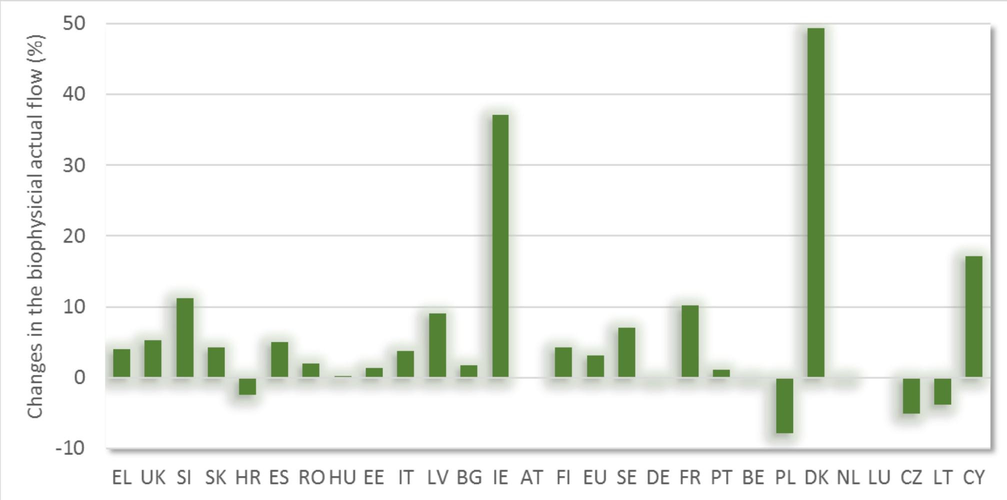



**Figure 4.6**. Changes in the actual flow of timber provision between 2006 and 2012.

## 4.5 Limitations of the accounting approach and further developments

The main limitations of the approach are related to **data availability**. For the calculation of the ecosystem contribution coefficient, there was no available data for the years 2000 and 2006. The $EcoCon_{timber}$ calculated is an average between 2010 and 2014 and remains static. The coefficient may show changes when time series data become available and the same procedure we describe in this report could be applied. Attention should be paid to the fact that changes could reflect variations in the costs of inputs rather than modification in ecosystem productivity.

**Ideally, the best way to assess supply and use table in physical and monetary terms would be to use the dataset based on EFA for all countries**. Because of data gaps we had to find alternative solutions that involved to use one source to compile supply and use table in physical terms (i.e. FAO –FE dataset) and a different source to compile supply and use table in monetary terms (i.e., a combination of EFA questionnaire and Forest Economic Accounts).

A possible **alternative for the valuation in monetary terms is to calculate resource rent** based on standard SNA measures of gross operating surplus (ref. SEEA CF from 5.99 to 5.129): by deducting specific subsidies, adding back specific taxes and deducting the user costs of produced assets, composed of consumption of fixed capital and the return to produced assets. The source of information in this case would be the Economic aggregates of forestry (ref. ESTAT dataset [for_eco_cp]). In [for_eco_cp] the Net Operating surplus can be found, calculated by deducting consumption of fixed capital from the gross operating surplus. The problem in using this dataset is that the measurements reported for United Kingdom and Cyprus are negative. Moreover, when comparing these records with values reported by other sources, such as volume of timber over bark in EFA (ref. ESTAT dataset [for_vol_efa]) and monetary supply and use of wood in the rough (ref. ESTAT dataset [for_emsuw]), the differences are remarkable and no consistency can be found.

There is indeed an issue in resource rent calculation: often low or zero value is given. This happens because many natural features are considered free and only the return to invested capital and remuneration to work remain. If a resource rent approach has to be applied, more arguments are needed to justify higher values: this can be the object of future research and applications.

Other studies are using resource rent procedures to account for timber provision. However, one study concerns agroforestry farms in Andalusia (Ovando et al., 2016) and another study concerns one province in the Netherlands (Remme et al., 2015). Their outcomes are not comparable to our approach because of the administrative size (in terms of results to be compared) and the extent of available information (in terms of methodology) because data are available at (almost) local level. However, we can confirm that the overall used approach is to look at the market price, and specifically at the SNA.

**Another limitation is related to the biophysical mapping**. The actual flow assessed refers to FAWS. Spatially explicit data of only these type of forests is not available at European level and the downscale was based on the forest extent based on CLC. We have explored different alternatives to delineate FAWS. Protected areas, slope, and accessibility are among the main restrictions (Alberdi et al., 2016). In 50% of the countries 'protected areas' are excluded from FAWS, therefore omission of protected areas for the mapping of the actual flow would be as wrong as including them. As regards to the restriction 'slope', Slovenia applies a threshold of 35% slope while Spain uses the exploitation threshold of 45–50% slope, which in the Atlantic area can reach 75–80% slope. Defining a common threshold for all EU countries is not to straightforward (Alberdi et al., 2016). Further developments of timber provision accounts may consider updating the mapping of the actual flow by using the upcoming map of FAWS, currently under development by the Bioeconomy Unit at JRC.

In terms of further developments, the calculation of the Net Present Value as monetary estimate for the Capacity Accounts might require the calculation of the potential flow of timber provision (see La Notte et al. (2019b) for further definition of the potential flow), considering not only the amount of NAI and felling but also the age of the forest.

## 4.6 Summary of timber provision accounts

**Box 2.** Timber provision accounts: main outcomes

Timber provision accounts can be entirely compiled through official statistics.

Few comments on the accounting outcomes:

— At the EU level the costs of human inputs to timber extraction are 27% of the value of timber Net Annual Increments, meaning that the ecosystem contribution is estimated as 73% of the value of timber extracted;

— At the EU level the value of timber provision, understood as the ecosystem contribution, is about 14.5 billion EUR in 2012;

— Countries with the highest actual flow in absolute terms (total actual flow) are Germany, Sweden and Finland, mainly because of the large extent of the FAWS in these countries;

— When it comes to relative terms (actual flow/hectare), Sweden and Finland do not rank high: this is mainly due to their bioclimatic conditions which limits primary productivity;

— For most of the EU countries, the flows from the forest ecosystems in physical terms increased between 2006 and 2012; only few countries (such as Poland, Czechia, and Lithuania) record a slight decrease (about 5%).

Any in-depth analysis would require information on species and management practices that at the moment are not available at European scale.

Timber provision accounts are the best example of how a simplified procedure for ES SUTs can be implemented. No modelling is required; geo-processing is only needed for mapping ES flows.

Limitations of the approach are mainly due to data availability. The procedure to compile SUTs in physical and monetary terms is relatively simple, having all the needed datasets, specifically the European Forest Accounts (EFA). In this application we had to apply a number of assumptions to fill data gaps, but when expected data might become available, the reliance on assumptions will be reduced.

# 5 Global climate regulation

Global climate regulation as an ecosystem service includes the sequestration of greenhouse gases from the atmosphere by ecosystems (modified from CICES V.5.1, Haines-Young and Potschin (2018)). A comprehensive assessment of the role of ecosystems in mitigating climate change should consider the different greenhouse gases such as carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) and their interactions[8]. In this experimental account of global climate regulation, we focus only on $CO_2$, using carbon (C) sequestration as proxy to measure the regulating effect that ecosystems may have. This proxy is the most frequently used in the literature (Haines-Young & Potschin, 2018). More concretely in this chapter, we assess terrestrial C sequestration, which is the process by which atmospheric $CO_2$ is taken up by plants through photosynthesis. Then, C will be stored in the biomass and soils influenced also by the management practices. It is also important to highlight that C sequestration by water bodies such as seas, rivers, and lakes is not considered in this account.

Ecosystem services accounts can be based on different approaches depending on data availability. Ideally, available official data and statistics providing information to account for the actual flow of the service should be used. When data are not available, development of spatially explicit models is needed. For the accounts of C sequestration as proxy of global climate regulation, the inventories on Land Use, Land Use Change and Forestry (LULUCF) already report data at country level on greenhouse gases (GHG) uptake and emissions by managed ecosystems or land cover types. LULUCF is a specific sector included in national inventories on GHG. The European Union, as a party to the United Nations Framework Convention on Climate Change (UNFCCC) reports annual inventories on GHG emissions and removals within its territorial boundaries, represented by the area covered by its Member States (MS) (European Environment Agency, 2018). Each country follows the 2006 IPCC guidelines defined by UNFCCC under the Kyoto Protocol in reporting their net GHG emissions in annual national inventories. C sequestration accounts based on the inventories are described in section 5.1. Complementarily, we also applied a simplified approach to estimate soil organic carbon (SOC) stocks over Europe (Section 5.2).

Although LULUCF data are available for the years 1990-2016, in the framework of the INCA project, C sequestration accounts are compiled for the reference years 2000, 2006, and 2012. These years match with the availability of CORINE Land Cover (CLC) maps used in ecosystem extent accounts and other ecosystem services in the INCA project.

[8] See for instance Tian et al. (2016) and Lugato et al. (2018) for further discussion.

## 5.1 Carbon sequestration accounts based on GHG inventories

### 5.1.1 LULUCF inventories

The main purpose of this study is to build the accounts of C sequestration as a proxy of global climate regulation. Therefore, a detailed discussion on the results is beyond the scope of this report that would require an exhaustive review of the complex methodology behind the compilation of the LULUCF inventories. For a detailed overview of LULUCF results we recommend to consult European Environment Agency (2018).

LULUCF inventories report the estimates of emissions and removals of GHG as yearly volumes of $CO_2$ resulting from direct human-induced land use, land use change and forestry activities. Each country reports for every land use category their role as either source or sink of $CO_2$. It means that reported values do not provide information on the emissions and sequestration separately for each ecosystem. LULUCF inventories have been used in this report to quantify the actual flow of C sequestration as proxy of global climate regulation using as source data GHG emissions by source sector (source: EEA) [env_air_gge] (EEA, 2018) (Table 5.1).

**Table 5.1**. Data used from the dataset of greenhouse gas emissions by source sector.

| Source sectors for air emissions (AIREMSECT) | Type of emission in [env_air_gge] (EEA, 2018) | Climate regulation accounts |
|---|---|---|
| Land use, land use change, and forestry (LULUCF) | negative emissions | Actual service flow ($CO_2$ uptake) |
| | positive emissions | Ecosystem emissions |
| Fuel combustion in energy industries | positive emissions | Emissions by economic activity |
| Fuel combustion in petroleum refining | | |
| Fuel combustion in manufacturing industries and construction | | |
| Fuel combustion in transport | | |
| Fuel combustion in cars | | |
| Fuel combustion in light duty trucks | | |
| Fuel combustion in motorcycles | | |
| Fuel combustion in commercial and institutional sector | | |
| Fuel combustion by households | | |
| Fuel combustion in agriculture, forestry and fishing | | |
| Other fuel combustion sectors n.e.c. | | |
| Industrial processes and product use | | |
| Agriculture | | |

The relevance of the LULUCF sector in the inventories is given by its contribution to mitigate climate change by reducing emissions, and maintaining and enhancing sinks and carbon stocks within ecosystems (Regulation (EU) 2018/841). The LULUCF inventories report $CO_2$ emissions and removals for the following land use and land cover categories: Forest Land, Cropland, Grassland, Wetland, Settlements, and Other land. Each land-use category is further divided into land remaining in the same category (i.e., Forest Land remaining Forest Land) or shifting to another category due to land cover conversion (i.e., Grassland converted to Forest Land).

For each land-use category, the main activities producing emissions or removals of $CO_2$ are (IPCC, 2006):

- Forest Land: afforestation, forest management, deforestation and wildfires;
- Cropland: conversion of land to cropland, deforestation, cropland management and drainage;
- Grassland: conversion of land to grassland, deforestation, grassland management and drainage;
- Wetland: conversion of land to wetland, peat extraction, drainage;
- Settlements: conversion of land to settlements, changes in biomass of land remaining settlements (green areas).

$CO_2$ uptake is considered as the actual flow of C sequestration as proxy of global climate regulation. The actual flow is required to fill in the supply and use accounting tables. $CO_2$ uptake corresponds to the land-cover emissions with negative sign (net sinks) reported in the LULUCF inventories ([env_air_gge]) (EEA, 2018) (Table 5.1). In this sense, we considered $CO_2$ uptake from the atmosphere to the ecosystem as the proxy for the assessment of the ecosystem service (green arrow, Figure 5.1). However, ecosystems also generate $CO_2$ emissions to the atmosphere that should be considered for a comprehensive assessment of the net role of ecosystems in $CO_2$ flows. Ecosystem emissions of $CO_2$ are also assessed (Table 5.1, Figure 5.1), in comparison with the actual flow of C sequestration. Similarly, emissions derived from economic activities are also considered for complementary analysis in the account of global climate regulation (Table 5.1, Figure 5.1).

National inventories sectors are classified following emission source sectors as established by the Intergovernmental Panel on Climate Change (IPCC). In particular, IPCC 2006 Guidelines for National Greenhouse Gas Inventories and the Supplement on Wetlands (IPCC, 2006; IPCC, 2014b) offers methodologies and guidelines with the purpose of helping Parties to the UNFCCC to prepare their national GHG inventories. However, in compiling national inventories each Member State uses an individual methodology to estimate GHG emissions and $CO_2$ uptake from the LULUCF sector.

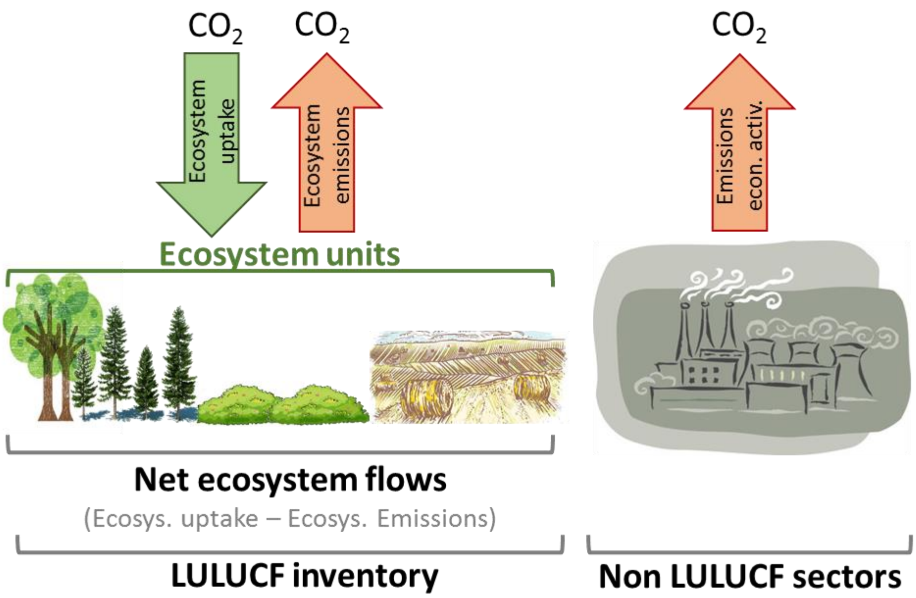



**Figure 5.1.** Scheme of the main $CO_2$ fluxes analysed for climate regulation accounts.
(Source: own elaboration)

The methodologies differ and reflect country-specific definitions in line with specific national circumstances. For instance, the quantitative thresholds used to define Forest Land change are based on parameters adopted by each Member State. While for Germany, France or Finland the minimum tree height for Forest Land is 5 meters, it is set at 3 meters for Spain or at 2 meters for Austria. In this report, we explore the feasibility of using LULUCF inventories to develop C sequestration accounts. However, standardisation of methodologies applied across countries may enhance the suitability of these data for a regular update of C sequestration accounts.

### 5.1.2 Biophysical mapping: woodland and forest $CO_2$ uptake

GHG inventory data have been used to map $CO_2$ uptake. The biophysical mapping has been done only for Forest land (in the sense of LULUCF), which corresponds to 'Woodland and forest' according to the MAES ecosystem classification (Maes et al., 2013). 'Woodland and forest' is the only ecosystem type for which almost all countries report $CO_2$ uptake, and there is indeed an actual flow of C sequestration. Other ecosystem types such as grasslands and wetlands show more variability and they are reported as sources or sinks of $CO_2$ depending on the reported year and country (see section 5.1.3 for further details). Therefore, their mapping would not be consistent across space and time.

Table 5.2 presents national inventories for 'Woodland and forest'. Inter-annual variation of the reported values are mainly due to changes in the rate of timber harvesting and natural disturbance events such as wind storms and wildfires in Mediterranean countries (European Environment Agency, 2018). The lack of consistency among the methodologies implemented by different countries to report LULUCF inventories hampers the robust comparison of $CO_2$ sequestration among countries. Ignoring differences in the methodologies applied by countries may lead to erroneous interpretations. However, to go more in depth in these details is out of the scope of this report.

In 2012, all MS (except Malta) reported $CO_2$ uptake (positive sign in Table 5.2) for 'Woodland and forest' ecosystem. Countries contributing significantly to $CO_2$ uptake at EU level are France, Germany, Finland, Sweden, Poland, and Spain, with over 55% of the total EU $CO_2$ uptake.

For some countries, we can see very important changes over time (i.e., Austria, Bulgaria, and Finland) derived from the methods implemented by MS to derive carbon stock changes. However, the time series provided by each country including the base year and all subsequent years for which the inventory has been reported is based on the same methodology. In this way, data can be used in a consistent manner, ensuring that changes in emission trends are not introduced as a result of changes in estimation methods or assumptions over the time series of estimates.

$CO_2$ uptake by 'Forest land' reported by LULUCF inventories represents the actual flow of C sequestration, which was spatially disaggregated to map this ecosystem service and perform further analyses on synergies and trade-offs among other ecosystem services mapped in KIP INCA. Mapping the actual flow of C sequestration was done at 1 km x 1 km grid cell size using Dry Matter Productivity (DMP) as proxy. DMP is derived from the Copernicus service information data (© European Space Agency). DMP is a measure of the overall growth rate or dry biomass increase of the vegetation expressed in kilograms of dry matter per hectare over a period of time (Copernicus Global Land Operations, 2018). The spatial disaggregation was performed on the Woodland and forest ecosystem type, which includes all forest in CLC and transitional woodland shrub. The methodology here developed for the spatial allocation of the $CO_2$ uptake at national level is grounded in the fact that DMP (growth in biomass) represents the rate of carbon input into terrestrial ecosystems (Cao & Woodward, 1998) (see methodological details in Annex 7).

Figure 5.2 shows the spatial allocation of the values of $CO_2$ uptake from 'Woodland and forest', as reported in the national inventories, distributed in relation to the rate of DMP. Although we have used a remote sensing product (DMP) as proxy for the downscaling, still the spatial differences in the mapped $CO_2$ uptake from 'Woodland and forest' is highly driven by the differences among the reported values by countries.

Further development of this experimental accounts should explore other mapping techniques reducing the border effect and generate a more realistic map. See limitations section (5.1.7) for further discussion on this issue.

**Table 5.2.** $CO_2$ uptake by 'Woodland and forest' per country.

| | $CO_2$ uptake (1,000 tonne C) by 'Woodland and forest'* | | | Percentage contribution at EU level |
|---|---|---|---|---|
| Country | 2000 | 2006 | 2012 | |
| Austria | 15,999 | 2,982 | 4,399 | 1% |
| Belgium | 2,580 | 3,351 | 3,102 | 1% |
| Bulgaria | 11,180 | 10,630 | 5,900 | 1% |
| Croatia | 7,919 | 8,129 | 6,371 | 1% |
| Cyprus | 0 | 196 | 287 | 0% |
| Czechia | 7,521 | 2,964 | 6,321 | 1% |
| Denmark | 605 | -419 | 4,103 | 1% |
| Estonia | 3,783 | 4,411 | 2,798 | 1% |
| Finland | 28,530 | 43,619 | 44,335 | 10% |
| France | 35,814 | 70,343 | 59,551 | 13% |
| Germany | 76,756 | 40,819 | 58,067 | 13% |
| Greece | 1,124 | 2,246 | 2,107 | 0% |
| Hungary | 464 | 2,817 | 4,232 | 1% |
| Ireland | 1,908 | 2,978 | 3,412 | 1% |
| Italy | 25,434 | 33,466 | 27,736 | 6% |
| Latvia | 14,133 | 10,458 | 6,604 | 1% |
| Lithuania | 9,300 | 4,448 | 9,874 | 2% |
| Luxembourg | 839 | 694 | 441 | 0% |
| Malta | 0 | 0 | 0 | 0% |
| Netherlands | 2,047 | 2,015 | 2,234 | 1% |
| Poland | 36,931 | 43,374 | 39,958 | 9% |
| Portugal | 9,275 | 10,894 | 10,946 | 2% |
| Romania | 27,841 | 26,433 | 25,444 | 6% |
| Slovakia | 8,026 | 5,689 | 5,955 | 1% |
| Slovenia | 4,575 | 5,964 | 5,422 | 1% |
| Spain | 39,476 | 39,876 | 39,460 | 9% |
| Sweden | 42,032 | 35,680 | 43,478 | 10% |
| United Kingdom | 22,007 | 23,127 | 21,893 | 5% |
| *Data derived from LULUCF inventories [env_air_gge] (EEA, 2018) | | | | |

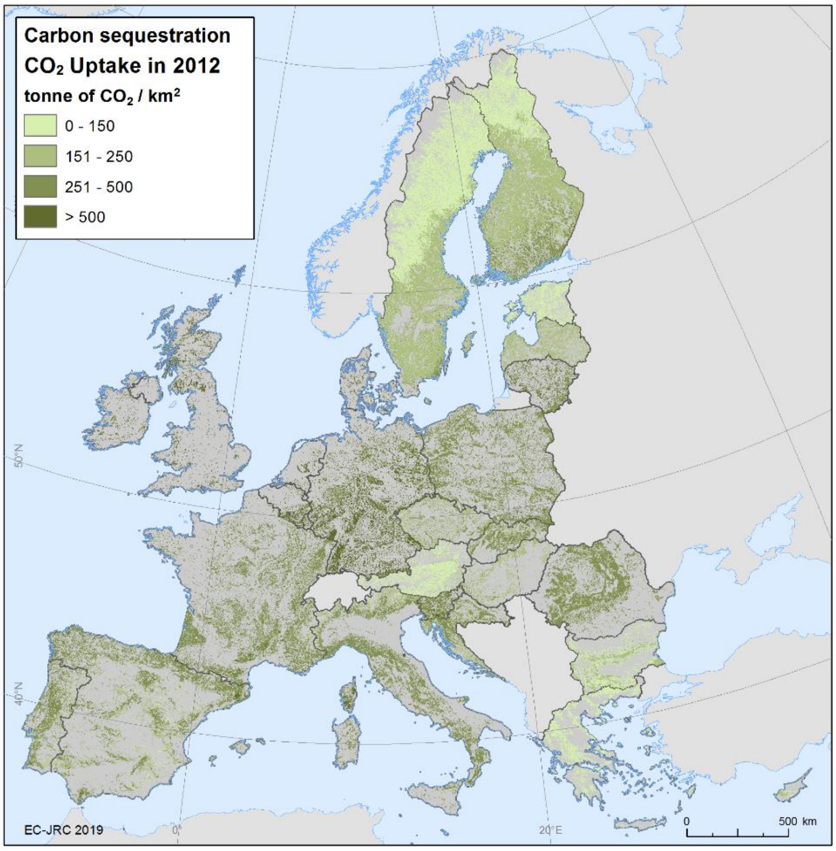



**Figure 5.2.** Actual flow of $CO_2$ uptake by 'Woodland and forest' in 2012.

### 5.1.3 Accounting in biophysical terms

The accounting tables in biophysical terms show the $CO_2$ uptake by all ecosystem types, as reported by countries (ecosystem uptake in Figure 5.1). $CO_2$ uptake considered for the C sequestration accounts corresponds to the emissions with negative sign reported in the LULUCF inventories as published by Eurostat ([env_air_gge]) (EEA, 2018) (Table 5.1). Table 5.3 presents supply and use tables (SUTs) at the EU level using the LULUCF land cover categories instead of MAES ecosystem types because of data constraints. The actual flow is the $CO_2$ uptake by all ecosystems, where 'Woodland and forest' is responsible for the 92% of total $CO_2$ uptake (Table 5.3, ES supply table). In this sense, mapping the $CO_2$ uptake only for 'Woodland and forest' would capture the majority of the actual flow. However, other ecosystem such as grasslands at EU level represent about 6% of the total $CO_2$ uptake.

In the use table, we inserted the "global society" as final user (Table 5.3, ES use table). One alternative could be to allocate the actual flow to the "Government" institutional sector; however, by considering that this item includes aggregates and balances for government production, income, and financial accounts, we preferred to keep it separated from the concept of "society" as whole. Accounting tables at country level are shown in Annex 8.

**Table 5.3**. Supply and use tables at the EU level in biophysical terms: $CO_2$ uptake (source data (EEA, 2018)).

CARBON SEQUESTRATION ACCOUNTS: accounting tables $CO_2$ uptake (source: LULUCF inventories published by Eurostat [env_air_gge])

***ES supply table***

| | Economic Units | | | | | | | | Ecosystem types | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Manufacturing & construction | Electricity, gas supply | Transport | Waste management | Other tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other land | Rivers and lakes | Marine |
| ***$CO_2$ uptake (1,000 tonne)*** | | | | | | | | | | | | | | | | |
| *2000* | | | | | | | | | 0 | 4,505 | 29,691 | 436,100 | 140 | 1,796 | | |
| *2006* | | | | | | | | | 0 | 6,128 | 27,938 | 437,601 | 151 | 2,159 | | |
| *2012* | | | | | | | | | 648 | 5,008 | 28,429 | 444,429 | 33 | 1,530 | | |

***ES use table***

| **$CO_2$ uptake (1,000 tonne)** | Primary sector | Manufacturing & construction | Electricity, gas supply | Transport | Waste management | Other tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other land | Rivers and lakes | Marine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *2000* | | | | | | | | 472,231 | | | | | | | | |
| *2006* | | | | | | | | 473,977 | | | | | | | | |
| *2012* | | | | | | | | 480,078 | | | | | | | | |

Emission accounts (source: [env_air_gge])

***Emission supply table***

| **$CO_2$ emissions (1,000 tonne)** | Primary sector | Manufacturing & construction | Electricity, gas supply | Transport | Waste management | Other tertiary sector | Households | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other land |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *2000* | 96,215 | 1,148,598 | 1,498,575 | 940,134 | 3,425 | 215,578 | 1,003,696 | 39,028 | 78,496 | 44,241 | 219 | 17,404 | 1,288 |
| *2006* | 91,305 | 1,127,486 | 1,598,972 | 1,002,706 | 3,813 | 237,873 | 1,040,187 | 44,982 | 73,158 | 40,856 | 471 | 20,578 | 1,718 |
| *2012* | 85,494 | 910,595 | 1,405,187 | 917,087 | 3,477 | 207,198 | 941,389 | 47,033 | 68,354 | 38,026 | 0 | 18,333 | 2,024 |

#### *5.1.3.1 Net ecosystem flows*

For many countries, different ecosystem types constitute sources of $CO_2$ and other GHG emissions to the atmosphere. This should be considered when interpreting the C sequestration accounts to properly assess the net ecosystem flows (Figure 5.1).

Table 5.4 shows at the EU level the total amount of $CO_2$ uptake by ecosystems, ecosystem emissions, and net ecosystem flows. Net ecosystem flows are calculated as the difference between $CO_2$ uptake and emissions[9], taking a positive sign when there is a net uptake and negative sign for net emissions (Figure 5.1). 'Woodland and forest' appears as the only ecosystem type with a net $CO_2$ uptake at the EU level for the period considered (years 2000, 2006, and 2012). This is due to larger $CO_2$ uptake than emissions. Ecosystem emissions show relatively low values (Table 5.4). Woodland and forest emissions equal to zero in 2012 mean that all the EU 28 countries reported 'Woodland and forest' as sinks of $CO_2$. While in Cyprus in 2000 and Denmark in 2006, reported 'Woodland and forest' as source of $CO_2$ (-219 and -471 thousand tonne of $CO_2$ respectively).

'Other land' also shows a net uptake of $CO_2$ for 2000 and 2006 (Table 5.4). However, net emissions (negative sign of net ecosystem flows) are reported at the EU level for 'Urban', 'Cropland', 'Grasslands' and 'Wetlands'. The role of 'Wetlands' as net source of $CO_2$ in the EU calls for special attention, given the potential role that this ecosystem may play as carbon sinks and stocks of $CO_2$ (IPCC, 2014b; Nahlik & Fennessy, 2016). Despite the small net increase in wetland area (0.1%, Ecosystem Extent Accounts for Europe currently undertaken by the EEA) the data suggest net emissions of C from wetlands. This in turn seems to suggest that management is leading to (or failing to prevent) some degradation of the state of wetlands. Better management could stop this and make wetlands a positive source of climate regulation benefits. A detailed review of the LULUCF reports for each country may provide relevant information about the key drivers of the net emissions derived from wetlands. This outcome should be contrasted with complementary approaches and data to derive more robust conclusions.

Changes in management practices and land use would contribute to reduce net ecosystem emissions also for cropland. For instance, conversion of arable land to permanent crops would increase the C sequestration in the biomass, or refraining from tillage practices in arable land would favour C sequestration by soils (West & Post, 2002).

Net ecosystem flows have also been analysed at country level to assess whether ecosystems within a country act as net service providers or as sources of $CO_2$ (Table 5.5). EU ecosystems sequestered 306 million tonnes of $CO_2$ in 2012, which in relation to the extent of the ecosystems reported[10] corresponds to 72 tonnes/km$^2$, three tonnes per square kilometre more than in 2006. Table 5.5 also shows that ecosystems in three countries (Netherlands, Ireland, and Malta) act as net sources of $CO_2$; according to the values reported. In these countries, $CO_2$ uptake by mainly 'Woodland and forest' (Annex

[9] The mirror image of what is presented in the LULUCF inventories ([env_air_gge])
[10] Based on the extent of the accounting layers CLC.

8) was not enough to compensate emissions from other ecosystem types. On the contrary, Slovenia and Slovakia represent the countries with the highest net $CO_2$ uptake per square kilometre of land ecosystems.

**Table 5.4**. $CO_2$ uptake, emissions, and net flows at the EU-level per ecosystem type.

| Ecosystem type | Ecosystem uptake (1,000 tonne) | | | Ecosystem emissions (1,000 tonne) | | | Net ecosystem flows[1] (1,000 tonne) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2006 | 2012 | 2000 | 2006 | 2012 | 2000 | 2006 | 2012 |
| Urban | 0 | 0 | 648 | -39,028 | -44,982 | -47,033 | -39,028 | -44,982 | -46,385 |
| Cropland | 4,505 | 6,128 | 5,008 | -78,496 | -73,158 | -68,354 | -73,992 | -67,030 | -63,346 |
| Grassland | 29,691 | 27,938 | 28,429 | -44,241 | -40,856 | -38,026 | -14,550 | -12,918 | -9,597 |
| Woodland and forest | 436,100 | 437,601 | 444,429 | -219 | -471 | 0 | 435,881 | 437,130 | 444,429 |
| Wetland | 140 | 151 | 33 | -17,404 | -20,578 | -18,333 | -17,263 | -20,428 | -18,299 |
| Other land | 1,796 | 2,159 | 1,530 | -1,288 | -1,718 | -2,024 | 507 | 441 | -494 |
| Rivers and lakes | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Marine | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| TOTAL | 472,231 | 473,977 | 480,078 | -180,678 | -181,763 | -173,770 | 291,554 | 292,213 | 306,308 |

Source data: LULUCF inventories [env_air_gge] (EEA, 2018)

[1] Positive values indicate net uptake and negative values refer to net emissions

### 5.1.4 Mitigation of $CO_2$ emissions by ecosystems

The relevance of LULUCF sector in the inventories is given by its contribution to mitigate climate change by maintaining and enhancing sinks and carbon stocks within ecosystems but also in reducing emissions (Regulation (EU) 2018/841[11]).

In relation to the reduction of $CO_2$ emissions, we quantified for each country the ecosystem contribution to mitigate $CO_2$ emissions derived from the economic activity as the percentage between net $CO_2$ flows (calculated as the difference between the ecosystem uptake and ecosystem emission) and $CO_2$ emissions released by the economic activity (Figure 5.1) [(net $CO_2$ flow/ $CO_2$ emissions)*100]. From the same dataset reporting LULUCF inventories (ref. GHG emissions by source sector [env_air_gge] (EEA, 2018)), emissions classified by production processes are also available (i.e., combustion in energy, transformation industry, manufacturing industry but also extraction and distribution of fossil fuels, transport, waste treatment and disposal) (Table 5.1).

[11] https://eur-lex.europa.eu/eli/reg/2018/841/oj

**Table 5.5**. $CO_2$ uptake, emission, and net flows at the EU-level per country for 2012.

| Country | Thousand tonne of $CO_2$ for 2012 | | | Relative ecosystem flow* (tonne/km$^2$) |
|---|---|---|---|---|
| | Ecosystem $CO_2$ uptake | Ecosystem $CO_2$ emission | Net ecosystem flow | |
| Netherlands | 2,234 | -8,245 | -6,011 | -177 |
| Ireland | 3,412 | -9,012 | -5,600 | -82 |
| Malta | 1 | -4 | -2 | -8 |
| Denmark | 4,103 | -3,946 | 157 | 4 |
| Greece | 3,448 | -263 | 3,185 | 25 |
| Estonia | 2,798 | -1,498 | 1,299 | 30 |
| Germany | 58,067 | -44,686 | 13,381 | 38 |
| Austria | 4,643 | -1,069 | 3,574 | 43 |
| Latvia | 7,252 | -4,454 | 2,798 | 44 |
| Bulgaria | 7,046 | -1,929 | 5,117 | 47 |
| Hungary | 4,985 | -426 | 4,560 | 50 |
| United Kingdom | 30,915 | -18,553 | 12,362 | 51 |
| Belgium | 3,473 | -1,732 | 1,741 | 57 |
| Cyprus | 593 | -29 | 564 | 62 |
| Italy | 29,889 | -9,746 | 20,143 | 68 |
| **EU** | **480,078** | **-173,770** | **306,308** | **72** |
| Spain | 40,198 | -3,229 | 36,968 | 74 |
| France | 70,643 | -28,589 | 42,054 | 77 |
| Czechia | 6,707 | -298 | 6,409 | 82 |
| Sweden | 43,695 | -4,828 | 38,867 | 95 |
| Portugal | 12,470 | -3,715 | 8,756 | 97 |
| Romania | 27,592 | -4,079 | 23,514 | 100 |
| Croatia | 6,468 | -898 | 5,570 | 100 |
| Finland | 44,335 | -11,103 | 33,232 | 109 |
| Poland | 40,364 | -6,653 | 33,710 | 110 |
| Lithuania | 11,302 | -4,130 | 7,172 | 113 |
| Luxembourg | 496 | -120 | 376 | 145 |
| Slovakia | 7,340 | -195 | 7,145 | 147 |
| Slovenia | 5,608 | -341 | 5,267 | 261 |

Source data: LULUCF inventories (EEA, 2018)

*Referred to the extent of the ecosystems types reported in LULUCF taken from CLC accounting layers 2012

At the EU level, mitigation of $CO_2$ emissions by ecosystems in 2012 was about 7%, about 1% higher than in 2006 (Figure 5.3). This percentage lies within the range of mitigation (between 7-12%) calculated by Janssens et al. (2003) with a modelling exercise. The increase of the level of mitigation between 2006 and 2012 is due to a reduction of $CO_2$ emissions (about 12%) and an increase in $CO_2$ net uptake by the ecosystems (about 5%). Sweden and Finland are taking the lead of mitigating $CO_2$ emissions by ecosystems, with more than 50% of total $CO_2$ emissions mitigated by land ecosystems in 2012. Negative values for Ireland, the Netherlands, and Denmark are due to the role of land ecosystems as sources of $CO_2$ (Figure 5.3). In these countries, ecosystems do not contribute to mitigate $CO_2$ emissions, but they also contribute to increase them.

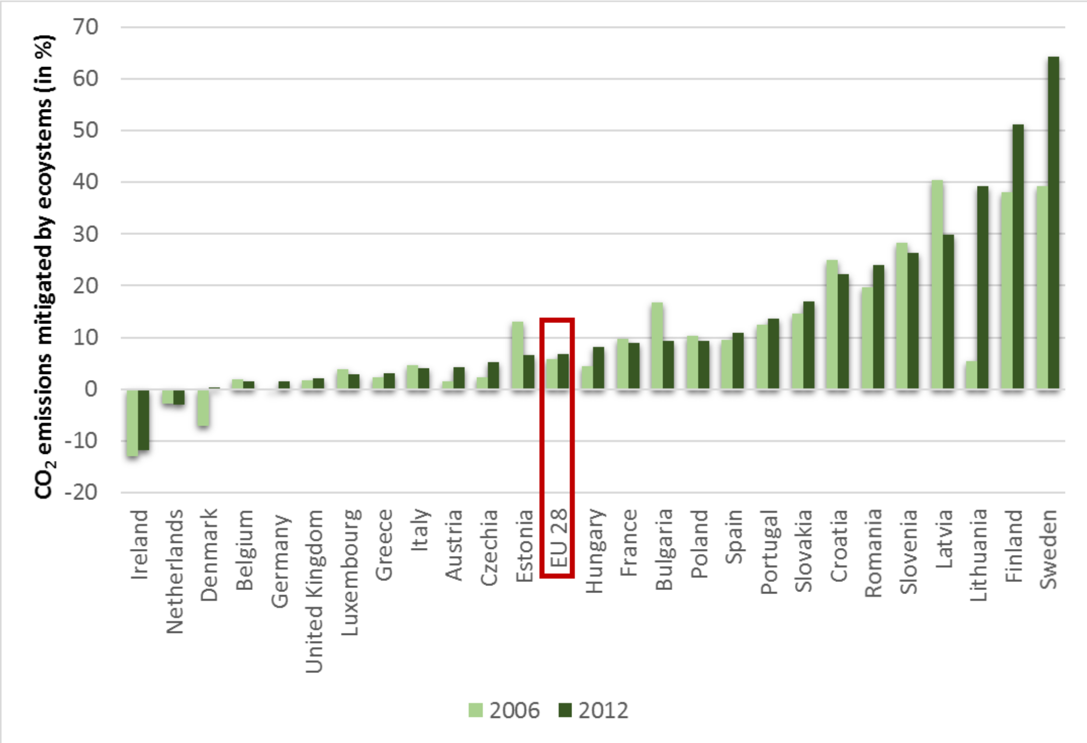



**Figure 5.3.** Role of net $CO_2$ flows in mitigating $CO_2$ emissions.

The percentage of mitigation of $CO_2$ emissions by ecosystems at the EU level looks relatively low compared to the values reported at global level reaching about 50% (Ballantyne et al., 2012); however it is important to bear in mind that in this experimental account the role of oceans, rivers and lakes is not accounted for.

#### *5.1.4.1 Combined presentation: ecosystem service and emission accounts*

Mitigation of $CO_2$ by ecosystems could also be assessed following the accounting structure by the integration of the supply and use tables for C sequestration with the accounting tables of $CO_2$ emissions (Table 5.3). Table 5.3 combines $CO_2$ emission accounts, that are typical of the SEEA Central Framework, with $CO_2$ uptake (used as proxy for global climate regulation ES) and emissions by ecosystem. Although we use the same term (i.e., emissions), there is a clear difference between the two measurements, which refer to different processes: the former is human pressure through production activities (including heating and transport by households), the latter is the outcome of an ecological process (C sequestration) in managed lands, where ecosystem management measures play a key role. In the ESTAT database, it is possible to find specific air emission accounts, however we choose to use the same dataset extracted for $CO_2$ uptake (i.e., [env_air_gge]) to guarantee full consistency and coherence among the different components.

Emissions by production processes are reported based on the Selected Nomenclature for sources of Air Pollution (SNAP), which includes activities such as combustion in energy, transformation industry, manufacturing industry but also extraction and distribution of fossil fuels, transport, waste treatment, and disposal and so on. The reference classification used in national accounts is NACE (*Nomenclature statistique des activités économiques dans la Communauté européenne*) that is structured by economic sectors. In order to move from SNAP to NACE, Eurostat has made available some tools (Eurostat, 2015) and "Correspondence between SNAP97 - CRF/NFR - NACE rev.2), 2012 edition"[12]). Following these guidelines, the $CO_2$ emissions reported in the GHG inventories have been allocated to the economic sectors and made it possible to build a presentation where the $CO_2$ emission account is combined with the ecosystem service account as reported in Table 5.3. The combined presentation allows to put together two pieces of information concerning the same policy issue: on one side it is possible to quantify the pressure generated by economic sectors and households, on the other side it is possible to quantify the service flow offered by ecosystem types, all expressed with the same unit (1,000 tonne). The mitigation effect offered by carbon fluxes can be compared with emission load per countries to find out whether and where the former increases and the latter decreases; once time series are available it will be possible to track virtuous paths over time.

#### *5.1.4.2 Complementary use table: ecosystem service allocation to the targets of policy action*

The reason why we consider carbon sequestration as ecosystem service relevant for society (and not just as a biogeochemical process) lies in the acceptance that GHG from human activities are the most significant driver of observed climate change, and climate change poses severe risks for socio-economic and environmental systems (IPCC, 2014a). Economic sectors face the challenge to reduce the exposure and vulnerability to actual and expected climate change: they would thus need to address questions around how to measure climate change vulnerability, adaptive capacity and adaptation cost and needs, through performance and benchmarking metrics (Linnenluecke et al., 2015).

As already stated in section 2, for ES characterized as sink services the amount of actual flow generated depends on the amount of emissions, which are considered as the ES demand. The case of climate regulation is peculiar because GHGs are a global issue in which the specific sources become irrelevant. However, mitigation policies are applied at national level by setting national/local targets (e.g., from the National Strategies for adaptation to Climate Change to the Covenant of Mayors) by applying a range of policy tools that may range from carbon trading and taxes on the emissions side, to PES on the sequestration side. From this perspective, the demand side (as indirect beneficiary) becomes a critical actor: in fact, if we consider that ecosystems did not assimilate

[12] The manual and xls tool are downloadable at https://ec.europa.eu/eurostat/web/environment/methodology

emissions, the emitting sectors would incur in unmet target, increased tax burden, and penalties. Industries are thus benefitting from the role that ecosystems are playing in storing emissions. The complementary allocation of actual flow to emitting sectors (i.e., enabling actors) allows this kind of policy analysis. Accounting for $CO_2$ emissions, allows us to provide a complementary use table (Table 5.6), where we allocate the actual flow (i.e., positive $CO_2$ uptake by ecosystems) to the $CO_2$ emitters that constitute the "driver" of this ecosystem service, and thus the target of policy action. The allocation of the actual flow has been undertaken by considering the ratio of each sector in terms of emissions compared to total emissions, as reported at the bottom of Table 5.6. The advantage of using the same dataset guarantees to allocate the actual flow to the emitting sectors in a consistent way.

**Table 5.6**. Complementary use table: $CO_2$ emissions and actual flow.

| ***Complementary ES use table*** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Economic Units** | | | | | | |
| **$CO_2$ uptake (1,000 tonne)** | Primary sector | Manufacturing & construction | Electricity, gas supply | Transport | Waste management | Other tertiary sector | Households |
| *2000* | 7,624 | 109,499 | 157,738 | 91,130 | 305 | 18,568 | 87,529 |
| *2006* | 7,369 | 110,328 | 138,595 | 106,247 | 258 | 20,300 | 90,879 |
| *2012* | 8,080 | 99,321 | 145,875 | 111,214 | 270 | 20,091 | 95,226 |
| ***Emission supply table*** | | | | | | | |
| **$CO_2$ emissions (1,000 tonne)** | | | | | | | |
| *2000* | 96,215 | 1,148,598 | 1,498,575 | 940,134 | 3,425 | 215,578 | 1,003,696 |
| *2006* | 91,305 | 1,127,486 | 1,598,972 | 1,002,706 | 3,813 | 237,873 | 1,040,187 |
| *2012* | 85,494 | 910,595 | 1,405,187 | 917,087 | 3,477 | 207,198 | 941,389 |
| ***Allocation of ES actual flow to $CO_2$ emitters*** | | | | | | | |
| *2000* | 0.02 | 0.23 | 0.33 | 0.19 | 0.001 | 0.04 | 0.19 |
| *2006* | 0.02 | 0.22 | 0.33 | 0.21 | 0.001 | 0.04 | 0.19 |
| *2012* | 0.02 | 0.20 | 0.32 | 0.22 | 0.001 | 0.04 | 0.20 |

The same perspective (i.e., indirect beneficiary) can become important at the corporate/sectoral levels due to policy. Compensation measures are one step of the mitigation hierarchy (BBOP, 2012): offsets of adverse impacts take place when those impacts cannot be avoided, minimized, rehabilitated or restored; compensation measures can take the form of positive management interventions, arrested degradation, protection of selected areas. The relationship between the level of $CO_2$ emission and the actual flow mitigation could be considered as a pre-screening information to raise concern about the need to start an assessment of sectoral vulnerability. The economic sectors that emit more $CO_2$ compared to the others are electricity and gas supply, followed by manufacturing and transport. For policy purposes, these are the sectors where the service flow would contribute the most; this allocation is undertaken ex-post and a cause-effect relationship cannot be established. However, in terms of compensation measures for the large $CO_2$ emitters this piece of information could be useful. For example: sectors responsible for the highest $CO_2$ emissions may decide to invest in afforestation, wetland restoration and green infrastructure projects and "demonstrate" the good effect in terms of the actual flow of carbon sequestration of their investments.

### 5.1.5 Accounting tables in monetary terms: valuation

There are several valuation techniques available to translate the outcomes of the biophysical assessment in monetary terms, e.g., the social cost of carbon (SCC) and the abatement cost approach. SCC is the outcome of four modelling modules: socio-economic, climate, damage and discounting, and it is based on the probability distributions of emission scenarios (Nordhaus, 2013). Although very interesting, it represents a black box that does not allow a connection with the ES actual flow and the policy actors in the SUTs. Nevertheless, it can still be a useful comparison (Ricke et al., 2018). The approach based on abatement cost curves represents the cost of reducing additional units of pollution. Although used by the UK government, some consultancies[13] and research organisations (e.g., the Wuppertal Institute[14] developed the cost potential curves) they present some drawbacks (especially in terms of uncertainty and cross-sectoral actions) and are by nature dependent on country and local contexts. However, this approach could be developed by considering abatement costs that are sector specific, or by estimating target-consistent abatement costs at the economy-wide level thereby deriving a price that is consistent with reaching the targets in the most cost-efficient way. This second approach could be an interesting option to be explored for future experimental applications.

For this application, we base the monetary valuation on transactions concerning carbon that are to some extent already flowing in the SNA: carbon related taxes and Emission Trading Schemes (ETS). We base our assessment on the study on C rates of the Organisation for Economic Co-operation and Development (OECD, 2016).

Effective carbon rates are the total price that applies to $CO_2$ emissions from energy use because of market-based policy instruments. They have three components: carbon taxes (tax rate on energy based on its carbon content); specific taxes on energy use (primarily excise taxes set per physical unit or unit of energy; and the price of tradable emission permits (the opportunity cost of emitting an extra unit of $CO_2$).

[13]Ref. https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/a-cost-curve-for-greenhouse-gas-reduction
[14] Ref. https://wupperinst.org/en/

The OECD approach considers carbon prices as effective when they force emitters to take the damage of their emissions into account. Emission levels should thus be linked with the marginal cost of climate change from each emitted tonne of $CO_2$. To estimate this cost, the OECD report uses EUR 30 per tonne of $CO_2$, although many experts agree that the cost of carbon is too low even at EUR 40 per ton (Boyce, 2018; Daniel et al., 2018). The EUR 30 benchmark is based on the review of recent evidence (Alberici et al., 2014) on subsidies and costs of EU energy and constitutes the lower-end estimate of climate cost that records as central estimate EUR 50 per tonne of $CO_2$. The use of EUR 30 is a reference point which allows comparison of pricing policies across and within countries and does not represent a normative statement about the minimum level of pricing that should be implemented. The discussion concerning strength and weakness of this estimate are in the OECD report. For the sake of comparison, Nordhaus (2017) estimates that the (baseline) social cost of carbon is $31.2 per ton of $CO_2$ for 2015. Table 5.7 reports the $CO_2$ uptake supply and use tables in monetary terms. The use table allocates the actual flow to "global society".

We want to highlight that the choice of using OECD estimates only concerns the practical advantages of using real rates generated by market and regulation tools, and of having a clear connection with emitting sectors. On the other hand, we are aware that this kind of estimates do not allow any discussion or debate on equity and fairness. From this point of view, this valuation issue is open and further developments will be needed.

### 5.1.6 Trends in LULUCF inventories

Accounting tables in monetary terms at the EU level show a rise in the value of $CO_2$ uptake of about 1.6% between 2000 and 2012, which corresponds to an increase of 235 million euro (Table 5.7). This increase is mainly due to a higher $CO_2$ uptake by 'Woodland and forest'. However, $CO_2$ uptake also increased for urban and cropland (Table 5.7).

One of the disadvantages of using reported official data instead of biophysical models is the lack of knowledge of the drivers of changes in the actual flow. Still, LULUCF inventories provide some insights about the role of different drivers of the $CO_2$ flows (uptake and emissions) for each ecosystem within each year. LULUCF inventories provide separately the $CO_2$ flows for each reported year due to land converting to the ecosystem type of interest, unconverted land, drainage, or rewetting. Assessment of drivers for each year are based on the comparison of the initial and final situation of C pools within the specific year.

**Table 5.7**. Supply and use tables at the EU-level in monetary terms: $CO_2$ uptake.

***supply table***

| *Million EUR* | Primary sector | Manufacturing & construction | Electricity, gas supply | Transport | Waste management | Other tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland & forest | Wetland | Other land | Rivers and lakes | Marine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Economic Units** | | | | | | | | **Ecosystem types** | | | | | | | |
| *2000* | | | | | | | | | 0 | 135 | 891 | 13,083 | 4 | 54 | | |
| *2006* | | | | | | | | | 0 | 183 | 838 | 13,128 | 5 | 65 | | |
| *2012* | | | | | | | | | 19 | 150 | 853 | 13,333 | 1 | 46 | | |

***use table***

| *Million EUR* | Primary sector | Manufacturing & construction | Electricity, gas supply | Transport | Waste management | Other tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland & forest | Wetland | Other land | Rivers and lakes | Marine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *2000* | | | | | | | | 14,167 | | | | | | | | |
| *2006* | | | | | | | | 14,218 | | | | | | | | |
| *2012* | | | | | | | | 14,402 | | | | | | | | |

Figure 5.4 shows the relative importance of these drivers for each ecosystem type. Most of the $CO_2$ taken up by forest remaining forest is due to management practices favouring the biomass growth, while the role of land conversion to forest appears not as important for this ecosystem type. On the contrary, conversion of land into cropland, settlements and other land was the main driver favouring $CO_2$ emissions for these ecosystem types. In the case of grassland, land cover conversion (i.e., land converted to grassland) is promoting the $CO_2$ uptake. This is compensated by $CO_2$ emissions derived from unconverted grassland and drainage. In the case of wetlands, an ecosystem that might potentially act as sink of $CO_2$ (Nahlik & Fennessy, 2016), land cover changes, drainage and unconverted land all trigger the release of $CO_2$ to the atmosphere. These results suggest that improvement in the management practices of wetlands could enhance the capacity of these ecosystems to act as sink of $CO_2$.

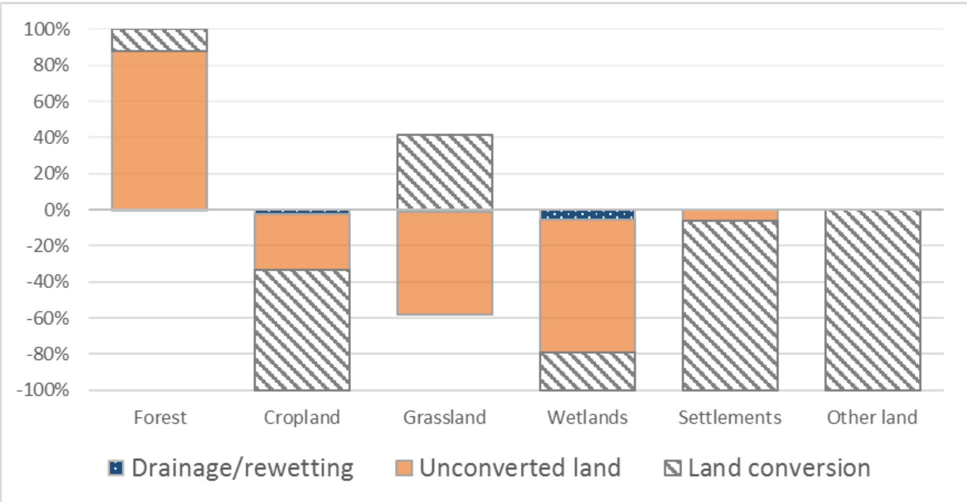



**Figure 5.4.** Drivers of $CO_2$ flows within the ecosystem in 2012.

## 5.1.7 Limitations of accounts based on LULUCF inventories

The main limitations of the approach presented here relate to the use of the LULUCF inventory data. The use of LULUCF inventories for C sequestration accounts does not cover all ecosystem types, excluding the role of river and lakes and marine ecosystems. Given the importance of these ecosystem types within the global carbon cycle (Sabine, 2004; Tranvik et al., 2009), it would be important to assess through complementary data/methods the role of these ecosystem types sequestering C.

Furthermore, LULUCF inventories report only data related to managed land, where human interventions and practices have been applied to for social, economic or ecological purposes (IPCC, 2006). This is so, because their main target are anthropogenic emissions and removals. Therefore, data on non-managed land are not available.

As highlighted in previous sections, there is also a lack of consistency in the methodology applied across countries. The methodology differs and reflects country specific definitions in line with specific national circumstances. Standardisation of methodologies applied across countries may enhance the suitability of these data for a regular update of C sequestration accounts. However, this type of accounting exercise can be useful to identify possible drawbacks of the data used and suggest measures to improve them for future accounting updates. Moreover, this accounting exercise would also benefit from the comparison with alternative methodologies.

Additionally, interpretation of changes in $CO_2$ uptake, as reported in LULUCF inventories, in relation to land cover and land use changes is complex. Official LULUCF inventories only report $CO_2$ uptake or emission per land use. More detailed information on the drivers could be gathered from the official country reports, however this type of information is not provided in a systematic way as complementary statistics to the LULUCF inventory data.

The method applied for the biophysical mapping of $CO_2$ uptake by 'Woodland and forest' also presents some limitations. Although we have used a remote sensing product (DMP) as proxy for the downscaling, still the spatial differences in the mapped $CO_2$ uptake from 'Woodland and forest' is highly driven by the differences among the reported values by countries. Further development of this experimental account should explore other mapping techniques reducing the border effect and produce a more realistic map. In addition, the downscaling is based on the assumption that a growth in the yearly biomass production for 'Woodland and forest' is related to the $CO_2$ uptake by the ecosystem, in proportion to the reported inventories. While DMP is used as proxy for downscaling $CO_2$ uptake, it only refers to the above ground biomass growth of the vegetation, whereas what is reported in inventories include the $CO_2$ sequestration from different carbon pools: belowground biomass, dead organic matter, and soils.

DMP is equivalent to Net Primary Productivity (NPP), which is a useful remote sensing product. In order to assess the actual role of ecosystems sequestering C it would be useful to have available derived products such as Net Ecosystem Production (NEP) or Net Biome Production (NBP). However, accurate estimations of NEP and especially NBP with ecosystem models are currently hampered by high uncertainties in the model results (Copernicus Global Land Operations, 2018; Luyssaert et al., 2010).

Further development of this account may consider the option of using as reference values for a given year, the average of three consecutive year. For instance, the values for the accounts of 2000 could be based on the average of 1999, 2000, and 2001 to reduce uncertainty that may arise from a specific year. However, this option would need to be validated before a more consolidated approach for ecosystem services accounts become available.

## 5.2 Thematic account of soil organic carbon

Soil is a major C reserve in terrestrial ecosystems and the decline in the content of C in soils is a considerable threat, as identified in the European Union Thematic Strategy for Soil Protection (COM(2006)231 final). Soil organic carbon (SOC) stock is what remains in soils after partial decomposition of organic material. The estimation and quantification of SOC stocks is relevant, given its role in mitigating GHG emissions. Globally, the soil pool stores an estimated 1,500 Pg C in the first meter of soil, which is more carbon than is contained in the atmosphere (roughly 800 Pg C) and terrestrial vegetation (500 Pg C) combined (FAO, 2017). Given the importance of the soil carbon pool, we also assessed SOC stocks in soils, complementary to LULUCF inventories, which already report data on $CO_2$ uptake by the soil pool.

The method we propose in this report is based on the approach presented in the toolbox of INtegrated Valuation of Ecosystem Services and Trade-offs (InVEST) (Natural Capital Project, 2018; Sharp et al., 2018). This approach uses land use and land cover maps to spatially allocate the amount of carbon stored in carbon pools, such as soil. A brief description of the method and results are described in the following sections.

Carbon storage in soil can be structured as an asset account, where we estimate an opening stock reporting the total carbon stored in soil. If changes driven by human or natural causes occur, then the closing stock will report different estimates and the difference between the opening and closing stock would represent the flow. However, under the current approach, we assume that SOC is under equilibrium once land cover changes takes place. Conversely, changes in SOC stock resulting from land management practices such as intensification of agricultural activities, deforestation, or land cover conversion occur very slowly (Jones et al., 2012) and are difficult to detect before 7–10 years (Smith, 2004). For example, a study from Bellamy et al. (2005) detected variations in SOC for agricultural land across England and Wales between 1978 and 2003.

Therefore, under the current approach estimation of the yearly actual flow by the difference between opening and closing stocks calculated would not be realistic. In fact, it assumes that a change in land use instantly generates a change in the carbon stored in soil. As previously explained, this is not the case. To be able to calculate the actual flow field data (e.g., comparison of LUCAS data for two different periods) or a more sophisticated model integrating an empirical annual rate of changes in SOC stocks should be applied.

### 5.2.1 Biophysical mapping of soil organic carbon

Following the rationale of InVEST, the mapping of SOC stocks is based on tables for which the content of SOC is given for the different ecosystem types. Land Use and Coverage Area frame Survey (LUCAS) data of year 2009 provides the organic C content in the topsoil (0-20 cm) at the EU level. LUCAS data were used to build a table showing the C content in soils for different land cover classes in Europe (in grams of C per kilogram of soil). In this report, we propose an enhancement of the table proposed by the InVEST approach, given the large extent of the study area, the heterogeneity in ecosystems and climatic zones (see Annex 9 for further technical details). For this enhancement, we calculated the average C content for each land cover class (based on level 2 of CLC) for different biogeographic regions: Alpine, Atlantic, Boreal, Continental, Mediterranean and Pannonian. The table used for the allocation based on the accounting layer of CLC of 2012 is shown in Annex 9-Table A.8.2.

Figure 5.5 represents SOC stocks for the year 2012. The largest amounts of SOC are stored in the Nordic regions, where low temperatures lead to low biological activities, thus decreasing the rate of decomposition of soil organic matter. Lowest values of SOC are found in large areas of arable land with little natural vegetation and/or intensive agriculture like the Po basin in Italy and the plateau in Spain.

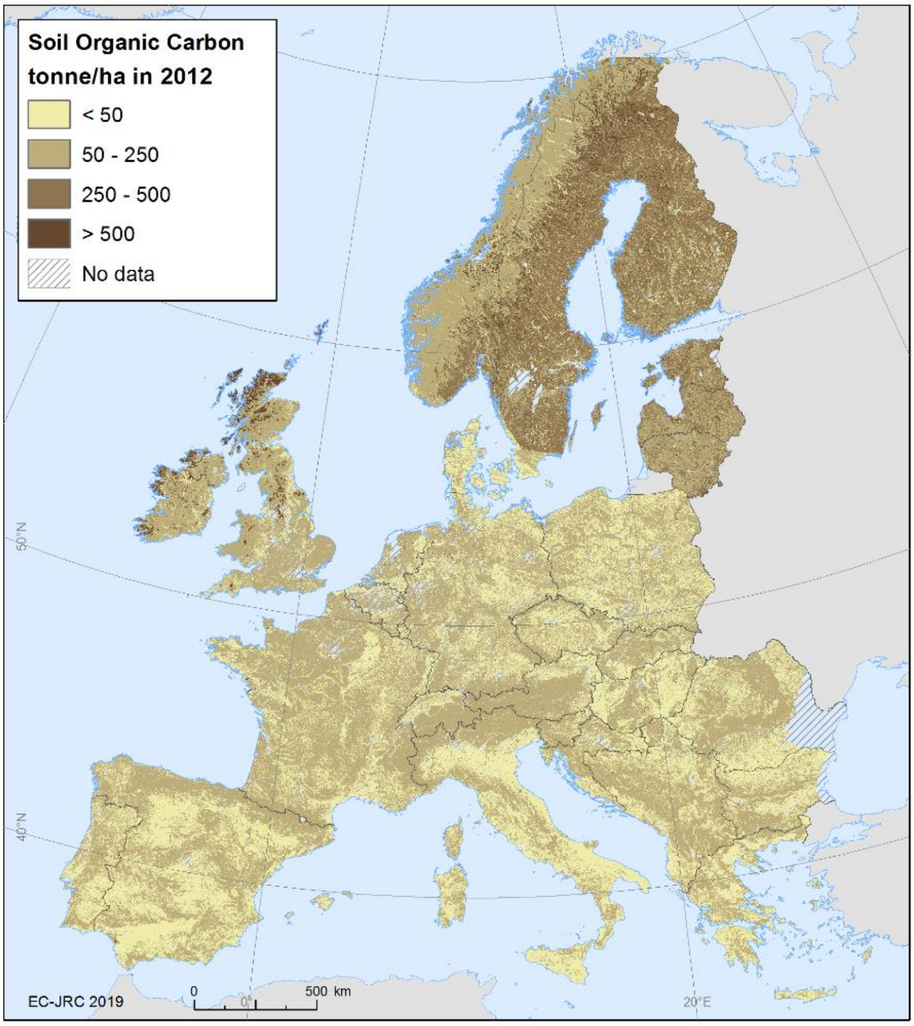



**Figure 5.5.** Map of soil organic carbon (tonne/ha in 2012).

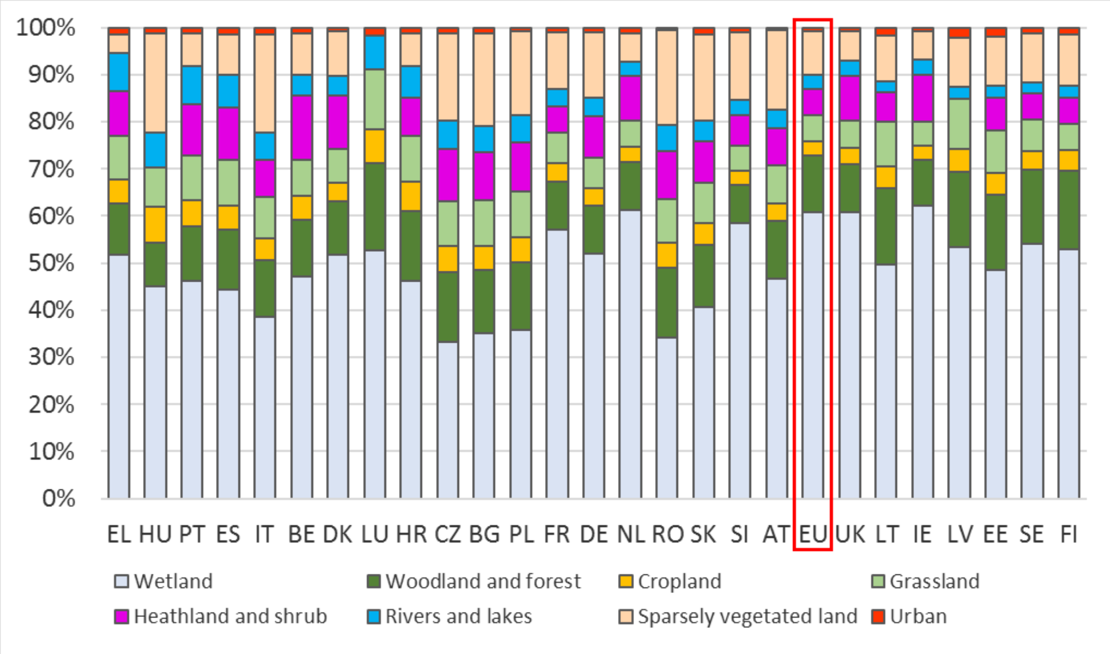
### 5.2.2 Accounting tables of SOC stocks in biophysical terms

SOC stocks by ecosystem type are presented in Table 5.8. These results are based on the method described above, where only land cover changes are considered. SOC stocks at the EU level decreased between 2000 and 2006 with 267 million tonnes of C, followed by an increase of 140 million tonne of C between 2006 and 2012. 'Woodland and forest', followed by 'Wetlands' present the largest SOC stocks. In both ecosystem types, there was a decrease of SOC stocks between 2000 and 2006, which then increased again between 2006 and 2012.

**Table 5.8.** Opening stock of SOC at the EU level in biophysical terms**.**

| million tonne of C | Urban | Cropland | Grassland | Heathland and shrub | Woodland and forest | Sparsely vegetated land | Wetland | Rivers and lakes | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Year 2000 | 213 | 7,088 | 3,965 | 1,423 | 27,996 | 722 | 8,380 | 408 | 50,195 |
| Year 2006 | 225 | 7,075 | 3,952 | 1,418 | 27,786 | 720 | 8,341 | 410 | 49,927 |
| Year 2012 | 238 | 7,059 | 3,940 | 1,415 | 27,940 | 719 | 8,345 | 413 | 50,068 |

In addition, Figure 5.6 shows the relative SOC stocks (in tonnes per hectare) for different ecosystem types. As expected, soils in wetland ecosystems perform the major role in storing SOC per hectare in all MS (Figure 5.6). Wetland ecosystems include marshes and peat bogs, which contain a mean value of SOC that ranges from 397 g C/kg in Boreal to 116 g C/kg in Continental biogeographical region (Annex 9-Table A.8.2). 'Woodland and forest' ecosystems, which cover 36% of the European territory (Maes et al., 2015), have the second largest SOC stocks at the EU level, as confirmed by de Brogniez et al. (2015), followed by sparsely vegetated land (EU bar in Figure 5.6).




(Countries are sorted from lower to higher average values of tonne of C per hectare)

**Figure 5.6.** Relative soil organic carbon per ecosystem type (tonne/ha in 2012).

### 5.2.3 Trends in soil organic carbon stocks

We assessed changes in SOC related to conversion in land cover between 2000, 2006, and 2012. We compared at country and the EU level the changes in SOC stocks according to the SOC maps generated using the accounting layers of CLC. This assessment of changes in SOC is a simplified approach for two main reasons:

- It only considers land cover changes as driver of changes in SOC;
- Changes reported here are only estimates of the potential changes in SOC stocks that may occur in the long term. However, as highlighted in the introduction of section 5.2, in this approach it is assumed that SOC stocks are in equilibrium once the change in land cover takes place, which is not correct (see section 5.2.4 for further details).

In spite of the limitations this approach presents, Figure 5.7 is useful to show the potential impact of land cover changes on SOC stocks in the long term. Land cover changes in the Netherlands, with a wetland expansion, and in Czechia, with an increase of grasslands and sparsely vegetated land at the expenses of cropland, may result in the long term in an increase of SOC stocks. On the contrary, Latvia shows the opposite trend, with losses of SOC stocks between 2000 and 2012 mainly as a consequence of grassland reduction.

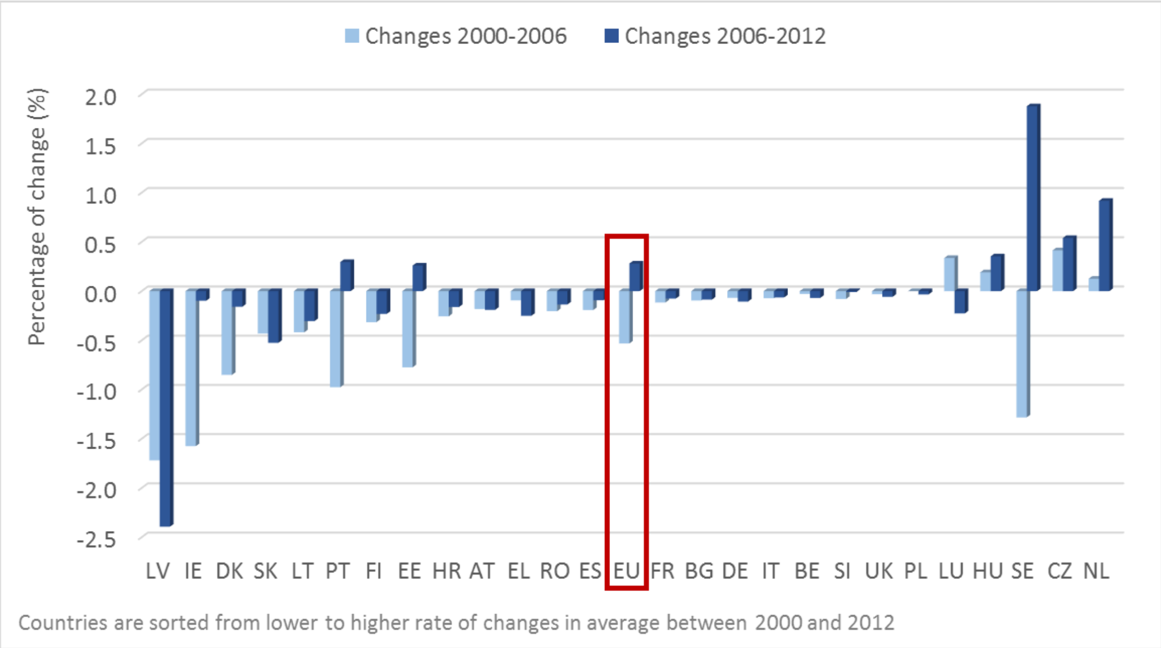



**Figure 5.7.** Potential changes in SOC stock derived from land cover changes.

### 5.2.4 Limitations of SOC stock accounts

The main limitation of the approach adopted for SOC accounts is that it is based only on land cover data. As in the InVEST approach, it is assumed that all areas of each land cover types store the same amount of C per unit areas, equal to the average of measured storage levels within that land cover type. However, other important determinants of SOC stocks such as land use, management practices, or disturbances are not accounted for. Although we have proposed an enhanced table to capture the heterogeneity across the EU territory, we did not consider the role of soil properties such as soil texture, which is also crucial in determining the storage of SOC. However, there were not enough LUCAS samples to integrate biogeographic regions with soil texture. The upcoming release of LUCAS top soil data for 2018, will contribute to enhance this methodology and assess changes in SOC stocks in areas in the absence of land cover changes.

When assessing changes in SOC, it is important to consider that under the current approach, we assume that SOC is under equilibrium once the land cover change takes place. However, changes in SOC stock resulting from land management practices such as intensification of agricultural activities, deforestation, or land cover conversion occur very slowly (Jones et al., 2012) and are difficult to detect before 7–10 years (Smith, 2004). For example, a study from Bellamy et al. (2005) detected variations in SOC for agricultural land across England and Wales between 1978 and 2003.

The monetary valuation of soil carbon storage has not been undertaken because as highlighted in the introduction of section 5.2 and above in the limitations section, the yearly actual flow in physical terms cannot be appropriately assessed by the current approach. Differences in opening and closing stocks should be only understood as the potential changes that may occur in the long term. Therefore, the high level of uncertainty to estimate the yearly actual flow, in both, biophysical and monetary terms, discouraged us to build the supply and use tables, since the message generated may be misleading.

## 5.3 Summary of carbon sequestration accounts

**Box 3.** Carbon sequestration accounts: main outcomes

**Accounts based on LULUCF inventories**

At the EU level, there is an overall net $CO_2$ uptake by ecosystems of 306 million tonne of $CO_2$ in 2012. Forest ecosystems are the only ecosystem type providing a net $CO_2$ uptake (444 million tonnes of $CO_2$ uptake in 2012); while the other ecosystem types are net sources of $CO_2$ (138 million tonnes of $CO_2$ emissions in 2012).

More attention should be paid to wetlands: although they are known for their role as sinks of $CO_2$, wetlands are reported at the EU as source of $CO_2$ to the atmosphere: implementation of adequate management practices (and stopping inadequate ones) may enhance the role of wetlands sequestering carbon.

Land ecosystems (Forest Land, Cropland, Grassland, Wetland, Settlements, and Other land) contribute to mitigate 7% of the total EU $CO_2$ emissions derived from economic activities/production processes. However, in this assessment the role of marine ecosystems and freshwater is not accounted for.

The value of $CO_2$ uptake by ecosystems has increased with about 1.6% between 2000 and 2012, which corresponds to an increase of 235 million euro.

Standardization of methodologies applied across countries may enhance the suitability of these data for a regular update of C sequestration accounts.

Combined presentations allow to frame together two sides of the same policy issue: (i) the pressure generated by economic sectors and households ($CO_2$ emissions) and (ii) the service flow offered by ecosystem types ($CO_2$ uptake).

**Accounts based on soil organic carbon stocks**

'Woodland and forest' and 'Wetlands' present the highest SOC stocks in the EU, both in absolute and relative terms (per hectare).

SOC stocks at the EU level decreased between 2000 and 2006 by 267 million tonnes, followed by an increase of 140 million tonnes between 2006 and 2012.

Countries with the most important potential increase in SOC stocks are the Netherlands, as a consequence of the wetland expansion, and Czechia as a result of an increase in grasslands and sparsely vegetated land at the expenses of cropland.

# 6 Flood control

Flood control as an ecosystem service is defined as the regulation of water flow by ecosystems that mitigates or prevents potential damage to economic assets (i.e., infrastructure, agriculture) and human lives (modified from CICES V.5.1, Haines-Young and Potschin (2018)).

All ecosystems but in particular forests, shrubland, grasslands and wetlands reduce runoff by retaining water in the soil and aquifers and slowing down the water flow. This prevents the rapid downstream runoff of surface water, hereby lowering peak runoff, and thus reduces the detrimental effects to citizens, farmland, and infrastructure from flooding. The accounting approach developed here presents the potential of ecosystems to regulate water flows together with the socio-economic demand for protection against river floods. Thus, we focus only on river floods, which is the most frequent and costly natural hazard (UNISDR, 2011).

Although there were not enough data to perform statistical trend analysis over a long time series, a comparison was carried out of the accounts of flood control by ecosystems between 2006 and 2012, for which there were available data. Although these two years are relatively close and significant changes may not have arisen, interpretation of the results may show some changes relevant for natural capital and policy decision support.

In the approach we present in this report to account for flood control by ecosystems, three **important principles** were applied.

Firstly, it was assumed that **flood control by ecosystems is delivered at all times** and not only during extreme rainfall that may induce floods threatening people and infrastructure. The rationale is that without the protective function of ecosystems also less intense or prolonged precipitation events could result in flooding. In this way, in the accounting tables, values are assigned to ecosystems for every accounting year, independently of the number of flood events derived from the precipitation patterns taking place in the specific accounting year.

Secondly, the assessment of the actual flow for flood control by ecosystems (required for accounting) is based on the conceptual ecosystem service (ES) framework (Maes et al., 2013), in which the **ecosystem service potential and socio-economic demand for the service are the main drivers of changes** in the service used (see Introduction of this report). The methodology we propose in this report is more suitable for natural capital accounts than other models such as those quantifying the attenuation of peak discharges. In the latter approach, quantification of the actual ecosystem service flow is highly driven by annual precipitation patterns (i.e., higher precipitation resulting in higher ES flow), which is not the main goal of natural capital accounts. In addition, attenuation of flow peak discharges considers just the ecosystem component, failing in capturing the demand for flood control as ecosystem service (socio-economic component) (Figure 1.1 in the Introduction section). Omission of the socio-economic component would ultimately contradict the notion of ecosystem service flow (Maes et al., 2013). As a consequence, the actual ecosystem service flow of flood control in this study is quantified as the number of hectares requiring flood control (demand) that are benefiting from the ecosystems reducing the upstream runoff (more details on the model are presented in section 6.1). This approach characterizes the extent to which benefiting areas depend on spatial flows from other locations providing the services. A similar approach was proposed by Serna-Chavez et al. (2014), but for flood control the integration of the directional slope-dependent flow was required.

Thirdly, the accounting approach takes into consideration the full **role of ecosystems controlling floods**. Ecosystems play a key role controlling floods by themselves but they also provide **support to defence measures** already in place. Societies build dykes, dams and other infrastructure to control water flows and to protect people and economic assets from flooding reducing the damage potentially generated. Without the protective function of upstream ecosystems, more investments in defence measures would be needed to maintain the same or higher level of protection. Therefore, ecosystems provide flood control with or without defence measures. In this sense, we have quantified the service flow of flood control in biophysical terms without considering the role of defence measures. Ultimately, the role of defence measures becomes crucial in the monetary valuation (section 6.2), since the presence of defence measures already in place reduces the damage caused by floods (Jongman et al., 2014), and therefore the potential damage that could be avoided by ecosystems. In this regard, the value of the ES flow can be split in two different values: 1) When flood control is only provided by natural capital (NC, meaning the ecosystem) and, 2) When floods are controlled by both natural capital and defence measures (NC+). Understanding how ecosystems contribute to control flooding, also when defence measures are present, is an important step forward. It shows how ecosystems add value to existing man-made protection against flooding. Importantly, the actual ES flow delivered for NC+ specifically reports the ecosystem contribution to controlling floods and does not include the flows generated by defence man-made assets. Their assessment should be sought in the SNA, because it is already part of the accounting mainframe.

The results provided for flood control accounts refer only to river floods. Other type of floods (e.g., flash (pluvial) floods and coastal flooding) are not covered by this study.

## 6.1 Biophysical assessment

In the methodology we propose in this report, the actual ES flow of flood control requires the assessment of the ES potential and ES demand to delineate the **service providing areas** (SPA) and **service demanding areas** (SDA), respectively. This approach was adopted to be consistent with the method already applied for the account of other ecosystem services (Vallecillo et al., 2018; Vallecillo et al., 2019) for a final integration of ecosystem service accounts. The actual use of the ES (or actual ES flow) depends on the spatial relationship between SPA and SDA, which is based on the direction that the water flows (slope-dependent) taking into account the whole river basin. Only if the SPA are situated upstream from the SDA the actual service flow will be generated. Finally, the actual service flow is economically valuated to produce the associated accounting tables (Figure 6.1).

In the method here proposed, precipitation is indirectly accounted for in the delineations of potential flooding areas. It means that there may be flooding prone areas with a lack of precipitation for the year assessed (e.g., 2006 and 2012), but still they may have an actual ES flow due to the protective role of ecosystems, independently of the rain in that specific year.

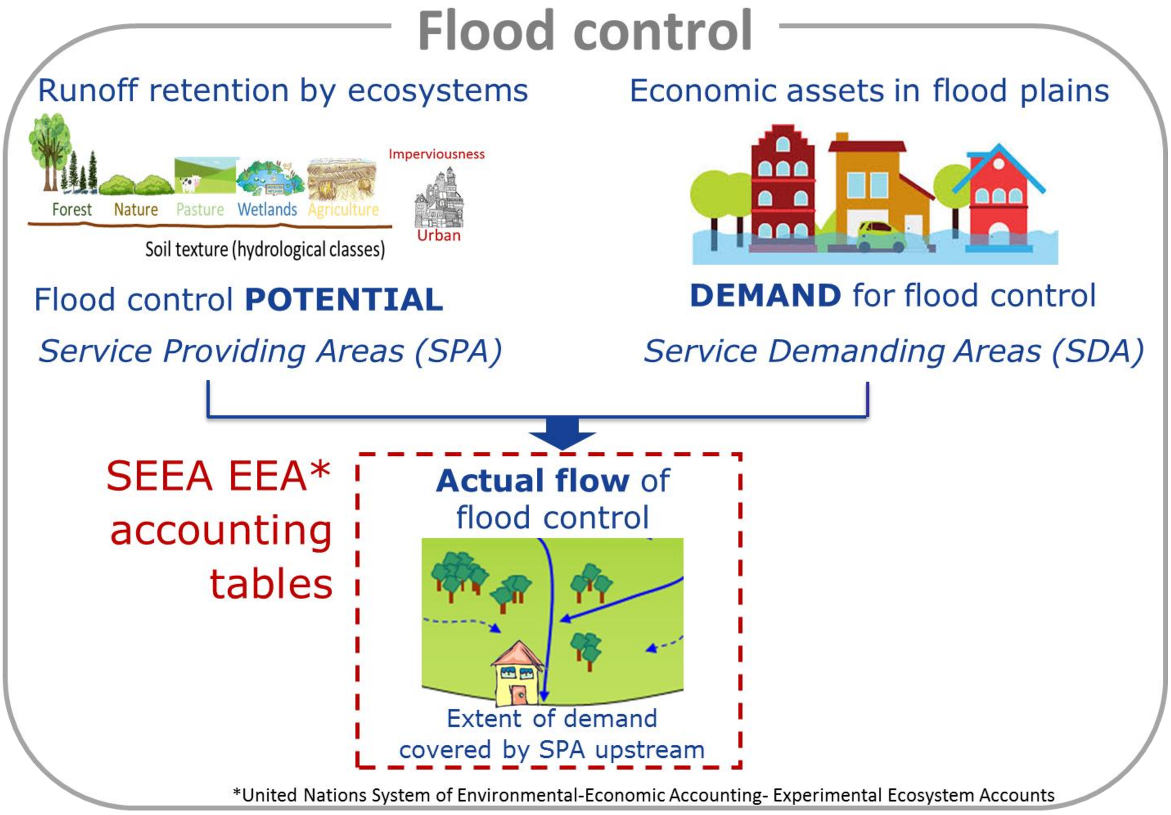



**Figure 6.1.** Scheme of the main components of flood control by ecosystems.

The sections below describe the methods and data used for mapping and assessment of different components of flood control as ecosystem service. The temporal coverage of flood control accounts is determined by the availability of the **input data** used for the assessment of the different components of the ecosystem service: ES potential, demand for flood control, and actual ES flow. In Annex 10 input data to map flood control by ecosystems are described. Thus, the assessment was limited to years in which imperviousness data (European Union, 2018) were available (i.e., 2006 and 2012). All spatial analyses were performed at grid cell of 100 m x 100 m resolution (for population the resolution was 250 m x 250 m) and results were aggregated at sub-catchment level for visualization purposes. Sub-catchments were used as spatial reference unit for mapping. The river catchment data are based on the Arc Hydro model (Bouraoui et al., 2009) and have an average size of 180 km$^2$. Maps, and therefore all derived outcomes, show the results for sub-catchments for which all datasets presented data. This refers only to EU-26 excluding Cyprus and Malta, and some regions in Croatia, Bulgaria and Finland.

### 6.1.1 Ecosystems potential to control floods

**ES potential** for flood control was quantified as the extent of SPA per sub-catchment. The delineation of the SPA was based on a **dimensionless indicator of potential runoff retention** that includes five main steps (Figure 6.2):

1. Curve Number scoring for land cover classes. The Curve Number (CN) method was originally developed by the USDA Soil Conservation Service (1972) and estimates the approximate amount of runoff generated as a function of the land cover and the underlying hydrological soil group properties. This method is still widely used with different purposes in the literature (see Muche et al. (2019) for a detailed review). Annex 11 shows the lookup table of the CN values applied for the different combinations of land-cover types and soil type.
2. Correction of CN values by the impervious coverage per grid cell in the study area. Imperviousness level, measured in percentage, is a key indicator of the condition of ecosystems (Maes et al., 2018) and directly determines the ability of soil to retain and infiltrate water; driving therefore the ecosystems potential to control floods (United States Department of Agriculture, 1986).
3. Adjustment of the CN value by slope. The original CN method was created for flat areas, hence to consider this important factor determining runoff, we applied the slope-modified CN method (Huang et al., 2006). Steeper slopes generate a faster movement of water within the landscape, reducing infiltration and therefore the ecosystem contribution to controlling floods.
4. Integration of natural and semi-natural land covers in riparian zones (also including flood plains) (Clerici et al., 2011). This step was necessary to guarantee that semi-natural land covers in riparian zones are included as SPA given their important role retaining and absorbing runoff (European Commission, 2007; Grizzetti et al., 2017). The CN method does not specifically consider the key role of riparian zones; therefore, we assigned the maximum CN value to semi-natural land cover according to CORINE land cover map (see Annex 10) [codes 244, 311-313, 321-324, 411-423] in riparian zones (see input data in Annex 10).
5. The final CN scores show higher values when there is higher runoff. Therefore, the final indicator of potential runoff retention was calculated as difference between the maximum CN value obtained for the reference year 2012 and the CN score in a given location. In this way, high values indicate high ecosystem potential to provide flood control.

The indicator of potential runoff retention provides spatially explicit data to identify key areas for flood control (i.e., when indicator is above a certain threshold) and to delineate SPA. Although the use of SPA, instead of the indicator of potential runoff retention, may be considered as an oversimplification, it is the basis for a spatial approach of ES at the landscape scale (Sutherland et al., 2018; Syrbe & Walz, 2012). Spatial assessments pairing SPA with the corresponding benefiting areas can provide insights into the role of spatial flows in the delivery of a particular ecosystem service (Serna-Chavez et al., 2014) as also demonstrated in previous ecosystem service account developed in INCA (Vallecillo et al., 2018; Vallecillo et al., 2019). This also allows us moving from a dimensionless indicator (potential runoff retention) to biophysical units as hectares of SPA per sub-catchment to quantify ES, that can support the compilation of accounting tables in physical terms as required by SEEA EEA (UN, 2017).

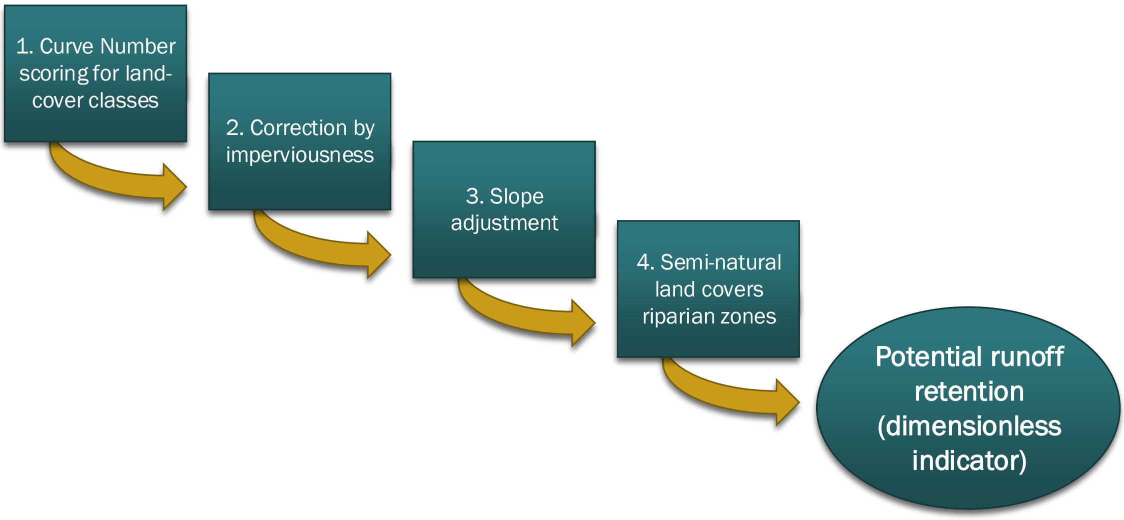



**Figure 6.2.** Steps to calculate the indicator of potential runoff retention.

For the delineation of SPA, we set different thresholds on the potential runoff retention for three broad ecosystem typologies: 1) urban areas; 2) cropland; and 3) semi-natural ecosystems that include the rest of land cover classes (Annex 1 for correspondence with CLC). Setting the same threshold for the whole study areas would discard some relevant zones within cropland and urban areas playing a significant role in controlling floods for these typologies of ecosystems, which present distinct characteristics from semi-natural ecosystems. The threshold value for semi-natural ecosystems was based on the average values of the potential runoff retention at the EU level for semi-natural land covers classes in 2012, minus the standard deviation. The threshold was less conservative for urban areas and cropland (i.e., average values of the mean of potential runoff retention plus the standard deviation). See Annex 12 with the average values, standard deviation of potential runoff retention and the thresholds for each broad ecosystem typology. The rules set to define different thresholds allowed us to distinguish between suitable and non-suitable areas for flood control within the broad ecosystem typologies considered which present advantages from the ecosystem management point of view. For instance, SPA for semi-natural ecosystems excluded only 5% of their extent. The main land covers excluded as SPA are bare rocks and sparsely vegetated areas, which means that their role to control floods is low compared to other semi-natural ecosystems. Therefore, ecosystem restoration/nature based solution could be adopted in this situation to increase runoff retention. For agricultural areas, only 33% are considered SPA, including mainly agro-forestry areas, pastures, and areas with natural vegetation. Therefore, measures targeting the increase of natural vegetation in arable land for instance, could increase the extent of SPA in agricultural areas. In the case of urban areas, 15% are SPA, which correspond to artificial surfaces with low imperviousness level. Decrease of impervious areas (e.g., green roofs, parking areas with permeable surfaces) would increase runoff retention, acting therefore as SPA.

The thresholds set present also important limitations such as the relatively arbitrary criteria to choose them, given the lack of scientific knowledge to set a reasonable threshold. However, for comparative purposes the thresholds calculated for the year 2012 were applied for 2006 to properly track changes over time and make sound comparisons. Further development of the account proposed here should include sensitivity analysis of the thresholds chosen.

### 6.1.2 Demand for flood control

In this study, the demand for flood control is defined as the area of economic assets located in flood plains. More specifically, demand accounts for the total spatial extent of economic assets that could be potentially affected by a 1 in 500 year flood, independently of whether they are protected by defence measures or natural capital.

Different economic assets, corresponding to CLC classes, were identified as demand for flood control and they were grouped in two broad land types (Table 6.1):

- Agricultural land: non-irrigated arable land, permanently irrigated land, vineyards, fruit trees and berry plantations, olive groves, pastures, annual crops associated with permanent crops, complex cultivation patterns, land principally occupied by agriculture, with significant areas of natural vegetation and agro-forestry areas.
- Artificial land: mineral extraction sites, industrial or commercial units, construction sites, road and rail networks and associated land, port areas, airports, dump sites, green urban areas, sport and leisure facilities, continuous urban fabric and discontinuous urban fabric.

These broad types of economic assets were used to report aggregated values for the demand in a meaningful way; however, they were considered separately for the economic valuation (see section 6.2). The mapped economic assets were used to delineate SDA in a spatially explicit way and to quantify their extent per sub-catchment for mapping.

As part of the demand, we also quantified the total amount of the population inhabiting in SDA for the maximum return period (500 years). Population data were only available for 2015 (Annex 10). Population is assessed separately from economic assets and not given a monetary value. Total population in SDA of 2006 and 2012 was calculated to build a map the corresponding maps at sub-catchment level.

**Table 6.1.** Correspondence between land-cover types and economic activities.

| Broad demand types | CLC classes (LABEL 3) | Economic activities NACE classification* |
|---|---|---|
| **Artificial land** | Continuous urban fabric | Other tertiary and households |
| | Discontinuous urban fabric | Other tertiary and households |
| | Green urban areas | Other tertiary and households |
| | Sport and leisure facilities | Other tertiary and households |
| | Road and rail networks and associated land (main roads from TeleAtlas are also added) | Transportation |
| | Port areas | Transportation |
| | Airports | Transportation |
| | Industrial or commercial units | Manufacturing and mining |
| | Mineral extraction sites | Manufacturing and mining |
| | Dump sites | Waste management |
| | Construction sites | Construction |
| **Agricultural land** | Non-irrigated arable land | Agriculture |
| | Permanently irrigated land | Agriculture |
| | Vineyards | Agriculture |
| | Fruit trees and berry plantations | Agriculture |
| | Olive groves | Agriculture |
| | Pastures | Agriculture |
| | Annual crops associated with permanent crops | Agriculture |
| | Complex cultivation patterns | Agriculture |
| | Land principally occupied by agriculture, with significant areas of natural vegetation | Agriculture |
| | Agro-forestry areas | Agriculture |
| *Statistical Classification of Economic Activities in the European Community | | |

### 6.1.3 Actual ecosystem service flow of flood control

The **use of the ecosystem service** (actual ES flow) is based on the spatial relationship between SPA and SDA, more concretely as the directional flow (runoff) dependent on the slope of the terrain (Fisher et al., 2009). We quantified the use of the service for each grid cell of SDA (where there is demand for flood control). For each grid cell of the SDA, we computed **the share of the area upstream of the SDA cell covered by SPA**, where the entire interconnection of sub-catchments within a river basin was taken into account. This share is calculated as the ratio between the upstream surface area covered by SPA and the total upstream surface area, Ratio $SPA_{up}$. Grid cells situated in uplands typically have a small upstream surface area whereas grid cells situated in low land have a larger upstream surface area. A ratio equal to 1 indicates that the whole area upstream of the considered grid cell is covered by SPA (maximum use or actual ES flow); while a ratio of 0 means that the area upstream of a grid cell is not covered by SPA at all, and remains therefore without flood control provided by ecosystems. This ratio was next multiplied with the grid cell size to calculate the actual ES flow per grid cell of SDA (Equation 6.1).

$$Actual\ ES\ flow\ (ha) = Ratio\ SPA_{up}\ *\ SDA_{Grid\ cell\ size}\ (ha) \qquad \text{(Equation 6.1)}$$

The **actual ES flow** of flood control is thus expressed as the **number of hectares of the demand (SDA) covered by the ecosystem (SPA) in a given year**. Therefore, the approach used in this report quantifies the role of the ecosystems to control floods in relative terms, compared to the best situation for flood control by ecosystems (i.e., when the whole upstream area of the demand is covered by SPA). Finally, the actual ES flow per grid cell of SDA was aggregated calculating the sum at sub-catchment level to map the actual ES flow of flood control. The actual ES flow will change if any of the input data used to assess ES potential changes. For example, increasing imperviousness, deforestation, or loss of natural areas in riparian zones will reduce the total size of the SPA. As a result, the Ratio $SPA_{up}$ will decrease and so, too, the actual flow of the ecosystem service. Similarly, afforestation or expansion of semi-natural land covers in riparian areas may increase the Ratio $SPA_{up}$ (depending where changes take place) and increase the actual flow of the ES. On the other hand, increasing the SDA because of urbanization or agricultural expansion will also increase the actual flow, and especially if the expansion does not take place at the expenses of SPA and there are SPA upstream from the new demand areas.

The annual actual flow of the ecosystem service, expressed in hectares is ultimately recorded in the supply and use tables of the account. The allocation of the actual flow to the ecosystem types and economic units is further explained in section 6.3. This ES flow or use of the service is thus dependent on changes in ecosystems situated upstream as well as on changes in the demand set by people and the economy.

Further development of this experimental account of flood control by ecosystems may consider calculating the actual flow weighting by the different values of potential runoff retention within each SPA (i.e., forest may retain more runoff than agricultural areas within the same SPA) and perform the corresponding sensitivity analysis. In this application, we discarded this option to be consistent with the approach used for the account of other ecosystem services (Vallecillo et al., 2018). However, the different role of each ecosystem type in providing the service is taking into account when filling in the accounting tables (see section 6.3).

Complementary to the actual ES flow, we also estimated the total amount of the population benefiting from the role of ecosystems in controlling floods in SDA.

This was done by extracting the population in SDA and multiplying it by the $Ratio\ SPA_{up}$ (Equation 6.2).

$$Beneficiaries\ (number\ of\ people) = Population\ demand * Ratio\ SPA_{up}$$

(Equation 6.2)

### 6.1.4 Unmet demand

By assessing the different components of flood control described in the previous sections, the so called unmet demand can be quantified, which is important for land management and policy decisions aiming the enhancement of benefits generated by ecosystem services to the society. The quantification of the actual ES flow as the number of hectares of demand covered by the ecosystem makes it feasible to quantify the unmet demand in the same terms. The unmet demand quantifies the part of the demand (economic assets and population) that is unprotected by ecosystems in the whole upstream basin. In the face of an extreme rain episode, areas of unmet demand are more likely to suffer flooding. The unmet demand is quantified according to equation 6.3:

$$Unmet\ demand\ (ha) = Demand(ha) - Actual\ flow(ha)$$ (Equation 6.3)

However, in flood plains of importance to society, defence measures (e.g., levees, dykes) are already in place guaranteeing a certain level of protection that should be considered when assessing the unmet demand. At the EU level, data on the flood protection level are provided in terms of the return period of the flood event that can be borne by the defence measures in place (Annex 10) (Dottori et al., 2016; Jongman et al., 2014). In the case of the Netherlands, the level of protection is high enough to defend people and economic assets from floods for the maximum return period considered (500 years). Therefore, we assumed that in this country, the demand for flood control is satisfied by the current level of protection and thus, the unmet demand was not calculated.

Unmet demand was calculated as the percentage of the total demand for flood control at sub-catchment level (excluding the Netherlands).

It is important to highlight here that data available on the protection level provided by defence measures in place (Dottori et al., 2016) indirectly integrate the supporting role of ecosystems in controlling floods. The protection level is designed to give protection up to a given return period flood given a specific landscape setting (i.e., land covers). Changes in land cover upstream would alter water levels downstream and consequently the level of protection. It means that the presence of defence measures does not imply the lack of ecosystem's role controlling floods, but rather ecosystems support the performance of defence measures. Actually, without the protective function of upstream ecosystems, more investment in artificial defence measures would be needed to maintain or guarantee the same level of protection.

## 6.2 Monetary valuation

The actual ES flow of flood control quantified in biophysical terms is translated into monetary terms using as valuation technique the avoided damage cost. In the monetary valuation, the role of defence measures already in place is of especial relevance, since they guarantee certain level of protection to economic assets in flooding areas reducing the damage generated by floods.

The estimation of the damages cost is adapted from the methodology and data presented in Huizinga (2007). This methodology has been broadly used in the literature for the assessment of the flood damage cost (Feyen et al., 2012; Rojas et al., 2013; Scussolini et al., 2016). A damage function gives the **damage cost** in EUR/$m^2$ as a function of the water depth in the flooded area per damage class (Figure 6.3). Damage functions vary among countries based on the Gross Domestic Product (GDP) per capita. Prices are assumed as fixed: no discounting or inflation was taken into consideration.

At EU level, data on flood water levels is available from flood inundations maps for different return periods: 10, 20, 50, 100, 200 and 500 years (Dottori et al., 2016) (see data info in Annex 10). These maps show the potential inundation without the artificial defence measures; but include the ecosystem component of flood control. This presents some limitations that are further discussed at the end of this section and in section 6.6.

The damage cost is calculated using flood inundation maps for the return periods available at the EU level: 10, 20, 50, 100, 200, and 500 years, for different damage classes: buildings, commerce, industry, roads, and agriculture. Damage functions for each class are adapted to the CLC classes used to identify economic assets based on Huizinga (2007): this is where we can find the allocation from damage classes to CLC classes.

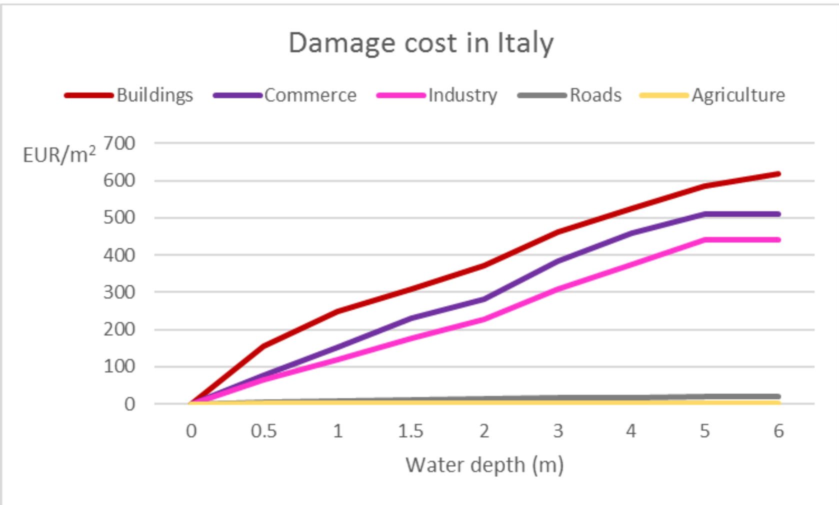



**Figure 6.3.** Example of the damage function for Italy for different economic assets.

Damages cost are used as the basis to develop a proxy of the monetary value of flood control by ecosystems by multiplying them by the number of square meters of demand covered by the ecosystem (actual ES flow) (Equation 6.4). The proxy of the avoided cost assumes that a higher damage is avoided if there is a larger coverage of upstream ecosystems controlling floods (actual ES flow). For example, if a 1 ha grid cell of demand with a damage cost of 200 euro has an actual service flow equal to 0.75 would result in an avoided cost equal to 150 euro/ha.

$$Avoided\ Cost\ (EUR) = Damage\ (EUR/m^2) * Actual\ ES\ flow\ (m^2)$$ (Equation 6.4)

The avoided cost estimated for each return period at grid cell level is then used to calculate the actual flow in monetary terms (Equation 6.5, area under the curve in Figure 6.4). It is based on the equation used to estimate of Expected Annual Damage by Feyen et al. (2012):

$$Actual\ flow\ (EUR/Year) = \sum_{10}^{500}\left((f_i - f_{i-1}) * \frac{AC_i + AC_{i-1}}{2}\right)$$

(Equation 6.5)

Where $f_i$ is the frequency of each return period $(\mathrm{f} = 1/\mathrm{return\ period}\ i)$ and $AC_i$ is the avoided cost (as calculated with Equation 6.4) estimated for the return period $i$.

As mentioned before, flood prone areas present defence measures that protect economic assets up to a certain return period intensity. In this context, we calculated the actual flow in monetary terms considering the role of the defence measures by excluding the potential damage of events with a return period lower than the protection standard. The resulting actual flow (EUR/year) reflects the value of the service where the only contribution of controlling floods is derived from natural capital ($Actual\ flow_{NC}$). Hence, Equation 6.5 was truncated at the return period of the protection level (Figure 6.4). For instance, if an area has a level of protection of 50 years, damage caused by return periods below this number will not be considered, decreasing accordingly the potential damage from floods (Equation 6.6 is derived from the truncation of Equation 6.5 for a return period of 50 as an example):

$$Actual\ flow_{NC}\ (EUR/Year) = \sum_{50}^{500}\left((f_i - f_{i-1}) * \frac{AC_i + AC_{i-1}}{2}\right)$$

(Equation 6.6)

With this approach, we can also calculate the monetary value of the actual ES flow of flood control when floods are controlled by natural capital only (NC) and by both natural capital in support to defence measures (NC+) (Figure 6.4).

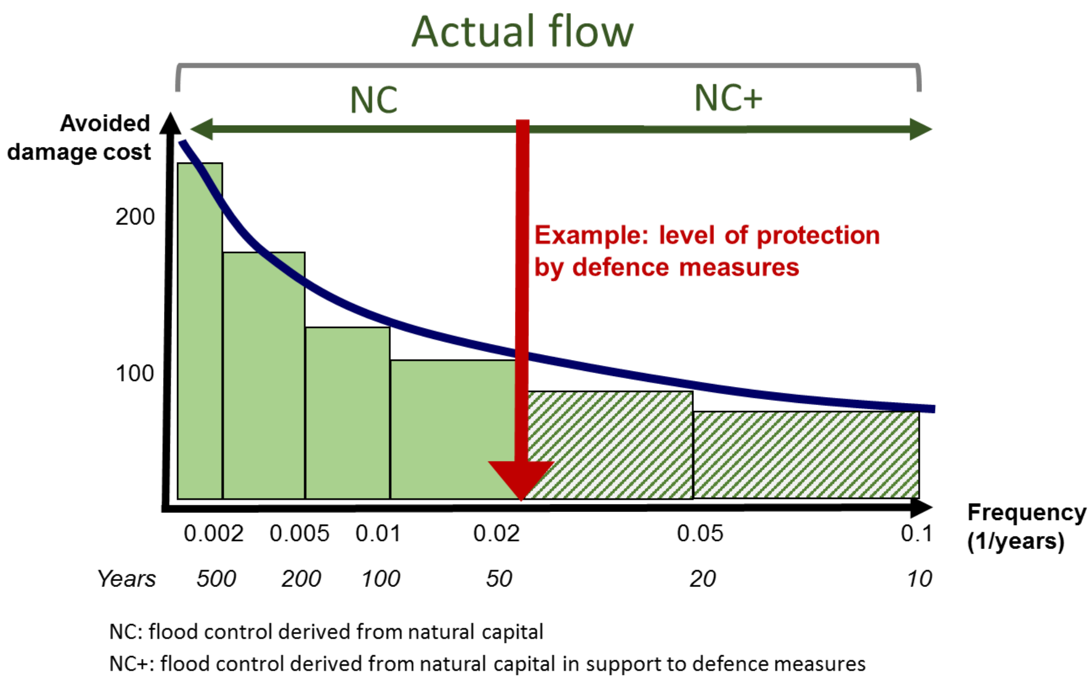



**Figure 6.4.** Illustrative example of the actual flow in monetary terms and curve truncation.

The advantage of the method proposed is the simplicity in terms of modelling and data needs. However, it is important to acknowledge that the method applied for the monetary valuation presents some limitations. The damage curve used is based on simulated water levels reached for different return periods that already integrate the role of ecosystems (more concretely as represented by CLC 2006). Damages without ecosystem flood control would actually be much larger, since the water level reached for each return period would be also higher if the ecosystem was not there. Given that a situation without ecosystems cannot be realistically simulated, we use the damage function with ecosystems in place as a proxy for the avoided cost evaluation. Therefore, with the current method applied the value of ecosystem to control floods is to some extent underestimated. This issue is further discussed in the limitations (section 6.6).

## 6.3 Accounting tables

The accounting tables are compiled in **biophysical and monetary terms**. Values at national level for the accounting tables are calculated by summing up the value of the actual ES flow (in biophysical and monetary terms) at sub-catchment level. The allocation of the sub-catchments to the different countries was done based on the position of the sub-catchment centroid. Therefore, transboundary catchments (shared by two countries) were only allocated to the country where the centroid of the sub-catchment is located (see section 6.6 on model limitation).

An additional step is needed to find a correspondence between the different damage classes in CLC (still classified as economic assets) and the NACE economic sectors of national accounts. The detailed description of each CORINE Land Cover (CLC) class (Kosztra et al., 2017) specifically reports what is (in/)applicable for and what is included (and excluded). This detailed information allows to move from the categories of damage function-CLC (Huizinga, 2007) that defines “assets” to the NACE classification used in SNA that defines economic sectors.

The **supply table** shows the contribution of the different ecosystem types to generate the actual ES flow. For the allocation of the ES flow in the supply table, we quantified first the extent of different ecosystem types shaping the SPA, but that are also upstream from the demand in each country. Since the role of each ecosystem type per unit area is highly variable (i.e., forests retain more runoff than cropland), the extent of each ecosystem type was weighted by a correction factor calculated with Equation 6.7:

$$Correction\ factor_i = (100 - Average(CN_{j \in i}))/100 \qquad \text{(Equation 6.7)}$$

Where $i$ is the ecosystem type and $CN_{j \in i}$ is the CN of the land cover $j$ belonging to the ecosystem type $i$ (CN values are shown in Annex 11). This equation results in the following correction factors: 0.27 for urban, 0.42 for cropland, 0.78 for woodland and forest, 0.56 for grassland, 0.64 for heathland, 0.33 sparsely vegetated land and 0.8 for wetland. The weighted extent (i.e., extent multiplied by the correction factor) was then used to distribute and allocate the total actual flow in relative proportion to the values obtained. The correspondence between CLC classes and ecosystem types is based on Annex 1.

The **use table** shows how much economic sectors and households use the actual ES flow. The allocation of the ES flow for the use table is based directly on the model output. Land cover type, corresponding to economic sectors and households (Table 6.1), and the actual ES flow for each grid cell of demand are known. Therefore, the actual flow was summed up for each economic sector and household separately. Correspondence between land-cover types and economic activities were done according to CLC nomenclature guidelines (Kosztra et al., 2017) (Table 6.1).

## 6.4 Results: flood control by ecosystems

### 6.4.1 Biophysical maps

The maps with the different **components of flood control**[15] by ecosystems at sub-catchment level are presented in Figure 6.5. These are: A. Flood control potential; B. Flood control demand; C. Actual ES flow; and D. Unmet demand for flood control.

The **ES potential** for flood control is higher in forested areas in Europe[16] and reaches lower values in the main agricultural plains, e.g., in the east of the UK, southern Spain, the Po plain in Italy and in Romania. **ES demand** is mostly situated in river valleys and increases in downstream direction and in urban areas.

The **actual service flow** is generated in SDA depending on the amount of SPA upstream. For the **unmet demand**, it is observed that large areas of unmet demand match spatially with areas under low ES potential. As mentioned in the methods, in the Netherlands the unmet demand is considered as absent since defence measures guarantee protection from floods for the considered return period (500 years).

By visually comparing the maps, areas with low flood control potential (Figure 6.5A) match spatially with extensive areas of arable land and lowlands with intense human development, where the demand for flood control is high (Figure 6.5B). This generates relatively low actual ES flow (Figure 6.5C); especially in areas of arable land, where high unmet demand occurs, because there is not enough flood control by either ecosystems or defence measures (Figure 6.5D).

[15] All data are shared in the JRC data catalogue under the MAES collection (https://data.jrc.ec.europa.eu/collection/maes)

[16] All results provided in the study refer only to EU-26, excluding Cyprus, Malta, and some regions in Croatia, Bulgaria and Finland.

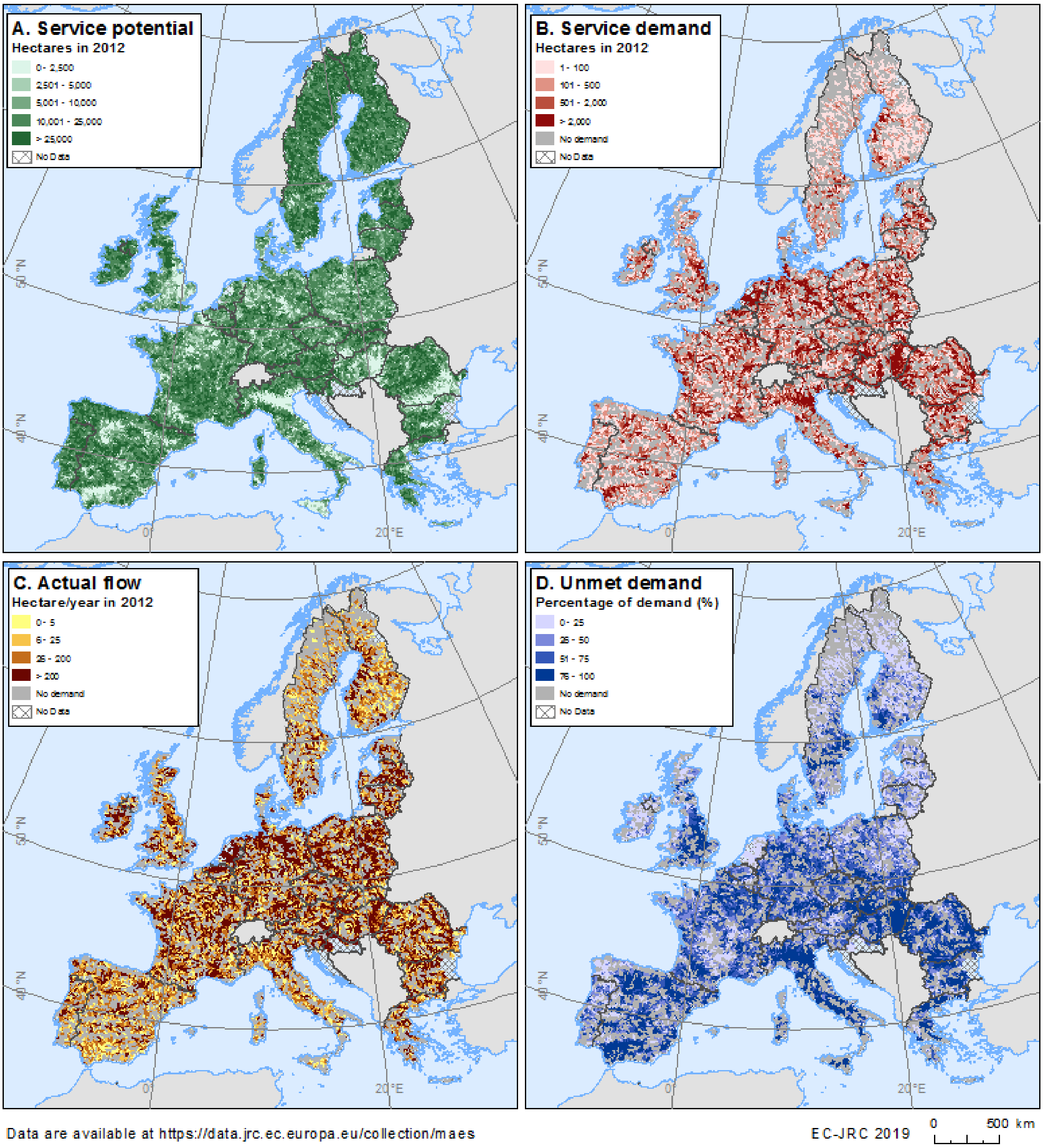



**Figure 6.5.** Maps of the components of flood control as ecosystem service (2012).

Figure 6.6 presents the total amount of people per sub-catchment that are exposed to potential floods in urban areas (for the maximum return period available: 500 years) and which therefore need protection against flooding (population demand). This represents about 8% of the total EU population. Of the total population in need of flood protection, only 19% benefit from ecosystems controlling floods. Importantly, there is 68% of the total EU population that is unprotected by natural control by ecosystems (unmet demand).

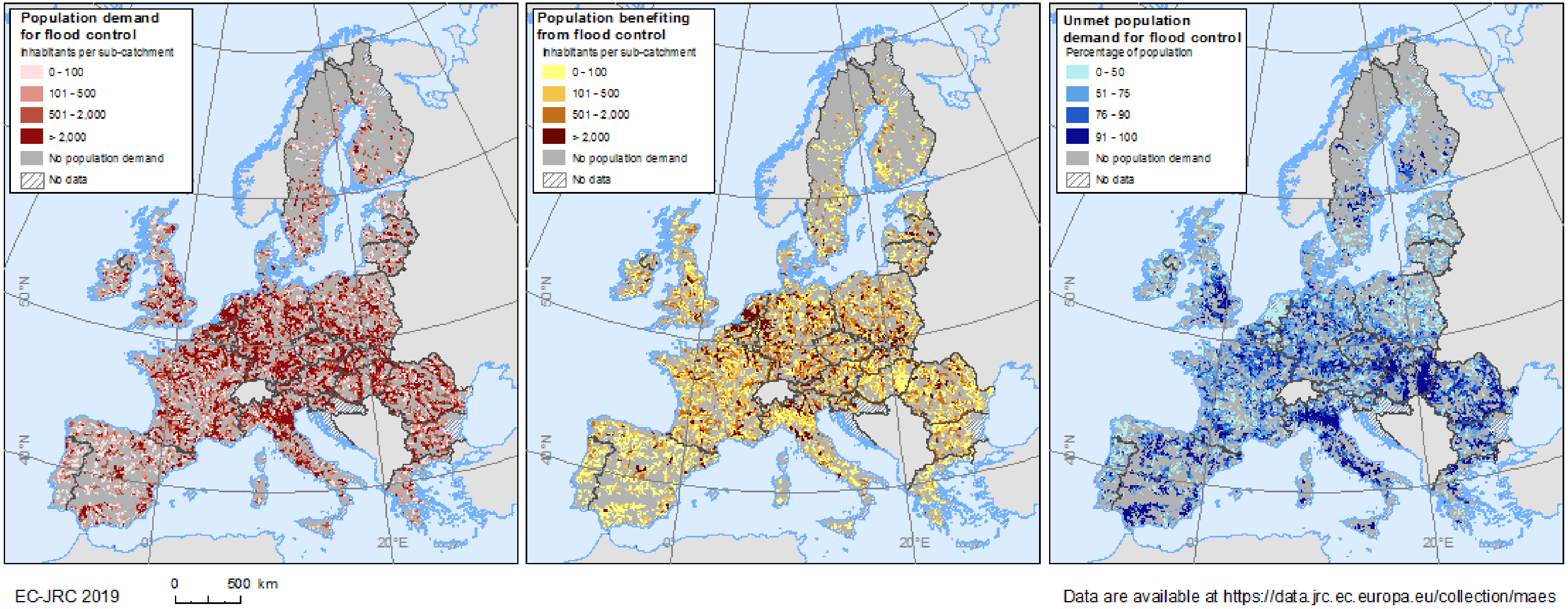



**Figure 6.6.** Maps of population demand, population use, and unmet demand for flood control in 2012.

### 6.4.2 Accounting tables

The following tables show the actual flow of flood control in physical (Table 6.2) and monetary terms (Table 6.3). The EU value of flood control as ecosystem service is estimated as 16,312 million euro in 2012. The supply and use tables in monetary terms (in million euro) show how different ecosystems contribute to flood control (Table 6.3). This table shows the monetary value of flood control by ecosystems by breaking down the total value into $Actual\ flow_{NC}$ and $Actual\ flow_{NC+}$ (Figure 6.4).

Table 6.3 (a) reports the estimation of the contributions of ecosystems to flood control, also where defence measures are in place. In this sense, Table 6.3 shows that natural capital is mainly supporting defence measures (80% by NC+), but it also play an important role controlling floods in the absence of defence measures (20% by NC), where the only contribution to control floods is derived from ecosystems.

In the first case (NC+), a decrease of the ecosystem contribution to controlling floods would require to invest more in defence measures and guarantee the same level of protection. In the second case (NC), a decrease in natural capital would directly imply a decrease in flood control for the final beneficiaries. However, practitioners should keep in mind that accounting tables in monetary terms (Table 6.3) cannot be used to estimate the economic values of flood control provided by defence measures, since they only quantify the role of ecosystems.

The total value of flood control delivered by ecosystems in the EU is the sum of all values for a specific year reported in the supply table. In 2006, the total value amounted to 16,127 million euro and increased by 1.14% to 16,312 million euro in 2012. The same values are returned in the use table which reports the use of flood control by different economic sectors.

From the supply table (Table 6.3 (a)), it is possible to calculate that slightly more than 70% of the total supply value is generated by woodland and forest, even if woodland and forest cover about 36% of the EU (Maes et al., 2015) demonstrating their importance in protecting economic assets against flooding. These outcomes from the supply table are fully consistent with the meaning of the whole adopted procedure: flood control is generated by SPA, and mainly by woodland and forests. In contrast, cropland, which is also a dominant land type in the EU, contributed only to 6%. Grasslands contributed 19% and wetlands just over 2%.

From the use table (Table 6.3 (b)), it is possible to calculate that most of the service flow at the EU[17] (72%) is used by other tertiary economic sectors and households and serves for the protection of residential buildings. When comparing the percentages which refer to monetary estimates with those concerning the surface extension which refer to biophysical estimates (see tables in Annex 13 and Table 6.2) a remarkable difference can be noticed (e.g., agricultural sector versus other tertiary sectors and households). This difference can

[17] Results refer only to EU-26, excluding Cyprus, Malta, and some regions in Croatia and Bulgaria

be easily explained by the fact that the estimated cost per square meter of residential areas is much higher than the estimated cost per square meter of agricultural land. The difference is about three orders of magnitude (e.g., in Belgium the maximum damage expected for residential area is about € 718/$m^2$ and for agricultural land is about € 0.73/$m^2$). In the case of flood control, although the outcomes of the biophysical model are strictly translated into monetary terms, the differences among residential, commercial, and other uses make it evident how interpretation of tables in physical and monetary terms needs to be carefully tackled. Here, it is useful to recall that agriculture is considered both in the supply and use table. Soils in cropland have a role in retaining water (although not at the same levels of forests, grassland or wetlands) while at the same time farmland is using the service for protection of its assets.

Another 13 % is used by mining, manufacturing, and energy production, again for the protection of buildings and infrastructure. About 9% is used by the transport sector for the protection of transport networks. Note that Table 6.3 does not contain information about the monetary value of natural capital to protect people against flooding.

**Table 6.2.** Flood control supply (a) and use (b) tables for EU[18] in physical terms (hectares).

| | Type of economic units | | | | | Ecosystem Types | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Rest of the world | ***Total*** | Urban areas | Cropland | Grassland | Heathland and shrub | Woodland and forest | Sparsely vegetated land | Wetlands |
| *hectare* | | | | | | | | | | | | | |
| 2006 | | | | | | 4,187,973 | 26,159 | 315,864 | 772,658 | 72,379 | 2,932,927 | 247 | 67,740 |
| 2012 | | | | | | 4,169,559 | 26,239 | 313,591 | 767,010 | 72,032 | 2,922,936 | 243 | 67,508 |

*Supply table (a)*

| | Type of economic unit | | | | | | | | Ecosystem Types | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Total** | Agriculture | Mining, manufacturing & energy production | Construction | Transport | Waste management | Other tertiary and Households | Rest of the world | Green urban areas | Cropland | Grassland | Heathland and shrub | Woodland and forest | Sparsely vegetated land | Wetlands |
| *hectare* | | | | | | | | | | | | | | | |
| 2006 | 4,187,973 | 3,691,255 | 39,667 | 3,526 | 301,218 | 1,669 | 150,638 | | | | | | | | |
| 2012 | 4,169,559 | 3,671,353 | 41,710 | 3,825 | 299,210 | 1,645 | 151,817 | | | | | | | | |

*Use table (b)*

[18] Results refer only to EU-26, excluding Cyprus, Malta, and some regions in Croatia, Bulgaria, and Finland

**Table 6.3.** Flood control supply (a) and use (b) tables for EU[19] in monetary terms (million euro).

| | Economic units | | | | | Ecosystem Types | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Rest of the world | ***Total*** | Urban areas | | Cropland | | Grassland | | Heathland and shrub | | Woodland and forest | | Sparsely vegetated land | | Wetlands | |
| *million EUR* | | | | | | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC |
| 2006 | | | | | | **16,127** | 70 | 18.64 | 781 | 230.4 | 2,554 | 545.22 | 253 | 97.2 | 8,764 | 2,480.3 | 0.74 | 0.173 | 243 | 89.1 |
| 2012 | | | | | | **16,312** | 71 | 18.85 | 782 | 232.9 | 2,581 | 548.10 | 256 | 100.2 | 8,883 | 2,505.6 | 0.74 | 0.175 | 244 | 89.4 |

*Supply table (a)*

| | Economic units | | | | | | | | | | | | | | Ecosystem Types | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Total*** | Agriculture | | Manufacturing & energy production | | Construction | | Transport | | Waste management | | Other tertiary and Households | | Rest of the world | Green urban | Cropland | Grassland | Heathland and shrub | Woodland and forest | Sparsely vegetated land | Wetlands |
| *million EUR* | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | | | | | | | | |
| 2006 | **16,127** | 621 | 183.1 | 1,754 | 392.8 | 133 | 23.4 | 1,026 | 366.15 | 0.059 | 0.015 | 9,132 | 2,495 | | | | | | | | |
| 2012 | **16,312** | 617 | 182.1 | 1,822 | 414.5 | 137 | 27.9 | 1,020 | 364.49 | 0.056 | 0.015 | 9,220 | 2,506 | | | | | | | | |

*Use table (b)*

*NC+: areas where the actual ES flow of flood control provides also support to defence measures*

*NC: areas where the actual ES flow of flood control entirely depends on the role of the ecosystem (defence measures are absent)*

[19] Results refer only to EU-26, excluding Cyprus, Malta, and some regions in Croatia, Bulgaria, and Finland

Table 6.2 and Table 6.3 as well as the underlying maps of ES potential, ES use, ES demand and unmet demand (Figure 6.5 and 6.6) are useful to provide insights in how the role of ecosystem can be integrated in new plans with respect to flood control with a view on saving costs by enhancing natural retention measures.

In areas without artificial defence measure (NC), the ES flow represents the only protection against flooding available. Without it, the amount of unmet demand would raise, and as a consequence, also the exposure to potential floods.

Supply and use tables in physical and monetary terms, disaggregated for the 26 member states are available in Annex 13.

## 6.5 Trend analysis for the flood control components

A proper trend analysis was not feasible given the lack a data for a representative time series. However, comparison of flood control accounts at the EU-level[20] for 2006 and 2012 show some changes in this ecosystem service, especially in monetary terms. Global numbers at the EU level show a **decrease in the main components of flood control by ecosystems** in biophysical terms; that is of ES potential, ES demand, and ES flow. On the contrary, in monetary terms the **value of the actual flow of flood control has increased by 1.14%** (Table 6.4). This increase is explained by the increase in artificial land benefiting from ecosystems protection (actual flow for artificial land increased by 0.3%), which is translated in an increase of the monetary value of 1.23%. Importantly, when looking at the value of the actual flow in relation to the amount of demand (euro/km$^2$), a decrease in the value of the ecosystem service for artificial land is noticed (by -0.37%, which corresponds to 3 thousand euro/km$^2$ of artificial land). Although changes are not very important in relative terms, it appears to show a **negative trend for flood control by ecosystems**, meaning that the role of the ecosystem protecting from flood is decreasing. This is especially important for artificial land, and population, where there is also an increase of the unmet demand (Table 6.4).

In this sense, it is important to raise awareness of the need to adopt measures to enhance flood control by ecosystems, which becomes crucial given the increase of demand for this service by artificial land. Importantly, future climate change is expected to increase the damage caused by river floods in the EU (Feyen et al., 2012), which could be partially mitigated through nature-based solutions and ecosystem restoration in the key priority areas.

At the EU-level, 54% of the territory has a high ecosystem potential to reduce runoff (in SPA) and therefore to control floods. **Flood control potential** shows an insignificant net decrease of 0.01% between 2006 and 2012 (Table 6.4). Although this change is relatively

[20] Results refer only to EU-26, excluding Cyprus, Malta, and some regions in Croatia and Bulgaria

small, the gross change was higher with gains of SPA of 5,118 km$^2$ and losses of 5,331 km$^2$ (Figure 6.7).

**Table 6.4.** Changes in flood control at the EU level (EU-26) between 2006 and 2012.

| | 2006 | 2012 | Changes | Changes (%) |
|---|---|---|---|---|
| **ES Potential (km$^2$)** | **2,400,630** | **2,400,417** | **-213** | **-0.01%** |
| Gains (km$^2$) | | | 5,118 | |
| Loses (km$^2$) | | | 5,331 | |
| **ES Demand (km$^2$)** | **142,270** | **142,037** | **-233** | **-0.16%** |
| Artificial land (km$^2$) | 18,560 | 18,859 | 299 | 1.61% |
| Agricultural land (km$^2$) | 123,709 | 123,178 | -532 | -0.43% |
| Population (inhabitants) | 36,000,503 | | NA | NA |
| **ES Actual flow (km$^2$)** | **41,880** | **41,696** | **-184** | **-0.44%** |
| In artificial land (km$^2$) | 4,967 | 4,982 | 15 | 0.30% |
| In agricultural land (km$^2$) | 36,913 | 36,714 | -199 | -0.54% |
| Population (inhabitants) | 5,364,300 | 5,255,126 | -109,173 | -2.04% |
| Share met population-demand | 14.9 | 14.6 | -0.30 | |
| **Unmet demand (km$^2$)** | **95,169** | **95,111** | **-58** | **-0.06%** |
| Unmet demand artificial land (km$^2$) | 12,544 | 12,782 | 238 | 1.90% |
| Unmet demand agricultural land (km$^2$) | 82,625 | 82,329 | -296 | -0.36% |
| Unmet demand population (inhabitants) | 18,524,872 | 18,604,400 | 79,528 | 0.43% |
| **Monetary value actual flow (million euro)** | **16,127** | **16,312** | **185** | **1.14%** |
| In artificial land (million euro) | 15,323 | 15,512 | 189 | 1.23% |
| In artificial land (thousand euro/km$^2$) | 826 | 823 | -3 | -0.37% |
| In agricultural land (million euro) | 804 | 799 | -5 | -0.58% |
| In agricultural land (thousand euro/km$^2$) | 6.5 | 6.5 | 0 | -0.15% |

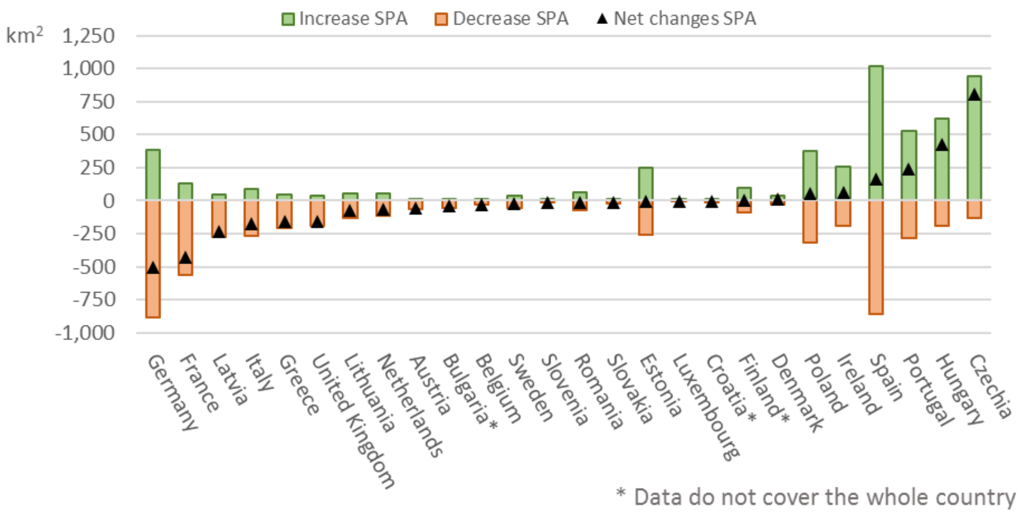



**Figure 6.7.** Gains and losses of Service Providing Areas between 2006 and 2012.

Changes in the potential of ecosystems to control floods are mainly due to land-cover changes. Ecosystem extent accounts provide useful complementary information to gain a better understanding of the drivers at country level. The approach adopted in this work by modelling flood control also highlights the role of **imperviousness as an important driver of change in ES potential**. Approximately 30% of the decrease of SPAs at the EU level is due to an increase in imperviousness, reaching more than 70% for countries like Slovenia and Poland (Figure 6.8).

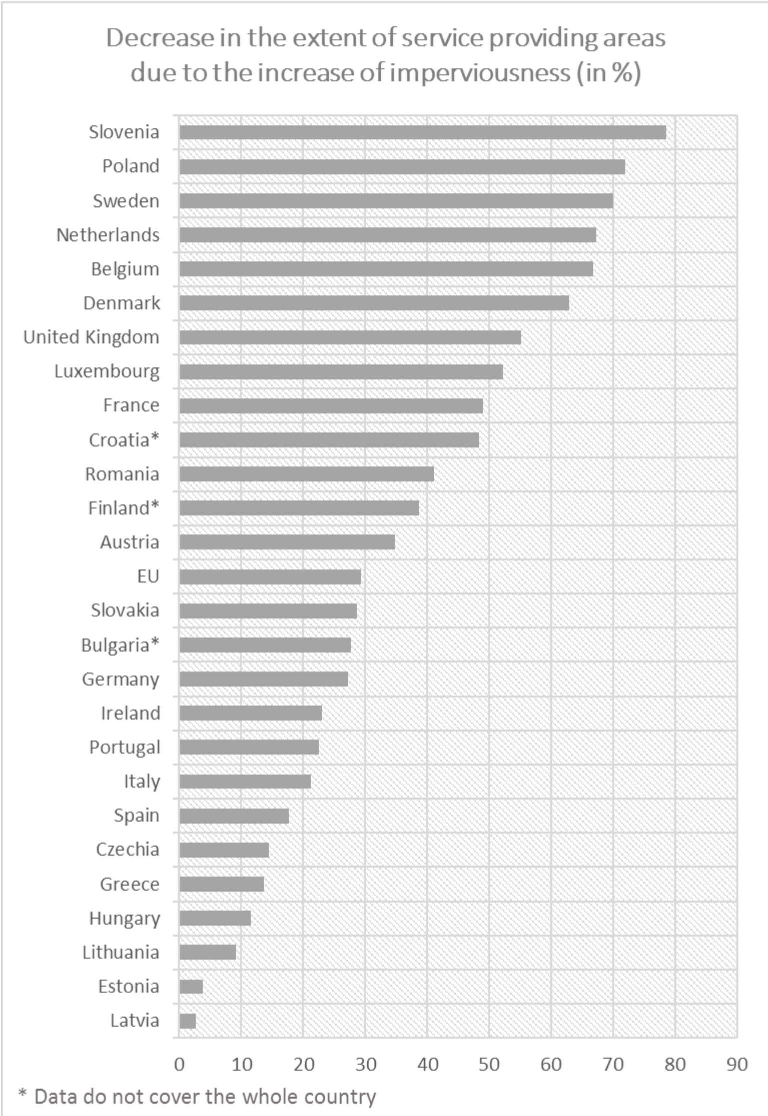



**Figure 6.8.** The role of imperviousness reducing flood control potential between 2006 and 2012.

The decrease in **demand for flood control** is higher than the decrease of ES potential between 2006 and 2012 (Table 6.4). However, when analysing the demand separately for artificial and agricultural land it can be seen that the demand for flood control increased at the EU level for artificial/built-up assets by 1.61%, with all countries showing a positive trend, especially Spain and the Netherlands (Figure 6.9). It means that urban expansion is taking place in areas exposed to floods. On the other hand, the demand for flood control by agricultural land has decreased by 0.43% at the EU level, with most countries showing also a negative trend.

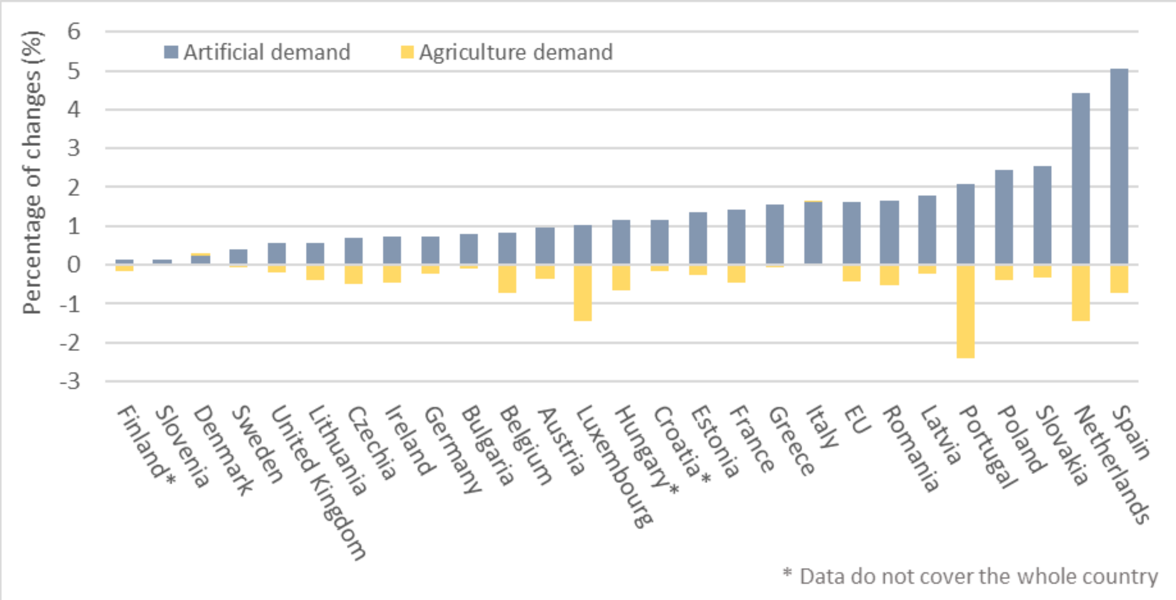



**Figure 6.9.** Changes in the demand for flood control between 2006 and 2012.

As consequence of the decrease in ES potential and demand for flood control, the **actual ES flow in biophysical terms** has also decreased and this at higher rate than the other two components (flood control potential and demand, Table 6.4). At country level, only Hungary and Czechia show an increase of the actual ES flow (Figure 6.10), being also the countries with the highest net increase in SPA (Figure 6.7). On the contrary, the **actual ES flow in monetary units** has increased by 1.14% mainly due to the increase of the actual ES flow in artificial areas. The increase of the value in artificial areas can be explained by the increase of the demand since the relative value of flood control in artificial areas has decreased with 3 thousand EUR/km$^2$.

Importantly, about **67% of the economic assets in flooding areas are not covered by ecosystems** (unmet demand). Changes in the total number of unmet demand show a decrease of -0.06% between 2006 and 2012, however the unmet demand notably increases for artificial land (by +1.90%) and for the population (by +0.43%, assuming no changes in population between 2006 and 2012). At country level, the most important increases of the unmet demand occur in Latvia and Estonia, while Portugal and Ireland show the highest decrease.

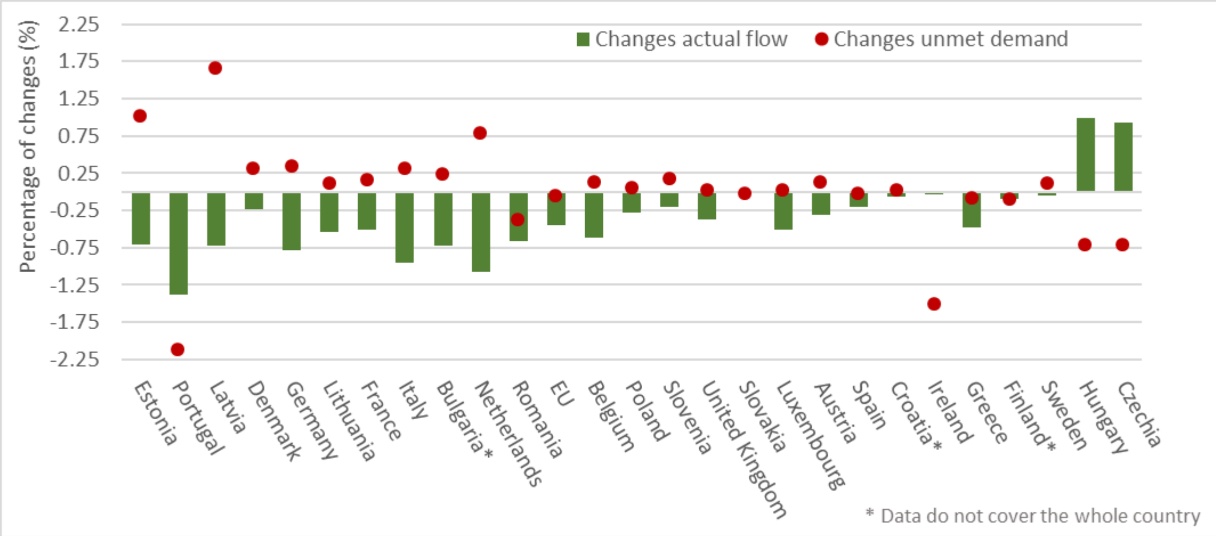



**Figure 6.10.** Changes in the actual ecosystem service flow and unmet demand between 2006 and 2012.

## 6.6 Limitations and further developments of the accounting approach

The account for flood control by ecosystems presented in this report is an experimental exercise to quantify the ES flow based on the interaction between ecosystems and socio-economic systems. For accounting purposes, we developed a **model based on the best available data that was suitable for its integration into an accounting system**. The approach used quantifies the role of the ecosystems regarding flood control in relative terms. It compares the current circumstances with the best situation for flood control (i.e., when the whole demand is covered by SPA). This method provides useful information to make flood control accounts in a consistent way and allows making comparisons over time.

However, as all modelling approaches, the method applied for flood control accounts presents some limitations that should be considered when interpreting the results. The assessment of flood control as ecosystem service already presents some **conceptual challenges** that hinder a proper assessment of the ecosystem role in controlling floods. Ideally, the quantification of the role of the ecosystem in controlling floods should be based on a simulation of different scenarios comparing the current conditions with a hypothetical situation in the absence of a target ecosystem, which is not very realistic. Alternatively, the absence of this target ecosystem should be substituted with other ecosystem type for the simulation. However, different assumptions should be taken to decide to which ecosystem type could be compared. In other words, to quantify the role of forest in controlling floods we should compare the current forest scenario with a scenario covered by another ecosystem type that could be artificial land, pasture, or cropland. Therefore, the role of forest could be provided in relative terms compared to other land cover types. In this case, the valuation method could provide the value of forest compared to the chosen alternative land cover based on the damage of the flooding areas simulated under the two scenarios.

Another limitation of the approach used is **that flood plains, and consequently the corresponding damage cost, are defined given the landscape condition of a specific year**. Therefore, somehow in the assessment we might be underestimating the role of some ecosystem types if they already contribute to reducing the extent of area flooded. This limitation would also be addressed by using simulations of different ecosystem scenarios. However, this alternative method would be much more demanding in terms of data needed, technical skills to make the flood inundation simulations and processing time, which make it difficult to generate regular updates required for accounting.

Other limitations are related to the **lack of data for representative time series**. Actually, the assessment of changes is based only on a period of 6 years. Even for the period assessed, data on the level of defence, the road network and population data are static over time. The lack of spatially explicit data at the EU level for different years hampered the integration of these variables in a dynamic way when modelling flood control by ecosystems.

As mentioned before, for the sake of simplicity, we allocated sub-catchments to the different country based on the place where the centroid of the catchment was located, ignoring therefore the complexity that may arise in the analysis in cases in which a sub-catchment is shared by two different countries. For instance, ecosystems in the upper part of a catchment belonging to one country may have an impact on the benefits generated to other country downstream of the catchment, where most of the demand is located. This is known in the literature as (Sonter et al., 2017), that should be considered in further development of the accounts for flood control by ecosystems.

## 6.7 Summary of flood control accounts

**Box 4.** Flood control accounts: main outcomes

Mapping flood control potential, demand, actual ecosystem service flow, and unmet demand over time gives relevant information:

- To identify where natural capital can provide flood control (ES potential); which is decreasing in most EU-countries.

- To identify where flood control is necessary and therefore, natural capital controlling floods can be beneficial for the society. All countries show an increase of artificial land in the need for flood control (demand).

- To identify where natural capital generates a higher actual ES flow of flood control (flow in biophysical terms), and where the benefits generated by this flow are higher (flow in monetary terms).

- This experimental of Supply and use tables in monetary terms shows a value of ES flow of flood control at the EU level of 16,312 million euro in 2012, which increased since 2006 by 1.14%. This increase is mainly due to an increase of artificial land benefiting from flood control by ecosystems.

- However, increase of the value of flood control does not imply an enhancement of natural capital controlling floods. Actually, the relative value of the service flow (as measured by the euros per $km^2$ of demand) has decreased for both, artificial and agricultural land.

- The negative trend for flood control is also confirmed by the increase of areas without protection from ecosystems (unmet demand): with an increase of unmet demand by 1.9% for artificial land and by 0.43% for the EU population. Within the process of developing flood risk management plans, a special consideration should be put on areas with high unmet demand.

- Supply and use tables show that 80% of the flood control ES flow in monetary terms enhances and support existing defence measures. However, there is an important role for ecosystem types in supporting these defence measures and through accounting, there might be the possibility to assess this contribution. The remaining 20% (in monetary terms) is not covered by defence measures and it is only protected by natural capital.

The outcomes of flood control accounts can support the development of flood risk management plans (EU Floods Directive). Of course, decision-making processes are complex, and complementary data at local scale would be needed before the policy decision is taken.

# 7 Conclusions: towards an integrated assessment

The ecosystem service accounts presented in this report, together with the accounts published in Part I (Vallecillo et al., 2018) constitute a practical application of the SEEA EEA (UN et al., 2014b). In the KIP INCA project, we have accounted so far for six ecosystem services. For three ecosystem services (crop provision, timber provision, and global climate regulation) we have applied a fast-track approach based on official statistics; while for the other three (crop pollination, flood control, and nature-based recreation) we have used spatially explicit models mapping the key components of ecosystem services: ES potential, ES demand and actual flow (or service use). Complementary assessment of the unmet demand has been also proved to be useful for ecosystem service accounts (La Notte et al., 2019b).

The use of currency expressed in euro as common unit to quantify the importance of each ecosystem service allows summing up all values to estimate the total value of ecosystem assets for the range of ecosystem services assessed (La Notte et al., 2019a). Ecosystem service accounts at the EU level are summarized in the supply and use tables for 2012 (Table 7.1 and Table 7.2, respectively). The supply table (Table 7.1) shows woodland and forest as the ecosystem type with the highest absolute and relative values. In absolute terms, cropland appears as the second most important ecosystem type given its large extent at the EU level. However, when it comes to relative values (value per square kilometre) cropland is among the ecosystem services with the lowest value. The value of rivers and lakes and coastal areas should be interpreted with caution, because their value is based only on nature-based recreation. Nonetheless, they also play a role in global climate regulation and flood control but these contributions could not be assessed by the model and data we used. After woodland and forest, the ecosystem type with a higher value for the six ecosystem services accounts available so far are wetlands. This value could be significantly higher if measures are implemented to favour the role of wetlands as sinks of $CO_2$ (see section on global climate regulation for a detailed discussion).

In relation to the use table for the six ecosystem service accounts at the EU level (Table 7.2) households, followed by agriculture, are the main beneficiaries of these ecosystem services. They are attributed with an annual monetary flow of about 62 billion euro and 25.7 billion euro, respectively. It is important to bear in mind that these results are an experimental exercise to account for ecosystem services in biophysical and monetary terms. As such, methods presented in Part I (Vallecillo et al., 2018) and in this report are subject to further development and adjustment. Therefore, values presented here are susceptible to be changed in the future before the method for the accounts can be consolidated. Updating and improving methodologies is a common practice for standard accounts and in particular for experimental accounts.

**Table 7.1.** Supply table in monetary terms for six ecosystem services.

| Year 2012, million EUR | Ecosystem type | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| Ecosystem service | Urban | Cropland | Grassland | Heathland and shrub | Woodland and forest | Sparsely vegetated land | Wetlands | Rivers and lakes | Coastal and intertidal areas | |
| **Crop provision** | | 20,560 | | | | | | | | **20,560** |
| **Timber provision** | | | | | 14,540 | | | | | **14,540** |
| **Global climate regulation** | 20 | 150 | 860 | 20 | 13,330 | 20 | 0 | NA | NA | **14,400** |
| **Flood control** | 90 | 1,010 | 3,130 | 360 | 11,390 | 0 | 330 | NA | NA | **16,310** |
| **Crop pollination** | | 4,360 | | | | | | | | **4,360** |
| **Nature-based recreation** | 80 | 4,070 | 7,480 | 3,100 | 30,720 | 1,350 | 2,300 | 1,010 | 280 | **50,390** |
| **VALUE (EUR million)** | 190 | 30,150 | 11,470 | 3,480 | 69,980 | 1,370 | 2,630 | 1,010 | 280 | **120,560** |
| **VALUE (EUR/km²)** | 900 | 18,750 | 22,668 | 19,230 | 44,010 | 23,220 | 26,840 | 9,270 | 1,460 | **26,470** |

Values rounded to the nearest tens

NA: not assessed

**Table 7.2.** Use table in monetary terms for six ecosystem services.

| Year 2012, million EUR | Economic units | | | | | | |
|---|---|---|---|---|---|---|---|
| | Primary sector | | | | | | |
| Ecosystem service | Agriculture | Forestry | Industry | Services | Households | Global society | TOTAL |
| **Crop provision** | 20,560 | | | | | | **20,560** |
| **Timber provision** | | 14,540 | | | | | **14,540** |
| **Global climate regulation** | | | | | | 14,400 | **14,400** |
| **Flood control** | 800 | 0 | 2,400 | 1,380 | 11,730 | | **16,310** |
| **Crop pollination** | 4,360 | | | | | | **4,360** |
| **Nature-based recreation** | | | | | 50,390 | | **50,390** |
| **VALUE (EUR million)** | 25,720 | 14,540 | 2,400 | 1,380 | 62,120 | 14,400 | **120,560** |

Values rounded to the nearest tens

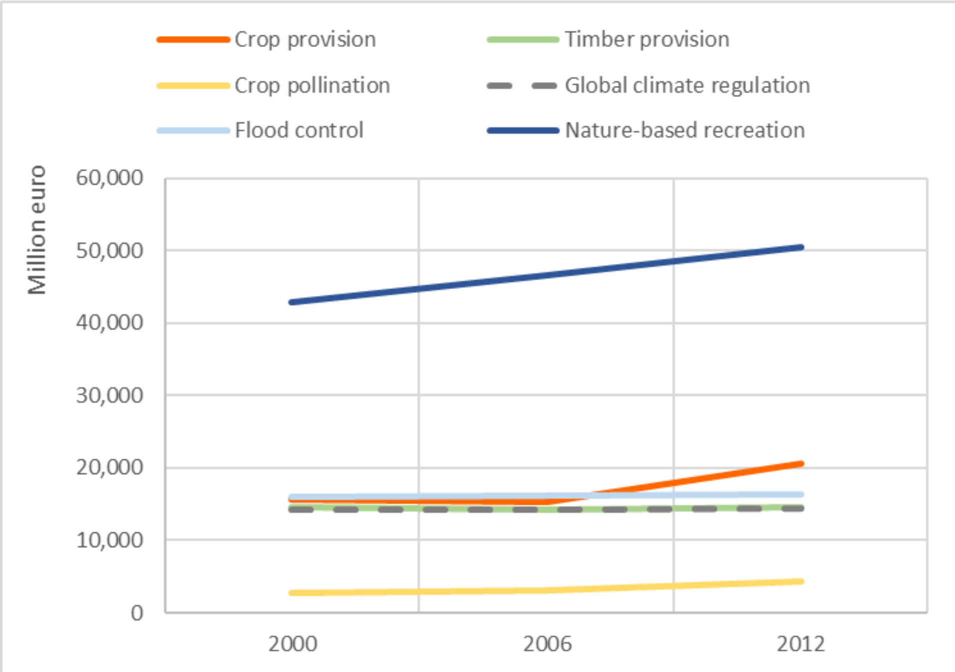
NA: not assessed

The changes over the time (year 2000, 2006, and 2012[21]) show an increasing trend in the value of the six ecosystem services assessed (Figure 7.1). However, this positive trend does not necessarily imply an enhancement of the natural capital, but rather a higher dependency of socio-economic systems on the role of ecosystems contributing to human well-being. This higher dependency is very clear for crop pollination and flood control, where the increase of the value of the actual flow is mainly due to an increase of the demand, and therefore an increase of the benefit generated. In the case of nature-based recreation, the increase of the value is mainly due to an increase of the ES potential, with the designation of new Natura 2000 sites as main driver, but also to an increase of the demand. Population increase implies that there are more inhabitants potentially benefiting from ecosystems for nature-based recreation.

Unfortunately, interpretation of changes for ecosystem services whose account was built on official reported data is more limited since detailed information on the drivers of change are lacking, unless a detailed study complementary to the accounts is carried out. Nevertheless, these fast-track accounts based on official reported data presents important advantages: they can be very easily replicated and updated, and they are based on official reported data at national level, which are already accepted by the reporting countries. Importantly, they provide relevant information to the whole picture of ecosystem services in a cost-effective way.

[21] Values for flood control in 2000 and nature-based recreation in 2006 were interpolated based on the same rate of changes quantified for the time period available.

**Figure 7.1.** Trend in the value of six ecosystem services at the EU level.




Future releases of pilot ecosystem services accounts will include water purification, habitat maintenance and soil erosion control. The final integrated assessment will be carried out at the end of the KIP INCA project, when a more comprehensive list of ecosystem services become available. The integration of ecosystem services accounts will be useful to make ecosystem service trade-offs in decision making more transparent, inform efficient use of resources, enhance resilience and sustainability, and avoid unintended negative consequences of policy actions (Schaefer et al., 2015).

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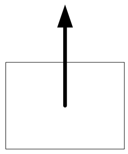
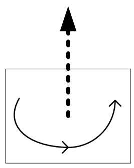
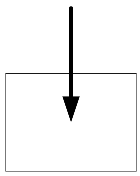
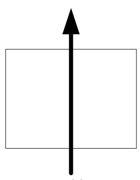
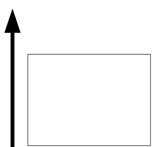
## Annexes

Annex 1. Correspondence between CORINE Land cover classes and ecosystem types (Maes et al. 2013).

| MAES ecosystem | CORINE Land Cover |
|---|---|
| Urban | Continuous urban fabric |
| | Discontinuous urban fabric |
| | Industrial or commercial units |
| | Road and rail networks and associated land |
| | Port areas |
| | Airports |
| | Mineral extraction sites |
| | Dump sites |
| | Construction sites |
| | Green urban areas |
| | Sport and leisure facilities |
| Cropland | Non-irrigated arable land |
| | Permanently irrigated land |
| | Rice fields |
| | Vineyards |
| | Fruit trees and berry plantations |
| | Olive groves |
| | Annual crops associated with permanent crops |
| | Complex cultivation patterns |
| | Land principally occupied by agriculture, with significant areas of natural vegetation |
| | Agro-forestry areas |
| Grassland | Natural grasslands |
| | Pastures |
| Heathland and shrub | Moors and heathland |
| | Sclerophyllous vegetation |
| Woodland and forest | Broad-leaved forest |
| | Coniferous forest |
| | Mixed forest |
| | Transitional woodland-shrub |
| Sparsely vegetated land | Beaches, dunes, sands |
| | Bare rocks |
| | Sparsely vegetated areas |
| | Burnt areas |
| | Glaciers and perpetual snow |
| Wetland | Inland marshes |
| | Peat bogs |
| Rivers and lakes | Water courses |
| | Water bodies |
| Marine inlets and transitional water | Salt marshes |
| | Salines |
| | Intertidal flats |
| | Coastal lagoons |
| | Estuaries |

Annex 2. Typologies of ES flow according to the role of ecosystems (source La Notte et al. (2019)[22]).

| **Role of the ecosystem** | **Potential flow** | **Description** |
|---|---|---|
|  Source: productivity | Net delivery of biomass or energy eventually leaving the ecosystem | Ecosystems act as sources of matter and energy in the form of biomass. |
|  Source: suitability | Delivery of biomass and energy generated within the ecosystem | Ecosystems act as sources of matter and energy by providing suitable habitats. |
|  Sink | Matter or energy absorbed by the ecosystem | Ecosystems act as sinks to store, immobilise or absorb matter. |
|  Buffer | Matter or energy flowing through the ecosystem | Ecosystems act as transformers, changing the magnitude of flows of matter or energy. |
|  Information | Information delivered by the ecosystem | Ecosystems deliver information. The information generated does not modify the original state of the ecosystem. |

*Legend:*

*squares represent an ecosystem unit and arrows represent the type of matter/energy/information delivered*

[22] La Notte, A., Vallecillo S., Marques A., Maes J., (2019). "Beyond the economic boundaries to account for ecosystem services." Ecosystem Services 35: 116-129. Available at https://www.sciencedirect.com/science/article/pii/S2212041617307246

Annex 3. Transformity coefficients applied in the emergy approach

| | | average /curent estimate | | Ghaley et al 2013 | | Coppola et al 2009 | | La Rosa et al 2008 | | Zhang et al 2007 | | Martin et al 2006 | | Brandt-Williams 2001 | | Ulgiati et al 1994 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **TRANSFORMITY** | | TRANSFORMITY | | TRANSFORMITY | | TRANSFORMITY | | TRANSFORMITY | | TRANSFORMITY | | TRANSFORMITY | | TRANSFORMITY | |
| | | **SEJ/J, or SEJ/g** | | SEJ/J, or SEJ/g | | SEJ/J, or SEJ/g | | SEJ/J, or SEJ/g | | SEJ/J, or SEJ/g | | SEJ/J, or SEJ/g | | SEJ/J, or SEJ/g | | SEJ/J, or SEJ/g | |
| | | | | **WHEAT** | | **WHEAT** | | **Oranges** | | **Crops** | | **CORN** | | **CORN** | | **SUGAR BEET** | |
| | unit | | | **DENMARK** | | **DENMARK** | | **Sicicly** | | **China(north)** | | **KANSAS** | | **FLORIDA** | | **ITALY** | |
| **Renewable Resources** | | | | | | | | | | | | | | | | | |
| sunlight | J | **1.00 E00** | | 1.00 E00 | **3,4** | 1.00 E00 | **5** | 1.00 E00 | **6** | 1.00 E00 | **4** | 1.00 E00 | | 1.00 E00 | **3,4** | 1.00 E00 | **2** |
| wind , kinetic energy | J | **2.50 E03** | | 2.45 E03 | **3,4** | 2.52 E03 | **5** | 1.5 E03 | **6** | 2.45 E03 | **4** | 1.50 E03 | **3** | | | | |
| evaporation | J | **3.00 E05** | | | | | | | | 3.06 E04 | **4** | | | *1.54 E04* | **3** | | |
| (corrected by 1.68) | | | | | | | | | | | | | | 2.85 E05 | | | |
| Rainfall (chem) | J | **3.05 E04** | | 3.02 E04 | **3,4** | | | 1.82 E04 | **3** | | | 1.82 E04 | **3** | | | 1.82 E04 | **2** |
| **Non Renewable Resources** | | | | | | | | | | | | | | | | | |
| Soil erosion/loss | J | **1.24 E05** | | 1.24 E05 | **7** | 1.24 E05 | **5** | 1.24 E05 | **3,4** | 1.92 E05 | **12** | 6.25 E04 | **2** | *7.38 E04* | **4** | *6.25 E04* | **2** |
| (corrected by 1.68) | | | | | | | | | | | | | | 1.24 E05 | | 1.05 E05 | |
| **Purchased inputs** | | | | | | | | | | | | | | | | | |
| N Fertilisers | g | **2.4 E10** | | 4.05 E10 | **7** | 2.42 E10 | **7** | 4.0 E10 | **4** | 2.41 E10 | **7** | 2.41 E10 | **7** | 2.41 E10 | **4** | 4.62 E09 | **2** |
| K fertilisers | g | **1.8 E09** | | 1.85 E09 | **7** | 1.47 E09 | **7** | 3.01 E9 | **4** | 1.74 E09 | **7** | | | 1.74 E09 | **3,4** | 2.96 E09 | **2** |
| P fertilisers | g | **2.2 E10** | | 3.70 E10 | **7** | 2.02 E10 | **7** | 3.69 E10 | **4** | 2.20 E10 | **7** | 2.20 E10 | **7** | 2.20 E10 | **4** | 1.78 E10 | **2** |
| Manure | g | **2.13 E08** | | 2.13 E08 | **10** | 2.13 E08 | **10** | | | | | | | | | | |
| irrigation water | g | **7.61 E05** | | | | | | 5.12 E5 | 9 | | | 13.3 E05 | **9** | | | | |
| Pesticide | g | **1.48 E10** | | | | 1.85 E09 | **4** | 1.48 E10 | **7** | 1.48 E10 | **7** | | | 1.48 E10 | **1** | | |
| Pesticide | J | **1.11 E05** | | | | | | | | | | | | | | *6.60 E04* | **2** |
| (corrected by 1.68) | | | | | | | | | | | | | | | | 1.11 E05 | |
| *Herbicide* | *g* | ***1.48 E10*** | | *2.52 E10* | ***7*** | | | | | | | *1.48 E10* | ***7*** | | | | |
| *Insecticide* | *g* | ***1.48 E10*** | | | | | | | | | | *1.48 E10* | ***7*** | *1.48 E10* | ***1*** | | |
| *Fungicide* | *g* | ***1.48 E10*** | | *2.52 E10* | ***7*** | | | | | | | | | *1.48 E10* | ***1*** | | |
| Seeds | g | **1.67 E09** | | 1.20 E08 | **13** | 1.20 E09 | orig | | | | | 3.64 E05 | **8** | | | | |
| Seeds | J | | | | | | | | | | | | | | | *6.60 E04* | **2** |
| (corrected by 1.68) | | | | | | | | | | | | | | | | 1.11 E05 | |
| Diesel oil/fuel | J | **1.11 E05** | | 1.11 E05 | **7** | 1.10 E05 | **4** | | | 1.6 E05 | **4** | *6.60 E04* | **3** | *6.60 E04* | **3,4** | *6.60 E04* | **2** |
| Gasoline | J | **1.11 E05** | | | | | | 1.1 E05 | **3,4** | | | | | | | *6.60 E04* | **2** |
| Lubricants | J | **1.11 E05** | | | | 1.10 E05 | **4** | | | | | | | | | *6.60 E04* | **2** |
| Steel Machinery | g | **1.12 E10** | | 1.12 E10 | **7** | 1.13 E10 | **5** | | | | | | | | | *6.60 E04* | **2** |
| steel & iron | g | **5.31 E09** | | | | | | | | | | | | | | | |
| Human Labour | J | **3.8 E05 - 1.2** | | | | 1.24 E07 | **5** | 7.38 E6 | **2** | 3.80 E05 | **11** | | | 4.50 E06 | **2** | 7.38 E06 | **2** |
| Electricity | J | **2.00 E05** | | | | 2.00 E05 | **2** | 1.43 E05 | **14** | 2.69 E05 | **4** | 2.00 E05 | **2** | 1.60 E05 | **3,4** | 2.00 E05 | **2** |

| | | | |
|---|---|---|---|
| **1** | Brown & Arding, 1991 | **8** | Trujillo, 1998 |
| **2** | Ulgiati 1994 | **9** | Buenfil 2000 |
| **3** | Odum 1996 Env Accounting | **10** | Bastianoni et al 2001 |
| **4** | Odum, Brown & Brandt Williams 2000 | **11** | Lan et al, 2002 |
| **5** | Odum 2000 | **13** | Coppola et al. 2009 |
| **6** | Brown , Bardi (2001) | **14** | Bastianoni et al ? Italian Electicity prod. |
| **7** | Brandt-Williams 2004 | **15** | Tiezzi, Italian calculation |

Annex 4. Accounting tables for crop provision.

A.4.1 – Supply of crop provision in physical terms (1,000 tonne), year 2006

| *1,000 tonne* | Institutional sectors: Agriculture | Fisheries | Secondary sector | Tertiary sector | Households | Rest of the world | Type of ecosystem unit: Urban | Cropland | Grassland | Woodland and forest | Heathland and shrub | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT | | | | | | | | 1,949 | | | | | | | |
| BG | | | | | | | | 1,498 | | | | | | | |
| BL | | | | | | | | 3,573 | | | | | | | |
| CZ | | | | | | | | 3,315 | | | | | | | |
| DE | | | | | | | | 31,572 | | | | | | | |
| DK | | | | | | | | 3,527 | | | | | | | |
| EE | | | | | | | | 410 | | | | | | | |
| EL | | | | | | | | 301 | | | | | | | |
| ES | | | | | | | | 6,758 | | | | | | | |
| FI | | | | | | | | 1,800 | | | | | | | |
| FR | | | | | | | | 28,810 | | | | | | | |
| HR | | | | | | | | 951 | | | | | | | |
| HU | | | | | | | | 4,864 | | | | | | | |
| IR | | | | | | | | 721 | | | | | | | |
| IT | | | | | | | | 9,396 | | | | | | | |
| LT | | | | | | | | 518 | | | | | | | |
| LV | | | | | | | | 1,409 | | | | | | | |
| NL | | | | | | | | 5,640 | | | | | | | |
| PL | | | | | | | | 13,142 | | | | | | | |
| PT | | | | | | | | 1,327 | | | | | | | |
| RO | | | | | | | | 5,542 | | | | | | | |
| SE | | | | | | | | 1,758 | | | | | | | |
| SI | | | | | | | | 296 | | | | | | | |
| SK | | | | | | | | 1,638 | | | | | | | |
| UK | | | | | | | | 7,797 | | | | | | | |
| EU | | | | | | | | 138,513 | | | | | | | |

A.4.2 – Use of crop provision in physical terms (1,000 tonne), year 2006

| | Institutional sectors | | | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | Other economic sectors | Households | Rest of the world | |
| *1,000 tonne* | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | | | | |
| AT | 257 | 12 | 223 | 39 | 129 | 76 | 29 | 17 | 3 | 229 | 830 | 97 | 10 | | | | |
| BG | 695 | 1.4 | 125 | 6 | 230 | 0.06 | 0.53 | 295 | 0.39 | 3 | 94 | 9 | 39 | | | | |
| BL | 228 | - | 61 | 7 | 38 | 0.06 | 7 | - | 1.37 | 608 | 2,247 | 1 | 373 | | | | |
| CZ | 826 | - | 539 | 58 | 79 | 4 | 338 | 26 | 5 | 540 | 878 | 6 | 17 | | | | |
| DE | 3,829 | 8 | 2,434 | 249 | 393 | - | 1,068 | 19 | 73 | 3,909 | 17,440 | 140 | 2,009 | | | | |
| DK | 935 | - | 992 | 89 | - | - | 109 | - | 6 | 516 | 51 | 491 | 338 | | | | |
| EE | 114 | - | 143 | 42 | - | 0.141 | 57 | - | 1 | - | 4 | 30 | 20 | | | | |
| EL | 27 | 41 | 28 | 1 | 82 | 0.001 | 6 | 0.12 | 5 | 41 | 20 | 8 | 42 | | | | |
| ES | 725 | 122 | 1,733 | 274 | 554 | 2 | 4 | 128 | 94 | 805 | 655 | 1,407 | 256 | | | | |
| FI | 311 | - | 602 | 290 | - | 0.09 | 35 | 0 | 2 | 136 | - | 357 | 67 | | | | |
| FR | 4,915 | 267.21 | 1,860 | 161 | 1,165 | 0.11 | 699 | 378 | 280 | 3,235 | 12,730 | 2,366 | 753 | | | | |
| HR | 180 | 1.03 | 54 | 17 | 247 | 0.97 | 9 | 17 | 1 | 217 | 145 | 35 | 28 | | | | |
| HU | 1,377 | 10 | 403 | 65 | 943 | 8 | 148 | 297 | 9 | 391 | 1,111 | 17 | 86 | | | | |
| IR | 137 | - | 235 | 30 | - | - | 5 | - | 5 | 200 | 7 | 50 | 52 | | | | |
| IT | 387 | 447 | 232 | 73 | 1,196 | 3 | 1.34 | - | 29 | 1,036 | 1,869 | 3,967 | 156 | | | | |
| LT | 186 | - | 111 | 58 | 0 | 4 | 69 | - | 0 | 47 | 4 | 27 | 12 | | | | |
| LV | 433 | - | 402 | 67 | - | 8 | 105 | - | 8 | 170 | 98 | 28 | 90 | | | | |

| | Institutional sectors | | | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | Other economic sectors | Households | Rest of the world | |
| *1,000 tonne* | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | | | | |
| NL | 185 | - | 84 | 3 | 20 | 7 | 3 | - | 4 | 1,180 | 3,231 | 3 | 921 | | | | |
| PL | 1,647 | - | 1,126 | 1,520 | 211 | 21 | 445 | 0 | 5 | 1,827 | 5,166 | 0.27 | 1,173 | | | | |
| PT | 30 | 0.5092 | 19 | 15 | 107 | 0.016 | - | 2.0 | 1.2 | 50 | 388 | 667 | 48 | | | | |
| RO | 1,609 | 0.8768 | 227 | 100 | 2,323 | 0.005 | 28 | 258 | 10 | 157 | 170 | 444 | 214 | | | | |
| SE | 526 | - | 411 | 313 | 2 | - | 71 | - | 10.561 | 105 | 87 | 209 | 23 | | | | |
| SI | 22 | - | 12 | 2 | 48 | 0.01 | 1.45 | - | 0.007 | 25 | 173 | 0.9 | 12 | | | | |
| SK | 380 | 3 | 214 | 15 | 100 | 0.86 | 100 | 25 | 5 | 266 | 509 | 4 | 16 | | | | |
| UK | 2,097 | 1 | 1,024 | 165 | 17 | - | 586 | 0 | 197 | 1,529 | 80 | 1,600 | 501 | | | | |
| EU | 22,061 | 915 | 13,293 | 3,660 | 7,881 | 134 | 3,922 | 1,463 | 756 | 17,222 | 47,985 | 11,967 | 7,254 | | | | |

A.4.3 – Supply of crop provision in monetary terms (million euro), year 2006

| | Institutional sectors | | | | Type of ecosystem unit | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *million euro* | Agriculture | Other economic sectors | Households | Rest of the world | Urban | Cropland | Grassland | Woodland and forest | Heathland and shrub | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| AT | | | | | | 131 | | | | | | | |
| BG | | | | | | 197 | | | | | | | |
| BL | | | | | | 2,481 | | | | | | | |
| CZ | | | | | | 311 | | | | | | | |
| DE | | | | | | 1,965 | | | | | | | |
| DK | | | | | | 381 | | | | | | | |
| EE | | | | | | 67 | | | | | | | |
| EL | | | | | | 59 | | | | | | | |
| ES | | | | | | 891 | | | | | | | |
| FI | | | | | | 217 | | | | | | | |
| FR | | | | | | 2,887 | | | | | | | |
| HU | | | | | | 605 | | | | | | | |
| IR | | | | | | 83 | | | | | | | |
| IT | | | | | | 805 | | | | | | | |
| LT | | | | | | 42 | | | | | | | |
| LV | | | | | | 749 | | | | | | | |
| NL | | | | | | 380 | | | | | | | |
| PL | | | | | | 1,009 | | | | | | | |
| PT | | | | | | 95 | | | | | | | |
| RO | | | | | | 789 | | | | | | | |
| SE | | | | | | 227 | | | | | | | |
| SI | | | | | | 24 | | | | | | | |
| SK | | | | | | 158 | | | | | | | |
| UK | | | | | | 800 | | | | | | | |
| EU | | | | | | 15,353 | | | | | | | |

A.4.4 – Use of crop provision in monetary terms (million euro), year 2006

| | Institutional sectors | | | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | | | | |
| *million euro* | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | Other economic sectors | Households | Rest of the world | |
| AT | 32 | 2 | 25 | 4 | 18 | 10 | 7 | 4 | 0.3 | 8 | 18 | 2 | 1 | | | | |
| BG | 78 | 0.2 | 14 | 1 | 24 | 0.01 | 0.12 | 69 | 0.10 | - | 3 | - | 9 | | | | |
| BL | 501 | - | 128 | 18 | 83 | 0.14 | 26 | - | 0.37 | 609 | 159 | 0 | 957 | | | | |
| CZ | 101 | - | 66 | 6 | 10 | 1 | 79 | 6 | 1 | 20 | 17 | 0 | 3 | | | | |
| DE | 497 | 1 | 307 | 29 | 56 | - | 259 | 5 | 9 | 137 | 434 | 3 | 226 | | | | |
| DK | 106 | - | 151 | 14 | - | - | 28 | - | 1 | 21 | 3 | 24 | 34 | | | | |
| EE | 18 | - | 21 | 6 | - | 0.021 | 17 | - | - | - | - | 2 | 4 | | | | |
| EL | 5 | 10 | 5 | 0 | 16 | 0 | - | 0.04 | 6 | 2 | 1 | 0 | 14 | | | | |
| ES | 141 | 41 | 332 | 56 | 107 | 0 | 1 | 55 | 30 | 37 | 10 | 22 | 58 | | | | |
| FI | 51 | - | 94 | 43 | - | 0.01 | 12 | - | - | - | - | 18 | - | | | | |
| FR | 782 | 0.00 | 281 | 26 | 189 | 0.02 | 212 | 135 | 60 | 116 | 797 | 148 | 140 | | | | |
| HU | 209 | 1 | 52 | 9 | 126 | 1 | 34 | 115 | - | 16 | 27 | 0 | 15 | | | | |
| IR | 18 | - | 29 | 4 | - | - | 2 | - | 2 | - | 1 | 8 | 18 | | | | |
| IT | 58 | 105 | 34 | 12 | 177 | 1 | 0.22 | 13 | 11 | 49 | 89 | 198 | 58 | | | | |

| | Institutional sectors | | | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | Other economic sectors | Households | Rest of the world | |
| | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | | | | |
| *million euro* | | | | | | | | | | | | | | | | | |
| LT | 11 | - | 11 | 6 | - | 0 | 12 | - | - | 1 | 0 | - | 1 | | | | |
| LV | 248 | - | 246 | 44 | - | 5 | 110 | - | - | 25 | - | 3 | 69 | | | | |
| NL | 29 | - | 11 | 0 | 2 | 1 | 0 | - | 2 | 46 | 173 | 0 | 116 | | | | |
| PL | 245 | - | 156 | 193 | 29 | 2 | 114 | 1 | 2 | 76 | 67 | 0 | 125 | | | | |
| PT | 3 | 0.0019 | 3 | 2 | 20 | 0.003 | - | 0.6 | 0.7 | 3 | 18 | 33 | 11 | | | | |
| RO | 213 | 0 | 32 | 16 | 346 | 0.001 | 6 | 93 | - | 4 | 9 | - | 70 | | | | |
| SE | 75 | - | 56 | 39 | - | - | 19 | - | 0.001 | 4 | - | 31 | 4 | | | | |
| SI | 4 | - | 2 | 0 | 8 | 0.00 | 0.35 | 0.01 | 0.001 | - | 7 | 0.0 | 2 | | | | |
| SK | 50 | - | 30 | 2 | 13 | 0.11 | 23 | 15 | - | 10 | 12 | 0 | 3 | | | | |
| UK | 250 | - | 128 | 19 | 2 | - | 150 | - | 34 | 60 | 3 | 59 | 95 | | | | |
| EU | 3,724 | 162 | 2,214 | 547 | 1,225 | 20 | 1,112 | 512 | 159 | 1,243 | 1,848 | 552 | 2,033 | | | | |

A.4.5 – Supply of crop provision in physical terms (1,000 tonne), year 2012

| 1,000 tonne | Institutional sectors: Agriculture | Other economic sectors | Households | Rest of the world | Type of ecosystem unit: Urban | Cropland | Grassland | Woodland and forest | Heathland and shrub | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AT | | | | | | 2,031 | | | | | | | |
| BG | | | | | | 2,442 | | | | | | | |
| BL | | | | | | 3,696 | | | | | | | |
| CZ | | | | | | 3,826 | | | | | | | |
| DE | | | | | | 40,590 | | | | | | | |
| DK | | | | | | 3,332 | | | | | | | |
| EE | | | | | | 516 | | | | | | | |
| EL | | | | | | 312 | | | | | | | |
| ES | | | | | | 7,152 | | | | | | | |
| FI | | | | | | 1,688 | | | | | | | |
| FR | | | | | | 29,288 | | | | | | | |
| HR | | | | | | 956 | | | | | | | |
| HU | | | | | | 4,422 | | | | | | | |
| IR | | | | | | 772 | | | | | | | |
| IT | | | | | | 8,718 | | | | | | | |
| LT | | | | | | 721 | | | | | | | |
| LV | | | | | | 2,060 | | | | | | | |
| NL | | | | | | 6,019 | | | | | | | |
| PL | | | | | | 16,597 | | | | | | | |
| PT | | | | | | 1,294 | | | | | | | |
| RO | | | | | | 6,971 | | | | | | | |
| SE | | | | | | 1,884 | | | | | | | |
| SI | | | | | | 277 | | | | | | | |
| SK | | | | | | 1,586 | | | | | | | |
| UK | | | | | | 9,136 | | | | | | | |
| EU | | | | | | 156,287 | | | | | | | |

A.4.6 – Use of crop provision in physical terms (1,000 tonne), year 2012

| | Institutional sectors | | | | | | | | | | | | | | | | Types of ecosystem units |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | Other economic sectors | Households | Rest of the world | |
| *1,000 tonne* | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | | | | |
| AT | 285 | 11 | 194 | 30 | 170 | 7 | 39 | 14 | 1 | 278 | 930 | 62 | 10 | | | | |
| BG | 1,146 | 3 | 162 | 6 | 455 | 0.09 | 4 | 532 | 0.21 | 3 | 94 | 15 | 21 | | | | |
| BL | 239 | - | 62 | 5 | 48 | 0.27 | 10 | - | 1.04 | 527 | 2,351 | 1.23 | 452 | | | | |
| CZ | 936 | - | 452 | 62 | 101 | 2 | 453 | 18 | 3 | 652 | 1,126 | 5 | 13 | | | | |
| DE | 4,014 | 10 | 2,112 | 205 | 533 | - | 984 | 17 | 54 | 4,405 | 26,174 | 140 | 1,941 | | | | |
| DK | 889 | - | 1,098 | 80 | - | - | 134 | - | 5 | 516 | 66 | 179 | 365 | | | | |
| EE | 171 | - | 149 | 40 | - | 0.126 | 90 | - | 3 | - | 21 | 26 | 15 | | | | |
| EL | 35 | 41 | 41 | 1.2 | 91 | 0.005 | 1 | 2 | 6 | 8 | 32 | 12 | 41 | | | | |
| ES | 1,113 | 77 | 1,751 | 239 | 667 | 3 | 17 | 201 | 142 | 454 | 708 | 1,551 | 229 | | | | |
| FI | 374 | - | 497 | 296 | - | 0 | 26 | 0 | 5 | 74 | - | 357 | 59 | | | | |
| FR | 5,285 | 269.11 | 1,875 | 141 | 1,313 | 0.11 | 796 | 447 | 189 | 3,597 | 14,381 | 220 | 775 | | | | |
| HR | 206 | 1.03 | 56 | 23 | 217 | 0.38 | 11 | 25 | 1 | 152 | 197 | 51 | 16 | | | | |
| HU | 1,343 | 14 | 373 | 59 | 861 | 4 | 195 | 370 | 7 | 139 | 975 | 0.69 | 79 | | | | |
| IR | 129 | - | 307 | 38 | - | - | 13 | - | 6 | 221 | 5 | 10 | 43 | | | | |
| IT | 389 | 439 | 171 | 50 | 1,024 | 9 | 6 | - | 26 | 361 | 2,148 | 3,967 | 126 | | | | |
| LT | 350 | - | 78 | 67 | 2 | 4 | 122 | - | 2 | 55 | 24 | 13 | 5 | | | | |
| LV | 936 | - | 325 | 97 | - | 14 | 256 | - | 13 | 209 | 125 | 11 | 73 | | | | |

| | Institutional sectors | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | Other economic sectors | Households | Rest of the world | Types of ecosystem units |
| | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | | | | |
| *1,000 tonne* | | | | | | | | | | | | | | | | | |
| NL | 209 | - | 63 | 3 | 23 | 7 | 2 | - | 2 | 1,212 | 3,537 | 3 | 958 | | | | |
| PL | 1,860 | - | 1,087 | 1,375 | 444 | 34 | 527 | 0 | 7 | 1,786 | 8,523 | 0.55 | 952 | | | | |
| PT | 14 | 0.495 | 7 | 12 | 165 | 0.01 | - | 3 | 0.87 | 2 | 388 | 667 | 36 | | | | |
| RO | 1,992 | 2.183 | 368 | 111 | 2,898 | 0.02 | 63 | 403 | 12 | 144 | 324 | 470 | 184 | | | | |
| SE | 519 | - | 502 | 315 | 2 | - | 100 | - | 15.827 | 112 | 87 | 209 | 22 | | | | |
| SI | 26 | - | 15 | 1.0 | 44 | 0.01 | 3 | - | 0.002 | 32 | 148 | 1 | 7 | | | | |
| SK | 397 | 7 | 151 | 13 | 147 | 0.23 | 114 | 27 | 2 | 215 | 500 | 3 | 10 | | | | |
| UK | 1,984 | 1 | 1,170 | 187 | 17 | - | 739 | 1 | 140 | 1,623 | 1,202 | 1,600 | 471 | | | | |
| EU | 24,843 | 876 | 13,067 | 3,457 | 9,222 | 86 | 4,705 | 2,060 | 645 | 16,779 | 64,069 | 9,575 | 6,904 | | | | |

A.4.7 – Supply of crop provision in monetary terms (million euro), year 2012

| | Institutional sectors | | | | Ecosystem types | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | Other economic sectors | Households | Rest of the world | Urban | Cropland | Grassland | Woodland and forest | Heathland and shrub | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million euro* | | | | | | | | | | | | | |
| AT | | | | | | 184 | | | | | | | |
| BG | | | | | | 508 | | | | | | | |
| BL | | | | | | 2,721 | | | | | | | |
| CZ | | | | | | 537 | | | | | | | |
| DE | | | | | | 3,368 | | | | | | | |
| DK | | | | | | 461 | | | | | | | |
| EE | | | | | | 109 | | | | | | | |
| EL | | | | | | 67 | | | | | | | |
| ES | | | | | | 1,083 | | | | | | | |
| FI | | | | | | 236 | | | | | | | |
| FR | | | | | | 3,351 | | | | | | | |
| HU | | | | | | 891 | | | | | | | |
| IR | | | | | | 105 | | | | | | | |
| IT | | | | | | 925 | | | | | | | |
| LT | | | | | | 141 | | | | | | | |
| LV | | | | | | 442 | | | | | | | |
| NL | | | | | | 448 | | | | | | | |
| PL | | | | | | 1,438 | | | | | | | |
| PT | | | | | | 104 | | | | | | | |
| RO | | | | | | 1,571 | | | | | | | |
| SE | | | | | | 329 | | | | | | | |
| SI | | | | | | 26 | | | | | | | |
| SK | | | | | | 231 | | | | | | | |
| UK | | | | | | 1,286 | | | | | | | |
| EU | | | | | | 20,563 | | | | | | | |

A.4.8 – Use of crop provision in monetary terms (million euro), year 2012

| | Institutional sectors | | | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | Other economic sectors | Households | Rest of the world | |
| *million euro* | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | | | | |
| AT | 51 | 3 | 33 | 5 | 31 | 1 | 16 | 5 | 0.3 | 10 | 26 | 1.8 | 1 | | | | |
| BG | 202 | 0.45 | 29 | 1 | 74 | 0.02 | 2 | 190 | 0.07 | - | 4 | - | 6 | | | | |
| BL | 529 | - | 133 | 13 | 107 | 0.60 | 36 | - | 0.33 | 527 | 219 | 0.09 | 1,156 | | | | |
| CZ | 170 | - | 85 | 10 | 18 | 0.46 | 197 | 7 | 1 | 21 | 25 | 0.1 | 2 | | | | |
| DE | 845 | 2 | 411 | 39 | 112 | - | 429 | 6 | 12 | 189 | 937 | 5 | 381 | | | | |
| DK | 100 | - | 221 | 14 | - | - | 54 | - | 1 | 22 | 3 | 9 | 36 | | | | |
| EE | 32 | - | 27 | 6 | - | 0.023 | 38 | - | - | - | - | 1.3 | 4 | | | | |
| EL | 7 | 9 | 8 | 0.2 | 17 | 0.001 | - | 1 | 10 | 0 | 2 | 0.6 | 13 | | | | |
| ES | 288 | 16 | 341 | 43 | 140 | 0.54 | 6 | 81 | 37 | 17 | 17 | 37 | 60 | | | | |
| FI | 68 | - | 87 | 51 | - | 0.02 | 12 | - | - | - | - | 18 | - | | | | |
| FR | 1,053 | 0.001 | 336 | 25 | 250 | 0.02 | 322 | 190 | 56 | 132 | 767 | 12 | 207 | | | | |
| HU | 306 | 3 | 67 | 10 | 158 | 0.8 | 86 | 210 | - | 6 | 29 | 0.02 | 16 | | | | |
| IR | 22 | - | 52 | 7 | - | - | 5 | - | 3 | - | 0 | 0.4 | 17 | | | | |
| IT | 94 | 149 | 36 | 10 | 228 | 2.2 | 1 | 16 | 12 | 16 | 102 | 197 | 62 | | | | |
| LT | 68 | - | 13 | 8 | - | 0.7 | 50 | - | - | 1 | 0 | - | 1 | | | | |
| LV | 210 | - | 71 | 19 | - | 3.2 | 119 | - | - | 8 | - | 0.3 | 11 | | | | |

| | Institutional sectors | | | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | | | | | | | | | | | Other economic sectors | Households | Rest of the world | |
| | soft wheat | durum wheat | barley | oats | maize | other cereals | rape | sunflower | protein crops | sugar beet | fodder maize | other forage | potatoes | | | | |
| *million euro* | | | | | | | | | | | | | | | | | |
| NL | 56 | - | 19 | 1 | 4 | 1.9 | 1 | - | 0 | 60 | 129 | 0.1 | 177 | | | | |
| PL | 386 | - | 205 | 210 | 75 | 6.3 | 230 | 1 | 3 | 85 | 107 | 0.01 | 129 | | | | |
| PT | 3 | 0.0001 | 1 | 2 | 35 | 0.002 | - | 1 | 0.59 | 0 | 18 | 33 | 9 | | | | |
| RO | 406 | 0.0001 | 83 | 29 | 683 | 0.005 | 24 | 251 | - | 6 | 24 | - | 65 | | | | |
| SE | 101 | - | 87 | 48 | - | - | 41 | - | 0.005 | 3 | - | 44 | 5 | | | | |
| SI | 5 | - | 3 | 0.2 | 8 | 0.002 | 1 | 0 | 0.000 | - | 7 | 0.03 | 2 | | | | |
| SK | 71 | - | 30 | 2 | 26 | 0.04 | 49 | 25 | - | 8 | 17 | 0.1 | 2 | | | | |
| UK | 391 | - | 223 | 37 | 3 | - | 333 | - | 36 | 60 | 44 | 58 | 100 | | | | |
| | | | | | | | | | | | | | | | | | |
| EU | 5,465 | 183 | 2,600 | 592 | 1,970 | 18 | 2,053 | 984 | 172 | 1,171 | 2,476 | 417 | 2,462 | | | | |

Annex 5. Components of human contribution in timber provision (proxy used: average million euro).

| | Products of agriculture | Products of Forestry | Petroleum products | Chemical products |
|---|---|---|---|---|
| Belgium | 73.87 | 0.00 | 84.73 | 19.81 |
| Bulgaria | 4.23 | 59.62 | 34.15 | 13.66 |
| Czechia | 43.21 | 327.30 | 87.62 | 8.24 |
| Denmark | 8.31 | 169.27 | 21.96 | 0.04 |
| Germany | 195.00 | 1032.60 | 124.40 | 37.40 |
| Estonia | 4.59 | 95.94 | 31.91 | 9.20 |
| Ireland | 0.00 | 0.00 | 0.00 | 0.00 |
| Greece | 0.00 | 13.76 | 0.02 | 0.00 |
| Spain | 9.84 | 94.64 | 7.66 | 6.14 |
| France | 145.00 | 2079.40 | 94.12 | 31.92 |
| Croatia | 34.55 | 63.99 | 11.55 | 2.35 |
| Italy | 0.05 | 14.74 | 25.99 | 4.27 |
| Cyprus | 0.15 | 0.24 | 0.19 | 0.04 |
| Latvia | 0.22 | 327.47 | 69.43 | 3.22 |
| Lithuania | 0.40 | 103.68 | 0.00 | 1.98 |
| Luxembourg | 2.72 | 1.63 | 0.41 | 0.37 |
| Hungary | 14.21 | 113.34 | 8.44 | 5.92 |
| Malta | 0.00 | 0.00 | 0.00 | 0.00 |
| Netherlands | 5.60 | 32.80 | 4.00 | 1.00 |
| Austria | 0.00 | 1003.14 | 57.54 | 8.66 |
| Poland | 19.86 | 728.71 | 58.74 | 34.30 |
| Portugal | 20.99 | 110.59 | 31.51 | 12.67 |
| Romania | 35.48 | 275.63 | 8.70 | 0.00 |
| Slovenia | 0.43 | 37.85 | 21.47 | 1.49 |
| Slovakia | 14.07 | 365.13 | 4.81 | 1.36 |
| Finland | 10.18 | 781.09 | 164.33 | 82.10 |
| Sweden | 40.90 | 133.13 | 182.93 | 15.27 |
| United Kingdom | 66.26 | 485.38 | 88.16 | 30.04 |

Annex 6. Accounting tables for timber provision.

A.6.1 – Supply of timber provision in physical terms (million $m^3$), year 2006

| | Institutional sectors | | | | Ecosystem types | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Other economic sectors | Households | Rest of the World | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and other forest | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million $m^3$* | | | | | | | | | | | | | | |
| AT | | | | | | | | | 20.86 | | | | | |
| BE | | | | | | | | | 2.67 | | | | | |
| BG | | | | | | | | | 10.03 | | | | | |
| CY | | | | | | | | | 0.04 | | | | | |
| CZ | | | | | | | | | 16.82 | | | | | |
| DE | | | | | | | | | 84.21 | | | | | |
| DK | | | | | | | | | 2.81 | | | | | |
| EE | | | | | | | | | 8.29 | | | | | |
| EL | | | | | | | | | 3.56 | | | | | |
| ES | | | | | | | | | 30.41 | | | | | |
| FI | | | | | | | | | 56.44 | | | | | |
| FR | | | | | | | | | 41.38 | | | | | |
| HR | | | | | | | | | 5.59 | | | | | |
| HU | | | | | | | | | 6.63 | | | | | |
| IE | | | | | | | | | 3.56 | | | | | |
| IT | | | | | | | | | 30.41 | | | | | |
| LT | | | | | | | | | 7.68 | | | | | |
| LU | | | | | | | | | 0.50 | | | | | |
| LV | | | | | | | | | 10.29 | | | | | |
| NL | | | | | | | | | 2.00 | | | | | |
| PL | | | | | | | | | 38.53 | | | | | |
| PT | | | | | | | | | 12.83 | | | | | |
| RO | | | | | | | | | 24.11 | | | | | |
| SE | | | | | | | | | 59.33 | | | | | |
| SI | | | | | | | | | 6.18 | | | | | |
| SK | | | | | | | | | 10.33 | | | | | |
| UK | | | | | | | | | 20.21 | | | | | |
| EU | | | | | | | | | 515.69 | | | | | |

A.6.2 – Use of timber provision in physical terms (million m$^3$), year 2006

| | Institutional sectors | | | | Ecosystem types | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Other economic sectors | Households | Rest of the world | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and other forest | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million m$^3$* | | | | | | | | | | | | | | |
| AT | 20.86 | | | | | | | | | | | | | |
| BE | 2.67 | | | | | | | | | | | | | |
| BG | 10.03 | | | | | | | | | | | | | |
| CY | 0.04 | | | | | | | | | | | | | |
| CZ | 16.82 | | | | | | | | | | | | | |
| DE | 84.21 | | | | | | | | | | | | | |
| DK | 2.81 | | | | | | | | | | | | | |
| EE | 8.29 | | | | | | | | | | | | | |
| EL | 3.56 | | | | | | | | | | | | | |
| ES | 30.41 | | | | | | | | | | | | | |
| FI | 56.44 | | | | | | | | | | | | | |
| FR | 41.38 | | | | | | | | | | | | | |
| HR | 5.59 | | | | | | | | | | | | | |
| HU | 6.63 | | | | | | | | | | | | | |
| IE | 3.56 | | | | | | | | | | | | | |
| IT | 30.41 | | | | | | | | | | | | | |
| LT | 7.68 | | | | | | | | | | | | | |
| LU | 0.50 | | | | | | | | | | | | | |
| LV | 10.29 | | | | | | | | | | | | | |
| NL | 2.00 | | | | | | | | | | | | | |
| PL | 38.53 | | | | | | | | | | | | | |
| PT | 12.83 | | | | | | | | | | | | | |
| RO | 24.11 | | | | | | | | | | | | | |
| SE | 59.33 | | | | | | | | | | | | | |
| SI | 6.18 | | | | | | | | | | | | | |
| SK | 10.33 | | | | | | | | | | | | | |
| UK | 20.21 | | | | | | | | | | | | | |
| EU | 515.69 | | | | | | | | | | | | | |

A.6.3 – Supply of timber provision in monetary terms (million euro), year 2006

| | Institutional sectors | | | | Ecosystem types | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Other economic sectors | Households | Rest of the World | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and forests | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million euro* | | | | | | | | | | | | | | |
| AT | | | | | | | | | 478 | | | | | |
| BE | | | | | | | | | 109 | | | | | |
| BG | | | | | | | | | 228 | | | | | |
| CY | | | | | | | | | 2 | | | | | |
| CZ | | | | | | | | | 811 | | | | | |
| DE | | | | | | | | | 2,510 | | | | | |
| DK | | | | | | | | | 130 | | | | | |
| EE | | | | | | | | | 167 | | | | | |
| EL | | | | | | | | | 27 | | | | | |
| ES | | | | | | | | | 482 | | | | | |
| FI | | | | | | | | | 1,527 | | | | | |
| FR | | | | | | | | | 1,291 | | | | | |
| HR | | | | | | | | | 88 | | | | | |
| HU | | | | | | | | | 131 | | | | | |
| IE | | | | | | | | | 81 | | | | | |
| IT | | | | | | | | | 624 | | | | | |
| LT | | | | | | | | | 400 | | | | | |
| LU | | | | | | | | | 24 | | | | | |
| LV | | | | | | | | | 228 | | | | | |
| NL | | | | | | | | | 95 | | | | | |
| PL | | | | | | | | | 1,726 | | | | | |
| PT | | | | | | | | | 417 | | | | | |
| RO | | | | | | | | | 471 | | | | | |
| SE | | | | | | | | | 1,731 | | | | | |
| SI | | | | | | | | | 89 | | | | | |
| SK | | | | | | | | | 160 | | | | | |
| UK | | | | | | | | | 182 | | | | | |
| | | | | | | | | | | | | | | |
| EU | | | | | | | | | 14,210 | | | | | |

A.6.4 – Use of timber provision in monetary terms (million euro), year 2006

| | Forestry | Other economic sectors | Households | Rest of the World | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and other forest | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *million euro* | | | | | | | | | | | | | | |
| AT | 478 | | | | | | | | | | | | | |
| BE | 109 | | | | | | | | | | | | | |
| BG | 228 | | | | | | | | | | | | | |
| CY | 2 | | | | | | | | | | | | | |
| CZ | 811 | | | | | | | | | | | | | |
| DE | 2,510 | | | | | | | | | | | | | |
| DK | 130 | | | | | | | | | | | | | |
| EE | 167 | | | | | | | | | | | | | |
| EL | 27 | | | | | | | | | | | | | |
| ES | 482 | | | | | | | | | | | | | |
| FI | 1,527 | | | | | | | | | | | | | |
| FR | 1,291 | | | | | | | | | | | | | |
| HR | 88 | | | | | | | | | | | | | |
| HU | 131 | | | | | | | | | | | | | |
| IE | 81 | | | | | | | | | | | | | |
| IT | 624 | | | | | | | | | | | | | |
| LT | 400 | | | | | | | | | | | | | |
| LU | 24 | | | | | | | | | | | | | |
| LV | 228 | | | | | | | | | | | | | |
| NL | 95 | | | | | | | | | | | | | |
| PL | 1,726 | | | | | | | | | | | | | |
| PT | 417 | | | | | | | | | | | | | |
| RO | 471 | | | | | | | | | | | | | |
| SE | 1,731 | | | | | | | | | | | | | |
| SI | 89 | | | | | | | | | | | | | |
| SK | 160 | | | | | | | | | | | | | |
| UK | 182 | | | | | | | | | | | | | |
| EU | 14,210 | | | | | | | | | | | | | |

A.6.5 – Supply of timber provision in physical terms (million $m^3$), year 2012

| | Institutional sectors | | | | Ecosystem types | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Other economic sectors | Households | Rest of the World | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and forests | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million m³* | | | | | | | | | | | | | | |
| AT | | | | | | | | | 20.86 | | | | | |
| BE | | | | | | | | | 2.67 | | | | | |
| BG | | | | | | | | | 10.20 | | | | | |
| CY | | | | | | | | | 0.05 | | | | | |
| CZ | | | | | | | | | 15.96 | | | | | |
| DE | | | | | | | | | 84.20 | | | | | |
| DK | | | | | | | | | 4.20 | | | | | |
| EE | | | | | | | | | 8.41 | | | | | |
| EL | | | | | | | | | 3.70 | | | | | |
| ES | | | | | | | | | 31.93 | | | | | |
| FI | | | | | | | | | 58.83 | | | | | |
| FR | | | | | | | | | 45.58 | | | | | |
| HR | | | | | | | | | 5.46 | | | | | |
| HU | | | | | | | | | 6.65 | | | | | |
| IE | | | | | | | | | 4.87 | | | | | |
| IT | | | | | | | | | 31.57 | | | | | |
| LT | | | | | | | | | 7.39 | | | | | |
| LU | | | | | | | | | 0.50 | | | | | |
| LV | | | | | | | | | 11.22 | | | | | |
| NL | | | | | | | | | 2.00 | | | | | |
| PL | | | | | | | | | 35.51 | | | | | |
| PT | | | | | | | | | 12.98 | | | | | |
| RO | | | | | | | | | 24.58 | | | | | |
| SE | | | | | | | | | 63.48 | | | | | |
| SI | | | | | | | | | 6.87 | | | | | |
| SK | | | | | | | | | 10.77 | | | | | |
| UK | | | | | | | | | 21.26 | | | | | |
| | | | | | | | | | | | | | | |
| EU | | | | | | | | | 531.69 | | | | | |

A.6.6 – Use of timber provision in physical terms (million m$^3$), year 2012

| | Institutional sectors | | | | Ecosystem types | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Other economic sectors | Households | Rest of the World | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and forests | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million m$^3$* | | | | | | | | | | | | | | |
| AT | 20.86 | | | | | | | | | | | | | |
| BE | 2.67 | | | | | | | | | | | | | |
| BG | 10.20 | | | | | | | | | | | | | |
| CY | 0.05 | | | | | | | | | | | | | |
| CZ | 15.96 | | | | | | | | | | | | | |
| DE | 84.20 | | | | | | | | | | | | | |
| DK | 4.20 | | | | | | | | | | | | | |
| EE | 8.41 | | | | | | | | | | | | | |
| EL | 3.70 | | | | | | | | | | | | | |
| ES | 31.93 | | | | | | | | | | | | | |
| FI | 58.83 | | | | | | | | | | | | | |
| FR | 45.58 | | | | | | | | | | | | | |
| HR | 5.46 | | | | | | | | | | | | | |
| HU | 6.65 | | | | | | | | | | | | | |
| IE | 4.87 | | | | | | | | | | | | | |
| IT | 31.57 | | | | | | | | | | | | | |
| LT | 7.39 | | | | | | | | | | | | | |
| LU | 0.50 | | | | | | | | | | | | | |
| LV | 11.22 | | | | | | | | | | | | | |
| NL | 2.00 | | | | | | | | | | | | | |
| PL | 35.51 | | | | | | | | | | | | | |
| PT | 12.98 | | | | | | | | | | | | | |
| RO | 24.58 | | | | | | | | | | | | | |
| SE | 63.48 | | | | | | | | | | | | | |
| SI | 6.87 | | | | | | | | | | | | | |
| SK | 10.77 | | | | | | | | | | | | | |
| UK | 21.26 | | | | | | | | | | | | | |
| EU | 531.69 | | | | | | | | | | | | | |

A.6.7 – Supply of timber provision in monetary terms (million euro), year 2012

| | Institutional sectors | | | | Ecosystem types | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Other economic sectors | Households | Rest of the World | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and other forest | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million euro* | | | | | | | | | | | | | | |
| AT | | | | | | | | | 478 | | | | | |
| BE | | | | | | | | | 109 | | | | | |
| BG | | | | | | | | | 232 | | | | | |
| CY | | | | | | | | | 3 | | | | | |
| CZ | | | | | | | | | 769 | | | | | |
| DE | | | | | | | | | 2,510 | | | | | |
| DK | | | | | | | | | 195 | | | | | |
| EE | | | | | | | | | 169 | | | | | |
| EL | | | | | | | | | 28 | | | | | |
| ES | | | | | | | | | 507 | | | | | |
| FI | | | | | | | | | 1,591 | | | | | |
| FR | | | | | | | | | 1,422 | | | | | |
| HR | | | | | | | | | 86 | | | | | |
| HU | | | | | | | | | 131 | | | | | |
| IE | | | | | | | | | 112 | | | | | |
| IT | | | | | | | | | 648 | | | | | |
| LT | | | | | | | | | 385 | | | | | |
| LU | | | | | | | | | 24 | | | | | |
| LV | | | | | | | | | 248 | | | | | |
| NL | | | | | | | | | 95 | | | | | |
| PL | | | | | | | | | 1,591 | | | | | |
| PT | | | | | | | | | 422 | | | | | |
| RO | | | | | | | | | 480 | | | | | |
| SE | | | | | | | | | 1,853 | | | | | |
| SI | | | | | | | | | 99 | | | | | |
| SK | | | | | | | | | 167 | | | | | |
| UK | | | | | | | | | 192 | | | | | |
| EU | | | | | | | | | 14,544 | | | | | |

A.6.8 – Use of timber provision in monetary terms (million euro), year 2012

| | Institutional sectors | | | | Ecosystem types | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forestry | Other economic sectors | Households | Rest of the World | Urban | Cropland | Grassland | Heathland and shrub | Forest available for wood supply | Other woodland and other forest | Sparsely vegetated land | Wetlands | Rivers and lakes | Marine |
| *million euro* | | | | | | | | | | | | | | |
| AT | 478 | | | | | | | | | | | | | |
| BE | 109 | | | | | | | | | | | | | |
| BG | 232 | | | | | | | | | | | | | |
| CY | 3 | | | | | | | | | | | | | |
| CZ | 769 | | | | | | | | | | | | | |
| DE | 2,510 | | | | | | | | | | | | | |
| DK | 195 | | | | | | | | | | | | | |
| EE | 169 | | | | | | | | | | | | | |
| EL | 28 | | | | | | | | | | | | | |
| ES | 507 | | | | | | | | | | | | | |
| FI | 1,591 | | | | | | | | | | | | | |
| FR | 1,422 | | | | | | | | | | | | | |
| HR | 86 | | | | | | | | | | | | | |
| HU | 131 | | | | | | | | | | | | | |
| IE | 112 | | | | | | | | | | | | | |
| IT | 648 | | | | | | | | | | | | | |
| LT | 385 | | | | | | | | | | | | | |
| LU | 24 | | | | | | | | | | | | | |
| LV | 248 | | | | | | | | | | | | | |
| NL | 95 | | | | | | | | | | | | | |
| PL | 1,591 | | | | | | | | | | | | | |
| PT | 422 | | | | | | | | | | | | | |
| RO | 480 | | | | | | | | | | | | | |
| SE | 1,853 | | | | | | | | | | | | | |
| SI | 99 | | | | | | | | | | | | | |
| SK | 167 | | | | | | | | | | | | | |
| UK | 192 | | | | | | | | | | | | | |
| EU | 14,544 | | | | | | | | | | | | | |

## Annex 7. Mapping method for $CO_2$ uptake by Woodland and forest

Dry Matter productivity represents the overall growth rate or dry biomass increase of vegetation, expressed in kilograms of dry matter per hectare per day. Data was downloaded from Copernicus Global Land Service, delivered in compressed Network Common Data Form (netCDF) files having a global coverage. DMP images are derived from SPOT-VGT satellite imagery and are combined with (modelled) meteorological data from ECMWF. They are available at 1km resolution and are updated every 10 days.

Temporal information:

Each DMP layer is presented in a 10-days period. The startPosition of the 10-days period is always set to the $01^{st}$, $11^{th}$ and $21^{st}$ day of the month. The netCDF files were transformed into raster layers (MakeNetCDFRasterLayer) and then projected into ETRS_1989_LAEA coordinate system. A total of 36 raster layers for each year were achieved. These layers were processed to calculate per each reference (2000, 2006, 2012) year the annual DMP (gDM/ha) at 1 km resolution.

The DMP for each year was extracted (Extract by Mask) for Woodland and forest (MAES ecosystem classification), according to the accounting layers CLC; which includes broad-leaved forest, coniferous forest, mixed forest and transitional woodland-shrub.

The methodology here developed for the spatial allocation of the $CO_2$ uptake at national level assumes that a growth in biomass is related to $CO_2$ uptake (Kruger and Volin, 2006)[23]. Vegetation biomass grows through photosynthetic activity capturing $CO_2$ and removing it from the atmosphere. It represents a fundamental ecological process, which can be used to indicate the rate of removal of C from the atmosphere stored in form of biomass.

For the downscaling of CO2 uptake at national level, the total DMP was calculated at each MS level. DMP at each pixel was divided by the total DMP at country level to derive the relative value of DMP at country level for each pixel. This relative value was then multiplied by the reported $CO_2$ uptake by Woodland and forest (LULUCF inventories) to allocate at pixel level the woodland uptake in proportion to the annual DMP. Final maps of $CO_2$ uptake by Woodland and forest is in tonnes of $CO_2$ per year.

[23] Kruger & Volin (2006) Reexamining the empirical relation between plant growth and leaf photosynthesis. Functional Plant Biology 33, 421-429.

Annex 8. Accounting tables for carbon sequestration: $CO_2$ uptake.

A.8.1 – Supply of $CO_2$ uptake in physical terms (1,000 tonne), year 2006

| | Institutional sectors | | | | | Ecosystem types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| *1,000 tonne* | | | | | | | | | | | |
| AT | | | | | | | 94 | | 2,982 | | |
| BE | | | | | | | | 563 | 3,351 | | |
| BG | | | | | | | | 1,203 | 10,630 | | |
| CY | | | | | | | 173 | 123 | 196 | 15 | |
| CZ | | | | | | | | 443 | 2,964 | | |
| DE | | | | | | | | | 40,819 | | |
| DK | | | | | | | | | | | |
| EE | | | | | | | | | 4,411 | | |
| EL | | | | | | | 614 | 375 | 2,246 | | |
| ES | | | | | | | 1,051 | 1,611 | 39,876 | 135 | |
| FI | | | | | | | | | 43,619 | | |
| FR | | | | | | | | 9,110 | 70,343 | | |
| HR | | | | | | | | 109 | 8,129 | | |
| HU | | | | | | | 595 | 292 | 2,817 | | |
| IE | | | | | | | 184 | | 2,978 | | |
| IT | | | | | | | | 3,575 | 33,466 | | |
| LT | | | | | | | | 1,479 | 4,448 | | |
| LU | | | | | | | | 58 | 694 | | |
| LV | | | | | | | | | 10,458 | | |
| MT | | | | | | | 0.03 | 2 | | | |
| NL | | | | | | | | | 2,015 | | |
| PL | | | | | | | | 207 | 43,374 | | |
| PT | | | | | | | | | 10,894 | | 2,157 |
| RO | | | | | | | 2,105 | | 26,433 | | |
| SE | | | | | | | | 77 | 35,680 | | 2.17 |
| SI | | | | | | | 176 | 72 | 5,964 | | |
| SK | | | | | | | 1,136 | 258 | 5,689 | | |
| UK | | | | | | | | 8,379 | 23,127 | | |
| EU | | | | | | 0 | 6,128 | 27,938 | 437,601 | 151 | 2,159 |

A.8.2 – Use of $CO_2$ uptake in physical terms (1,000 tonne), year 2006

| | Institutional sectors | | | | | Ecosystem types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| *1,000 tonne* | | | | | | | | | | | |
| AT | | | | | 3,076 | | | | | | |
| BE | | | | | 3,914 | | | | | | |
| BG | | | | | 11,833 | | | | | | |
| CY | | | | | 508 | | | | | | |
| CZ | | | | | 3,407 | | | | | | |
| DE | | | | | 40,819 | | | | | | |
| DK | | | | | 0 | | | | | | |
| EE | | | | | 4,411 | | | | | | |
| EL | | | | | 3,235 | | | | | | |
| ES | | | | | 42,673 | | | | | | |
| FI | | | | | 43,619 | | | | | | |
| FR | | | | | 79,452 | | | | | | |
| HR | | | | | 8,238 | | | | | | |
| HU | | | | | 3,704 | | | | | | |
| IE | | | | | 3,162 | | | | | | |
| IT | | | | | 37,041 | | | | | | |
| LT | | | | | 5,927 | | | | | | |
| LU | | | | | 752 | | | | | | |
| LV | | | | | 10,458 | | | | | | |
| MT | | | | | 1.74 | | | | | | |
| NL | | | | | 2,015 | | | | | | |
| PL | | | | | 43,581 | | | | | | |
| PT | | | | | 13,051 | | | | | | |
| RO | | | | | 28,537 | | | | | | |
| SE | | | | | 35,759 | | | | | | |
| SI | | | | | 6,212 | | | | | | |
| SK | | | | | 7,082 | | | | | | |
| UK | | | | | 31,506 | | | | | | |
| EU | | | | | 473,977 | | | | | | |

A.8.3 – Supply of $CO_2$ uptake in monetary terms (million euro), year 2006

| | Institutional sectors | | | | | Ecosystem types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| *million euro* | | | | | | | | | | | |
| AT | | | | | | | 3 | | 89 | | |
| BE | | | | | | | | 17 | 101 | | |
| BG | | | | | | | | 36 | 319 | | |
| CY | | | | | | | 5.2 | 3.7 | 5.9 | 0.46 | |
| CZ | | | | | | | | 13 | 89 | | |
| DE | | | | | | | | | 1,225 | | |
| DK | | | | | | | | | 0 | | |
| EE | | | | | | | | | 132 | | |
| EL | | | | | | | 18 | 11 | 67 | | |
| ES | | | | | | | 32 | 48 | 1,196 | 4.05 | |
| FI | | | | | | | | | 1,309 | | |
| FR | | | | | | | | 273 | 2,110 | | |
| HR | | | | | | | | 3 | 244 | | |
| HU | | | | | | | 18 | 9 | 84 | | |
| IE | | | | | | | 6 | | 89 | | |
| IT | | | | | | | | 107 | 1,004 | | |
| LT | | | | | | | | 44 | 133 | | |
| LU | | | | | | | | 2 | 21 | | |
| LV | | | | | | | | | 314 | | |
| MT | | | | | | | | 0.05 | | | |
| NL | | | | | | | | | 60 | | |
| PL | | | | | | | | 6 | 1,301 | | |
| PT | | | | | | | | | 327 | | 65 |
| RO | | | | | | | 63 | | 793 | | |
| SE | | | | | | | | 2 | 1,070 | | 0.07 |
| SI | | | | | | | 5 | 2.17 | 179 | | |
| SK | | | | | | | 34 | 8 | 171 | | |
| UK | | | | | | | | 251 | 694 | | |
| EU | | | | | | 0 | 184 | 838 | 13,128 | 4.52 | 65 |

A.8.4 – Use of $CO_2$ uptake in monetary terms (million euro), year 2006

| | Institutional sectors | | | | | Ecosystem types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| *million euro* | | | | | | | | | | | |
| AT | | | | | 92 | | | | | | |
| BE | | | | | 117 | | | | | | |
| BG | | | | | 355 | | | | | | |
| CY | | | | | 15.2 | | | | | | |
| CZ | | | | | 102 | | | | | | |
| DE | | | | | 1,225 | | | | | | |
| DK | | | | | 0 | | | | | | |
| EE | | | | | 132 | | | | | | |
| EL | | | | | 97 | | | | | | |
| ES | | | | | 1,280 | | | | | | |
| FI | | | | | 1,309 | | | | | | |
| FR | | | | | 2,384 | | | | | | |
| HR | | | | | 247 | | | | | | |
| HU | | | | | 111 | | | | | | |
| IE | | | | | 95 | | | | | | |
| IT | | | | | 1,111 | | | | | | |
| LT | | | | | 178 | | | | | | |
| LU | | | | | 23 | | | | | | |
| LV | | | | | 314 | | | | | | |
| MT | | | | | 0.05 | | | | | | |
| NL | | | | | 60 | | | | | | |
| PL | | | | | 1,307 | | | | | | |
| PT | | | | | 392 | | | | | | |
| RO | | | | | 856 | | | | | | |
| SE | | | | | 1,073 | | | | | | |
| SI | | | | | 186 | | | | | | |
| SK | | | | | 212 | | | | | | |
| UK | | | | | 945 | | | | | | |
| EU | | | | | 14,219 | | | | | | |

A.8.5 – Supply of $CO_2$ uptake in physical terms (1,000 tonne), year 2012

| | **Institutional sectors** | | | | | **Ecosystem types** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| *1,000 tonne* | | | | | | | | | | | |
| AT | | | | | | | 244 | | 4,399 | | |
| BE | | | | | | | | 360 | 3,102 | 11 | |
| BG | | | | | | | | 1,147 | 5,900 | | |
| CY | | | | | | | 168 | 124 | 287 | 14 | |
| CZ | | | | | | | | 386 | 6,321 | | |
| DE | | | | | | | | | 58,067 | | |
| DK | | | | | | | | | 4,103 | | |
| EE | | | | | | | | | 2,798 | | |
| EL | | | | | | | 567 | 774 | 2,107 | | |
| ES | | | | | | | | 737 | 39,460 | | |
| FI | | | | | | | | | 44,335 | | |
| FR | | | | | | | | 11,092 | 59,551 | | |
| HR | | | | | | | | 96 | 6,371 | | |
| HU | | | | | | | 554 | 200 | 4,232 | | |
| IE | | | | | | | | | 3,412 | | |
| IT | | | | | | | | 2,145 | 27,736 | 8 | |
| LT | | | | | | | | 1,428 | 9,874 | | |
| LU | | | | | | | | 55 | 441 | | |
| LV | | | | | | 648 | | | 6,604 | | |
| MT | | | | | | | | 1 | 0 | | |
| NL | | | | | | | | | 2,234 | | |
| PL | | | | | | | | 405 | 39,958 | | |
| PT | | | | | | | | | 10,946 | | 1,524 |
| RO | | | | | | | 2,149 | | 25,444 | | |
| SE | | | | | | | | 212 | 43,478 | | 6 |
| SI | | | | | | | 157 | 28 | 5,422 | | |
| SK | | | | | | | 1,168 | 217 | 5,955 | | |
| UK | | | | | | | | 9,022 | 21,893 | | |
| EU | | | | | | 648 | 5,008 | 28,429 | 444,429 | 33 | 1,530 |

A.8.6 – Use of $CO_2$ uptake in physical terms (1,000 tonne), year 2012

| | Institutional sectors | | | | | Ecosystem types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| *1,000 tonne* | | | | | | | | | | | |
| AT | | | | | 4,643 | | | | | | |
| BE | | | | | 3,473 | | | | | | |
| BG | | | | | 7,046 | | | | | | |
| CY | | | | | 593 | | | | | | |
| CZ | | | | | 6,707 | | | | | | |
| DE | | | | | 58,067 | | | | | | |
| DK | | | | | 4,103 | | | | | | |
| EE | | | | | 2,798 | | | | | | |
| EL | | | | | 3,448 | | | | | | |
| ES | | | | | 40,198 | | | | | | |
| FI | | | | | 44,335 | | | | | | |
| FR | | | | | 70,643 | | | | | | |
| HR | | | | | 6,468 | | | | | | |
| HU | | | | | 4,985 | | | | | | |
| IE | | | | | 3,412 | | | | | | |
| IT | | | | | 29,889 | | | | | | |
| LT | | | | | 11,302 | | | | | | |
| LU | | | | | 496 | | | | | | |
| LV | | | | | 7,252 | | | | | | |
| MT | | | | | 1 | | | | | | |
| NL | | | | | 2,234 | | | | | | |
| PL | | | | | 40,364 | | | | | | |
| PT | | | | | 12,470 | | | | | | |
| RO | | | | | 27,592 | | | | | | |
| SE | | | | | 43,695 | | | | | | |
| SI | | | | | 5,608 | | | | | | |
| SK | | | | | 7,340 | | | | | | |
| UK | | | | | 30,915 | | | | | | |
| EU | | | | | 480,078 | | | | | | |

A.8.7 – Supply of $CO_2$ uptake in monetary terms (million euro), year 2012

| | Institutional sectors | | | | | Ecosystem types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| *million euro* | | | | | | | | | | | |
| AT | | | | | | | 7 | | 132 | | |
| BE | | | | | | | | 11 | 93 | 0.32 | |
| BG | | | | | | | | 34 | 177 | | |
| CY | | | | | | | 5.0 | 3.7 | 8.6 | 0.43 | |
| CZ | | | | | | | | 12 | 190 | | |
| DE | | | | | | | | | 1,742 | | |
| DK | | | | | | | | | 123 | | |
| EE | | | | | | | | | 84 | | |
| EL | | | | | | | 17 | 23 | 63 | | |
| ES | | | | | | | | 22 | 1,184 | | |
| FI | | | | | | | | | 1,330 | | |
| FR | | | | | | | | 333 | 1,787 | | |
| HR | | | | | | | | 3 | 191 | | |
| HU | | | | | | | 17 | 6 | 127 | | |
| IE | | | | | | | | | 102 | | |
| IT | | | | | | | | 64 | 832 | 0.24 | |
| LT | | | | | | | | 43 | 296 | | |
| LU | | | | | | | | 2 | 13 | | |
| LV | | | | | | 19 | | | 198 | | |
| MT | | | | | | | | 0.03 | | | |
| NL | | | | | | | | | 67 | | |
| PL | | | | | | | | 12 | 1,199 | | |
| PT | | | | | | | | | 328 | | 46 |
| RO | | | | | | | 64 | | 763 | | |
| SE | | | | | | | | 6 | 1,304 | | |
| SI | | | | | | | 5 | 0.84 | 163 | | |
| SK | | | | | | | 35 | 7 | 179 | | |
| UK | | | | | | | | 271 | 657 | | |
| EU | | | | | | 19 | 150 | 853 | 13,333 | 1.00 | 46 |

A.8.8 – Use of $CO_2$ uptake in monetary terms (million euro), year 2012

| | Institutional sectors | | | | | Ecosystem types | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *million euro* | Primary sector | Secondary sector | Tertiary sector | Households | Global society | Urban | Cropland | Grassland | Woodland and forest | Wetland | Other ecosystem types |
| AT | | | | | 139 | | | | | | |
| BE | | | | | 104 | | | | | | |
| BG | | | | | 211 | | | | | | |
| CY | | | | | 18 | | | | | | |
| CZ | | | | | 201 | | | | | | |
| DE | | | | | 1,742 | | | | | | |
| DK | | | | | 123 | | | | | | |
| EE | | | | | 84 | | | | | | |
| EL | | | | | 103 | | | | | | |
| ES | | | | | 1,206 | | | | | | |
| FI | | | | | 1,330 | | | | | | |
| FR | | | | | 2,119 | | | | | | |
| HR | | | | | 194 | | | | | | |
| HU | | | | | 150 | | | | | | |
| IE | | | | | 102 | | | | | | |
| IT | | | | | 897 | | | | | | |
| LT | | | | | 339 | | | | | | |
| LU | | | | | 15 | | | | | | |
| LV | | | | | 218 | | | | | | |
| MT | | | | | 0.03 | | | | | | |
| NL | | | | | 67 | | | | | | |
| PL | | | | | 1,211 | | | | | | |
| PT | | | | | 374 | | | | | | |
| RO | | | | | 828 | | | | | | |
| SE | | | | | 1,311 | | | | | | |
| SI | | | | | 168 | | | | | | |
| SK | | | | | 220 | | | | | | |
| UK | | | | | 927 | | | | | | |
| EU | | | | | 14,402 | | | | | | |

Annex 9. Assessment of soil organic carbon

In 2009, LUCAS was conducted in 23 European countries (EU-27 except Bulgaria, Romania, Malta and Cyprus) collecting a total of around 235,000 points of field observations about physical and chemical parameters in topsoil (0-20 cm), including SOC (EUROSTAT, 2009)[24].

For this assessment, LUCAS topsoil[25] (soil properties data) and LUCAS land cover and land use[26] data were downloaded. Topsoil OC of LUCAS data were intersected with a layer of biogeographic regions to calculate for each LUCAS land cover class and biogeographic region a look up table with the average OC.

Because LUCAS land cover classification differs from CLC classes, first, a table was built with the correspondence between both classification types (Table A.9.1).

In this way, the final lookup table with the average SOC was presented for each Biogeographical region and land cover of CLC (label 2). In order to define average values of SOC per each biogeographical region and CLC label 2, a threshold of 10 LUCAS points was defined. For categories with a presence of less than 10 points, the average SOC values were calculated based on different types of aggregation (Table A.9.2).

[24] Eurostat, (2009) Land Use and Coverage Area frame Survey (LUCAS).
[25] https://esdac.jrc.ec.europa.eu/content/lucas-2009-topsoil-data
[26] https://ec.europa.eu/eurostat/web/lucas/data/primary-data/2009

Table A.9.1. Correspondence between LUCAS and CORINE land cover classification.

| LUCAS Nomenclature | LUCAS Code | CLC LABEL2 | CLC LABEL2 Code |
|---|---|---|---|
| **Buildings with one to three floors** | A11 | Urban fabric | 11 |
| **Non build up area features** | A21 | Industrial, commercial and transport units | 12 |
| **Non build up linear features** | A22 | | |
| **Common wheat** | B11 | Arable land | 21 |
| **Durum wheat** | B12 | | |
| **Barley** | B13 | | |
| **Rye** | B14 | | |
| **Oats** | B15 | | |
| **Maize** | B16 | | |
| **Rice** | B17 | | |
| **Triticale** | B18 | | |
| **Other cereals** | B19 | | |
| **Potatoes** | B21 | | |
| **Sugar beet** | B22 | | |
| **Other root crops** | B23 | | |
| **Sunflower** | B31 | Heterogeneous Agricultural areas | 24 |
| **Rape and turnip rape** | B32 | | |
| **Soya** | B33 | | |
| **Cotton** | B34 | | |
| **Other fibre and oleaginous corps** | B35 | | |
| **Tobacco** | B36 | | |
| **Other non-permanent industrial crops** | B37 | | |
| **Dry pulses** | B41 | Arable land | 21 |
| **Tomatoes** | B42 | | |
| **Other fresh vegetables** | B43 | | |
| **Floriculture and ornamental plants** | B44 | Artificial, non-agricultural vegetated areas | 14 |
| **Strawberries** | B45 | Arable land | 21 |
| **Clovers** | B51 | Heterogeneous Agricultural areas | 24 |
| **Lucerne** | B52 | | |
| **Other leguminous and mixture fodder** | B53 | | |
| **Mix of cereals** | B54 | | |
| **Temporary grassland** | B55 | Pastures | 23 |
| **Apple fruit** | B71 | Permanent crops | 22 |
| **Pear fruit** | B72 | | |
| **Cherry fruit** | B73 | | |
| **Nut trees** | B74 | | |
| **Other fruit trees and berries** | B75 | | |

| LUCAS Nomenclature | LUCAS Code | CLC LABEL2 | CLC LABEL2 Code |
|---|---|---|---|
| **Oranges** | B76 | | |
| **Other citrus fruit** | B77 | | |
| **Olive groves** | B81 | | |
| **Vineyards** | B82 | | |
| **Nurseries** | B83 | | |
| **Permanent industrial crops** | B84 | Arable land | 21 |
| | BX1 | | |
| **Broadleaved and evergreen woodland** | C10 | Forest | 31 |
| **Coniferous woodland** | C20 | | |
| **Mixed woodland** | C30 | | |
| **Shrubland with sparse tree cover** | D10 | Scrub and/or herbaceous vegetation associations | 32 |
| **Shrubland without tree cover** | D20 | | |
| **Grassland with sparse tree/shrub cover** | E10 | | |
| **Grassland without tree/shrub cover** | E20 | | |
| **Spontaneously re-vegetated surfaces** | E30 | Pastures | 23 |
| **Bare land** | F00 | Open spaces with little or no vegetation | 33 |
| **Inland water bodies** | G10 | Inland Waters | 51 |
| **Inland running water** | G20 | | |
| **Inland marshes** | H11 | Inland wetlands | 41 |
| **Peatbogs** | H12 | | |
| **Salt marshes** | H21 | Maritime wetlands | 42 |
| **Salines** | H22 | | |
| The comparison between the two different nomenclature systems was done using the EEA technical report No 07/2006 Annex 4, where the two classifications were cross-tabulated and by reading the nomenclature descriptions of the two classification systems. | | | |

Table A.9.2. Lookup table of organic carbon content in soils (g C /kg of soil) per land cover type and biogeographic region.

| CLC Label 2 | Alpine | Atlantic | Boreal | Continental | Mediterranean | Pannonian |
|---|---|---|---|---|---|---|
| **Urban fabric** | No Data[10] | No Data[10] | No Data[10] | NoData[10] | NoData[10] | NoData[10] |
| **Industrial, commercial and transport units** | 64.17[1] | 37.06 | 64.17[1] | 23.61[2] | 13.51 | 23.61[2] |
| **Mine, dump and construction sites** | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] |
| **Artificial, non-agricultural vegetated areas** | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] |
| **Arable land** | 21.13 | 20.16 | 39.17 | 16.51 | 12.29 | 19.14 |
| **Permanent crops** | 24.59[3] | 23.63 | 24.59[3] | 22.33[4] | 14.09 | 22.33[4] |
| **Pastures** | 41.95 | 33.84 | 72.37 | 30.38 | 16.49 | 18.15 |
| **Heterogeneous agricultural areas** | 18.96 | 18.44 | 26.68 | 18.32 | 12.76 | 16.9 |
| **Forests** | 66.04 | 64.17 | 137.08 | 46.26 | 29.11 | 21.03 |
| **Scrub and/or herbaceous vegetation associations** | 39.03 | 60.52 | 59.96 | 36.53 | 24.58 | 28.89 |
| **Open spaces with little or no vegetation** | 83.16[5] | 37.49 | 83.16[5] | 57.18[6] | 10.58 | 57.18[6] |
| **Inland wetlands** | 397.01[7] | 378.9 | 397.01[7] | 115.73[8] | 115.73[8] | 115.73[8] |
| **Maritime wetlands** | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] |
| **Inland waters** | 18.58[9] | 18.58[9] | 18.58[9] | 18.58[9] | 18.58[9] | 18.58[9] |
| **Marine waters** | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] | No Data[10] |

[1] 3 samples recorded for Alpine biogeographical region. The mean was calculated for Alpine and Boreal biogeographical region, for a total of 17 soil samples.
[2] 2 samples recorded for Pannonian biogeographical region. The mean was calculated for Continental and Pannonian biogeographical region, for a total of 26 soil samples.
[3] 1 sample recorded for Boreal biogeographical region. The mean was calculated for Alpine and Boreal biogeographical region, for a total of 20 soil samples.
[4] 9 samples recorded for Pannonian biogeographical region. The mean was calculated for Continental and Pannonian biogeographical region, for a total of 128 soil samples.
[5] 1 sample recorded for Alpine biogeographical region. The mean was calculated for Alpine and Boreal biogeographical region, for a total of 38 soil samples.
[6] 1 sample recorded for Pannonian biogeographical region. The mean was calculated for Continental and Pannonian biogeographical region, for a total of 27 soil samples.
[7] 6 samples recorded for Alpine biogeographical region. The mean was calculated for Alpine and Boreal biogeographical region, for a total of 54 soil samples.
[8] 7 samples recorded for Continental and 5 samples recorded for Pannonian biogeographical region. No samples found in Mediterranean biogeographical region. The mean was calculated for Continental and Pannonean
[9] 12 samples recorded in total. The mean was calculated amongst all available samples and was assigned to each biogeographical region.
[10] Not enough sampling points. This land cover was chosen to be treated as No Data

The lookup table (Table A.9.2) was used to map SOC stock based on Equation 1 (FAO, 2017, Poeplau et al., 2017[27]):

(Equation 1)

$$SOC_{stock}(tonne\ C\ /\ ha) = OC_{cont}(g\ C\ /\ kg\ soil)\ x\ Bulk\ density\ (tonne\ soil\ m^3)\ x\ depth\ (m)$$

Where $SOC_{stock}$ is the Soil organic carbon stock per unit area (tonne C/ha), $OC_{cont}$ is the C concentration in the soil sample, as calculated in Table A.9.2 (in g C /kg of soil). Bulk density was downloaded from https://esdac.jrc.ec.europa.eu/content/topsoil-physical-properties-europe-based-lucas-topsoil-data (Ballabio et al., 2016[28]) and depth is the depth of soil samples for LUCAS (which is 0.2 m).

SOC stocks were calculated for each year of reference at 100 m resolution. For changes in SOC, European municipalities were taken into consideration. Average SOC per each year at EU municipality level was calculated (Zonal Statistics, Average) and the values from 2012 to 2006 were subtracted in order to track changes in SOC stocks.

[27] Poeplau, C., Vos, C. & Don, A. (2017) Soil organic carbon stocks are systematically overestimated by misuse of the parameters bulk density and rock fragment content. SOIL, 3, 61-66. 10.5194/soil-3-61-2017

[28] Ballabio, C., Panagos, P., Monatanarella, L. (2016) Mapping topsoil physical properties at European scale using the LUCAS database. Geoderma 261, 110-123

Annex 10. Input data for the biophysical mapping of flood control.

| Input data | Source | Spatial resolution | Temporal coverage | | |
|---|---|---|---|---|---|
| **Ecosystem service potential (indicator of potential runoff retention)** | | | | | |
| **Accounting layers CORINE land cover** | https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search;jsessionid=ECE3C056F58790227AD6D6DCC72446D6#/home | 100 m | 2000 | 2006 | 2012 |
| **EU Dem 100 m > derive slope (m/m)** | https://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1-0-and-derived-products/eu-dem-v1.0?tab=download | 100 m | Static | | |
| **USDA soil textural classes: hydraulic properties** | https://esdac.jrc.ec.europa.eu/resource-type/datasets | 500 m | Static | | |
| **Imperviousness** | https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/view | 100 m | NA[1] | 2006 | 2012 |
| **Riparian zones** | https://land.copernicus.eu/local/riparian-zones | Shapefile | Static | | |
| **Ecosystem service demand** | | | | | |
| **CORINE land cover: accounting layers > economic assets > agriculture and artificial** | https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search;jsessionid=ECE3C056F58790227AD6D6DCC72446D6#/home | 100 m | 2000 | 2006 | 2012 |
| **Road network** | TeleAtlas | Shapefile (rasterized at 100 m) | Static | | |
| **Population** | https://ghsl.jrc.ec.europa.eu/ghs_pop.php | 250 m | Static (2015) | | |
| **Flood hazard map (return period 500 years)** | https://data.jrc.ec.europa.eu/collection/id-0054 | 100 m | Static | | |
| **Actual flow (use)** | | | | | |
| **EU Dem 100 m > flow direction and flow accumulation** | https://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1-0-and-derived-products/eu-dem-v1.0?tab=download | 100 m | Static | | |
| **Monetary valuation** | | | | | |
| **Estimated flood protection level** | https://data.jrc.ec.europa.eu/dataset/959355de-514a-4126-a969-27793cd775aa | | Static | | |
| **Damage functions: Feyen et al. 2012** | https://link.springer.com/content/pdf/10.1007%2Fs10584-011-0339-7.pdf | Country | Static | | |
| [1]NA: Not available | | | | | |

Annex 11. Lookup table of the Curve Number values applied.

| | | Soil types* | | | |
|---|---|---|---|---|---|
| **CLC code** | **Description** | **A** | **B** | **C** | **D** |
| **111-133** | Artificial | 70.40 | 74.80 | 79.20 | 83.60 |
| **141** | Green urban areas | 24.45 | 35.32 | 40.75 | 43.47 |
| **142** | Artificial | 70.40 | 74.80 | 79.20 | 83.60 |
| **211** | Non-irrigated arable land | 51.25 | 59.66 | 65.02 | 68.08 |
| **212** | Permanently irrigated land | 59.65 | 69.44 | 75.67 | 79.24 |
| **213** | Rice fields | 59.65 | 69.44 | 75.67 | 79.24 |
| **221** | Vineyards | 49.28 | 57.36 | 65.44 | 71.91 |
| **222** | Fruit trees and berry plantations | 49.28 | 57.36 | 65.44 | 71.91 |
| **223** | Olive groves | 49.28 | 57.36 | 65.44 | 71.91 |
| **231** | Pasture | 32.96 | 46.41 | 53.14 | 56.50 |
| **241** | Annual crops associated with permanent crops | 51.32 | 59.74 | 68.15 | 74.88 |
| **242** | Complex cultivation patterns | 32.23 | 42.76 | 48.96 | 52.06 |
| **243** | Land principally occupied by agriculture, with significant areas of natural vegetation | 32.23 | 42.76 | 48.96 | 52.06 |
| **244** | Agro-forestry areas | 32.23 | 42.76 | 48.96 | 52.06 |
| **311** | Broad-leaved forest | 8.37 | 14.65 | 17.73 | 19.15 |
| **312** | Coniferous forest | 14.46 | 24.39 | 29.67 | 32.11 |
| **313** | Mixed forest | 11.88 | 19.38 | 23.44 | 25.31 |
| **321** | Natural grassland | 28.60 | 40.27 | 46.11 | 49.02 |
| **322** | Moors and heathland | 25.11 | 35.36 | 40.48 | 43.05 |
| **323** | Sclerophyllous vegetation | 25.11 | 35.36 | 40.48 | 43.05 |
| **324** | Transitional woodland-shrub | 18.87 | 27.25 | 31.44 | 33.54 |
| **332** | Bare rocks | 64.00 | 72.89 | 73.78 | 77.33 |
| **333** | Sparsely vegetated areas | 56.00 | 63.78 | 64.56 | 67.67 |
| **334** | Burnt areas | 43.94 | 61.88 | 70.85 | 75.33 |
| **411** | Inland marshes | 10.13 | 19.58 | 23.97 | 26.33 |
| **412** | Peat bogs | 10.13 | 19.58 | 23.97 | 26.33 |

* A. Sand, loamy sand, sandy loam. B. Silt, silt-loam, loam. C. Sandy clay-loam. D. Clay, silty clay, silty clay-loam, sand clay, clay-loam.

Annex 12. Criteria for the delineation of the Service Providing Areas (SPA) based on different criteria for three different broad ecosystem types.

| Land covers | CORINE Land Cover classes | Ecosystem service potential | | Criteria | Value | Threshold |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | | | |
| Artificial | Continuous urban fabric | 10.59 | 5.28 | Mean + Std.Dev | 15.87 | 27 |
| | Discontinuous urban fabric | 20.55 | 6.25 | Mean + Std.Dev | 26.80 | |
| | Industrial or commercial units | 16.04 | 7.94 | Mean + Std.Dev | 23.98 | |
| | Road and rail networks and associated land | 19.95 | 6.80 | Mean + Std.Dev | 26.74 | |
| | Port areas | 12.68 | 8.25 | Mean + Std.Dev | 20.93 | |
| | Airports | 22.41 | 7.45 | Mean + Std.Dev | 29.86 | |
| | Mineral extraction sites | 25.52 | 5.03 | Mean + Std.Dev | 30.55 | |
| | Dump sites | 25.77 | 5.22 | Mean + Std.Dev | 30.99 | |
| | Construction sites | 21.81 | 6.79 | Mean + Std.Dev | 28.60 | |
| | Sport and leisure facilities | 25.92 | 5.01 | Mean + Std.Dev | 30.93 | |
| Agricultural | Non-irrigated arable land | 41.85 | 5.93 | Mean + Std.Dev | 47.78 | 52 |
| | Permanently irrigated land | 30.35 | 6.11 | Mean + Std.Dev | 36.46 | |
| | Rice fields | 30.75 | 5.23 | Mean + Std.Dev | 35.98 | |
| | Vineyards | 42.42 | 6.54 | Mean + Std.Dev | 48.97 | |
| | Fruit trees and berry plantations | 41.43 | 7.31 | Mean + Std.Dev | 48.74 | |
| | Olive groves | 39.10 | 7.65 | Mean + Std.Dev | 46.76 | |
| | Pastures | 56.70 | 6.76 | Mean + Std.Dev | 63.47 | |
| | Annual crops associated with permanent crops | 40.56 | 9.42 | Mean + Std.Dev | 49.98 | |
| | Complex cultivation patterns | 58.20 | 6.71 | Mean + Std.Dev | 64.91 | |
| | Land principally occupied by agriculture | 59.24 | 6.89 | Mean + Std.Dev | 66.13 | |
| | Agro-forestry areas | 61.33 | 5.45 | Mean + Std.Dev | 66.78 | |
| Natural and semi-natural | Broad-leaved forest | 87.05 | 3.57 | Mean - Std.Dev | 83.48 | 61 |
| | Coniferous forest | 84.04 | 5.46 | Mean - Std.Dev | 78.58 | |
| | Mixed forest | 85.51 | 4.43 | Mean - Std.Dev | 81.09 | |
| | Natural grasslands | 60.12 | 5.48 | Mean - Std.Dev | 54.63 | |
| | Moors and heathland | 68.93 | 5.65 | Mean - Std.Dev | 63.28 | |
| | Sclerophyllous vegetation | 65.80 | 4.08 | Mean - Std.Dev | 61.72 | |
| | Transitional woodland-shrub | 77.81 | 5.42 | Mean - Std.Dev | 72.39 | |
| | Bare rocks | 28.31 | 3.64 | Mean - Std.Dev | 24.67 | |
| | Sparsely vegetated areas | 38.43 | 3.99 | Mean - Std.Dev | 34.43 | |
| | Burnt areas | 40.23 | 10.08 | Mean - Std.Dev | 30.15 | |
| | Inland marshes | 82.64 | 6.49 | Mean - Std.Dev | 76.15 | |
| | Peat bogs | 87.79 | 5.25 | Mean - Std.Dev | 82.54 | |
| | Green urban areas | 64.92 | 11.66 | Mean - Std.Dev | 53.26 | |

Annex 13. Supply and use tables for flood control in physical and monetary terms.

A.12.1 – Supply of flood control in physical terms (hectare), year 2006

| Economic unit | | | Ecosystem type | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Economic sectors | Households | **Total** | Urban areas | Cropland | Grassland | Heathland and shrub | Woodland and forest | Sparsely vegetated land | Wetlands |
| *hectare* | | | | | | | | | | |
| AT | | | 75,803 | 19.7 | 2,746.9 | 13,002.5 | 2,435.8 | 57,344.1 | 6.7 | 247.4 |
| BE | | | 58,552 | 379.9 | 14,044.7 | 13,767.8 | 231.2 | 29,708.2 | - | 419.7 |
| BG | | | 63,435 | 35.4 | 6,354.9 | 6,403.1 | 416.7 | 49,909.5 | 4.0 | 311.5 |
| CZ | | | 59,017 | 37.4 | 5,726.0 | 8,757.0 | 46.5 | 44,266.8 | - | 183.4 |
| DE | | | 692,442 | 7,056.3 | 11,706.7 | 169,046.5 | 3,357.5 | 497,003.4 | 4.5 | 4,267.4 |
| DK | | | 6,891 | 198.8 | 1,751.0 | 256.0 | 154.1 | 4,294.6 | - | 236.2 |
| EE | | | 32,934 | 138.7 | 2,456.4 | 2,493.1 | 4.9 | 26,282.1 | - | 1,558.5 |
| EL | | | 36,433 | 4.9 | 4,041.8 | 3,546.7 | 4,829.1 | 23,927.9 | 23.9 | 58.7 |
| ES | | | 122,383 | 50.6 | 11,814.7 | 15,637.7 | 22,642.5 | 72,057.3 | 16.9 | 163.1 |
| FI | | | 105,940 | 151.8 | 3,505.6 | 36.4 | 723.1 | 96,055.0 | 0.2 | 5,467.7 |
| FR | | | 568,090 | 274.9 | 44,656.9 | 135,816.3 | 8,129.2 | 376,733.1 | 61.5 | 2,417.8 |
| HR | | | 140,665 | 12.3 | 25,331.0 | 6,818.9 | 308.2 | 107,837.4 | 0.6 | 356.9 |
| HU | | | 195,569 | 164.7 | 15,692.4 | 26,940.9 | 101.2 | 149,451.0 | 2.3 | 3,216.2 |
| IE | | | 65,789 | 17.0 | 3,489.5 | 43,495.2 | 310.9 | 8,287.3 | 0.5 | 10,189.0 |
| IT | | | 129,030 | 35.3 | 9,962.7 | 8,467.8 | 3,557.0 | 106,643.1 | 98.0 | 266.0 |
| LT | | | 85,502 | 909.2 | 19,214.8 | 7,932.2 | 38.2 | 55,801.3 | - | 1,606.6 |
| LU | | | 2,836 | 1.3 | 500.1 | 589.0 | 0.5 | 1,743.7 | - | 1.8 |
| LV | | | 133,849 | 748.8 | 18,502.0 | 18,553.0 | 3.3 | 91,716.3 | - | 4,325.6 |
| NL | | | 299,874 | 2,022.9 | 5,995.4 | 68,322.8 | 1,427.5 | 219,855.3 | 2.3 | 2,248.0 |
| PL | | | 762,724 | 12,838.2 | 73,626.0 | 118,926.6 | 293.4 | 549,944.0 | 6.6 | 7,089.2 |
| PT | | | 36,563 | 85.1 | 7,509.5 | 3,275.5 | 4,707.4 | 20,954.8 | 3.8 | 26.7 |
| RO | | | 226,909 | 114.0 | 19,786.6 | 33,037.8 | 1,421.2 | 171,346.0 | 11.0 | 1,192.3 |
| SE | | | 103,332 | 235.0 | 1,657.9 | 885.9 | 4,605.3 | 88,735.1 | 0.5 | 7,212.0 |
| SI | | | 23,605 | 0.9 | 1,237.1 | 767.9 | 274.0 | 21,279.8 | 3.0 | 42.7 |
| SK | | | 47,148 | 11.3 | 3,225.0 | 3,620.9 | 177.8 | 40,036.7 | - | 76.3 |
| UK | | | 112,659 | 614.9 | 1,327.8 | 62,261.0 | 12,182.2 | 21,713.4 | 0.7 | 14,558.7 |
| EU | | | 4,187,973 | 26,159 | 315,864 | 772,658 | 72,379 | 2,932,927 | 247 | 67,740 |

A.12.2 – Use of flood control in physical terms (hectare), year 2006

| | Economic unit | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|
| | **Total** | Agriculture | Manufacturing & energy production | Construction | Transport | Waste management | Other tertiary and Households | |
| *hectares* | | | | | | | | |
| AT | 75,803 | 58,561 | 848 | 39.3 | 11,180 | 12.3 | 5,162 | |
| BE | 58,552 | 48,768 | 840 | 48.5 | 4,744 | 22.1 | 4,129 | |
| BG | 63,435 | 57,348 | 668 | 47.3 | 4,081 | 19.6 | 1,271 | |
| CZ | 59,017 | 48,138 | 1,443 | 26.1 | 5,565 | 229.3 | 3,616 | |
| DE | 692,442 | 604,352 | 9,254 | 225.3 | 48,057 | 179.3 | 30,375 | |
| DK | 6,891 | 6,294 | 32 | 2.5 | 227 | - | 336 | |
| EE | 32,934 | 29,821 | 143 | 51.9 | 2,277 | - | 641 | |
| EL | 36,433 | 33,528 | 190 | 39.7 | 2,358 | - | 317 | |
| ES | 122,383 | 102,300 | 1,755 | 318.6 | 14,978 | 180.5 | 2,850 | |
| FI | 105,940 | 79,563 | 768 | 41.5 | 18,741 | 77.9 | 6,748 | |
| FR | 568,090 | 495,044 | 7,211 | 107.2 | 50,108 | 117.4 | 15,502 | |
| HR | 140,665 | 133,633 | 301 | 23.0 | 6,162 | 0.9 | 545 | |
| HU | 195,569 | 185,987 | 398 | 74.8 | 6,693 | 45.3 | 2,371 | |
| IE | 65,789 | 62,373 | 165 | 21.8 | 2,412 | 1.6 | 815 | |
| IT | 129,030 | 110,606 | 1,690 | 41.4 | 13,646 | 2.8 | 3,043 | |
| LT | 85,502 | 77,539 | 687 | 34.8 | 4,315 | 38.0 | 2,887 | |
| LU | 2,836 | 1,596 | 51 | - | 869 | - | 320 | |
| LV | 133,849 | 116,764 | 1,977 | 392.6 | 8,204 | - | 6,511 | |
| NL | 299,874 | 266,765 | 1,692 | 1,457.4 | 22,135 | 57.1 | 7,768 | |
| PL | 762,724 | 696,729 | 4,237 | 325.3 | 29,802 | 565.7 | 31,065 | |
| PT | 36,563 | 32,553 | 176 | 52.8 | 3,370 | - | 411 | |
| RO | 226,909 | 214,293 | 1,204 | 29.6 | 6,757 | 22.4 | 4,603 | |
| SE | 103,332 | 71,412 | 1,449 | 35.1 | 20,418 | 26.2 | 9,991 | |
| SI | 23,605 | 19,117 | 235 | 8.5 | 3,575 | 0.2 | 670 | |
| SK | 47,148 | 41,582 | 581 | 32.8 | 3,364 | 19.8 | 1,568 | |
| UK | 112,659 | 96,588 | 1,672 | 47.8 | 7,179 | 50.3 | 7,121 | |
| | | | | | | | | |
| EU | 4,187,973 | 3,691,255 | 39,667 | 3,526 | 301,218 | 1,669 | 150,638 | |

A.12.3 – Supply of flood control in monetary terms (million euro), year 2006

| Economic units | Economic sectors | Households | *Total* | Urban areas NC+ | Urban areas NC | Cropland NC+ | Cropland NC | Grassland NC+ | Grassland NC | Heathland and shrub NC+ | Heathland and shrub NC | Woodland and forest NC+ | Woodland and forest NC | Sparsely vegetated land NC+ | Sparsely vegetated land NC | Wetlands NC+ | Wetlands NC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *million euro* | | | | | | | | | | | | | | | | | |
| AT | | | 949 | 0.21 | 0.034 | 29.71 | 4.70 | 140.63 | 22.23 | 26.34 | 4.16 | 620.21 | 98.04 | 0.073 | 0.0115 | 2.68 | 0.42 |
| BE | | | 708 | 4.03 | 0.569 | 148.90 | 21.02 | 145.96 | 20.60 | 2.45 | 0.35 | 314.96 | 44.46 | - | - | 4.45 | 0.63 |
| BG | | | 67 | 0.02 | 0.012 | 4.48 | 2.21 | 4.52 | 2.23 | 0.29 | 0.15 | 35.22 | 17.39 | 0.003 | 0.0014 | 0.22 | 0.11 |
| CZ | | | 426 | 0.23 | 0.038 | 35.54 | 5.78 | 54.35 | 8.83 | 0.29 | 0.05 | 274.73 | 44.66 | - | - | 1.14 | 0.19 |
| DE | | | 3,732 | 31.29 | 6.740 | 51.90 | 11.18 | 749.51 | 161.48 | 14.89 | 3.21 | 2,203.58 | 474.75 | 0.020 | 0.0043 | 18.92 | 4.08 |
| DK | | | 22 | 0.46 | 0.157 | 4.09 | 1.39 | 0.60 | 0.20 | 0.36 | 0.12 | 10.03 | 3.40 | - | - | 0.55 | 0.19 |
| EE | | | 38 | 0.09 | 0.069 | 1.63 | 1.21 | 1.65 | 1.23 | 0.00 | 0.00 | 17.44 | 12.99 | - | - | 1.03 | 0.77 |
| EL | | | 36 | 0.00 | 0.002 | 2.04 | 1.93 | 1.79 | 1.69 | 2.44 | 2.31 | 12.07 | 11.42 | 0.012 | 0.0114 | 0.03 | 0.03 |
| ES | | | 478 | 0.12 | 0.077 | 28.18 | 17.99 | 37.29 | 23.81 | 54.00 | 34.47 | 171.85 | 109.69 | 0.040 | 0.0258 | 0.39 | 0.25 |
| FI | | | 804 | 0.83 | 0.324 | 19.12 | 7.48 | 0.20 | 0.08 | 3.94 | 1.54 | 523.99 | 205.03 | 0.001 | 0.0005 | 29.83 | 11.67 |
| FR | | | 2,432 | 0.99 | 0.189 | 160.56 | 30.64 | 488.31 | 93.20 | 29.23 | 5.58 | 1,354.50 | 258.52 | 0.221 | 0.0422 | 8.69 | 1.66 |
| HR | | | 54 | 0.00 | 0.005 | 0.21 | 9.53 | 0.06 | 2.56 | 0.00 | 0.12 | 0.91 | 40.56 | 0.0000 | 0.0002 | 0.00 | 0.13 |
| HU | | | 156 | 0.11 | 0.021 | 10.51 | 1.97 | 18.04 | 3.39 | 0.07 | 0.01 | 100.08 | 18.80 | 0.002 | 0.00028 | 2.15 | 0.40 |
| IE | | | 155 | 0.03 | 0.011 | 6.01 | 2.21 | 74.87 | 27.54 | 0.54 | 0.20 | 14.26 | 5.25 | 0.001 | 0.00029 | 17.54 | 6.45 |

| Economic units | | | Ecosystem types | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Economic sectors | Households | ***Total*** | Urban areas | | Cropland | | Grassland | | Heathland and shrub | | Woodland and forest | | Sparsely vegetated land | | Wetlands | |
| | | | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC |
| *million euro* | | | | | | | | | | | | | | | | | |
| IT | | | 501 | 0.12 | 0.021 | 32.84 | 5.84 | 27.92 | 4.96 | 11.73 | 2.08 | 351.57 | 62.50 | 0.323 | 0.0574 | 0.88 | 0.16 |
| LT | | | 190 | 1.15 | 0.868 | 24.33 | 18.34 | 10.05 | 7.57 | 0.05 | 0.04 | 70.67 | 53.25 | - | - | 2.03 | 1.53 |
| LU | | | 166 | 0.07 | 0.009 | 25.88 | 3.35 | 30.48 | 3.95 | 0.02 | 0.00 | 90.24 | 11.70 | - | - | 0.09 | 0.01 |
| LV | | | 331 | 1.14 | 0.709 | 28.21 | 17.53 | 28.29 | 17.57 | 0.01 | 0.00 | 139.86 | 86.88 | - | - | 6.60 | 4.10 |
| NL | | | 935 | 6.07 | 0.239 | 17.98 | 0.71 | 204.93 | 8.07 | 4.28 | 0.17 | 659.44 | 25.96 | 0.007 | 0.00027 | 6.74 | 0.27 |
| PL | | | 1,456 | 17.92 | 6.586 | 102.76 | 37.77 | 165.98 | 61.01 | 0.41 | 0.15 | 767.53 | 282.13 | 0.009 | 0.0034 | 9.89 | 3.64 |
| PT | | | 66 | 0.04 | 0.111 | 3.74 | 9.76 | 1.63 | 4.26 | 2.34 | 6.12 | 10.43 | 27.23 | 0.002 | 0.0049 | 0.01 | 0.035 |
| RO | | | 199 | 0.07 | 0.031 | 12.07 | 5.30 | 20.16 | 8.85 | 0.87 | 0.38 | 104.56 | 45.92 | 0.007 | 0.0029 | 0.73 | 0.32 |
| SE | | | 1,303 | 1.67 | 1.289 | 11.81 | 9.09 | 6.31 | 4.86 | 32.80 | 25.26 | 631.93 | 486.74 | 0.004 | 0.0030 | 51.36 | 39.56 |
| SI | | | 106 | 0.00 | 0.001 | 4.42 | 1.16 | 2.74 | 0.72 | 0.98 | 0.26 | 76.01 | 19.99 | 0.011 | 0.0029 | 0.15 | 0.040 |
| SK | | | 127 | 0.03 | 0.004 | 7.48 | 1.17 | 8.40 | 1.31 | 0.41 | 0.06 | 92.90 | 14.52 | - | - | 0.18 | 0.028 |
| UK | | | 692 | 3.25 | 0.523 | 7.02 | 1.13 | 329.24 | 53.00 | 64.42 | 10.37 | 114.82 | 18.48 | 0.003 | 0.00056 | 76.99 | 12.39 |
| EU | | | 16,127 | 70 | 19 | 781 | 230 | 2,554 | 545 | 253 | 97 | 8,764 | 2,480 | 0.7 | 0.17 | 243 | 89.05 |

A.12.4 – Use of flood control in monetary terms (million euro), year 2006

| | Economic units | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Total*** | Agriculture | | Manufacturing & energy production | | Construction | | Transport | | Waste management | | Other tertiary and Households | | **Ecosystem types** |
| | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | |
| *million euro* | | | | | | | | | | | | | | |
| AT | 949 | 18.75 | 2.79 | 65.40 | 10.65 | 2.42 | 0.523 | 73.38 | 11.71 | 0.001 | 0.00013 | 659.91 | 103.93 | |
| BE | 708 | 11.04 | 1.58 | 89.44 | 11.72 | 2.11 | 0.310 | 25.57 | 3.70 | 0.002 | 0.00026 | 492.58 | 70.31 | |
| BG | 67 | 2.56 | 1.55 | 10.50 | 4.45 | 0.64 | 0.677 | 4.25 | 2.71 | 0.000 | 0.00005 | 26.80 | 12.71 | |
| CZ | 426 | 8.18 | 1.25 | 80.56 | 11.63 | 0.63 | 0.098 | 20.81 | 3.28 | 0.010 | 0.00134 | 256.09 | 43.29 | |
| DE | 3,732 | 148.22 | 30.51 | 583.32 | 117.73 | 9.41 | 1.757 | 209.04 | 47.50 | 0.008 | 0.00134 | 2120.11 | 463.95 | |
| DK | 22 | 1.04 | 0.36 | 0.42 | 0.09 | 0.14 | 0.035 | 0.58 | 0.21 | 0.000 | 0.00000 | 13.91 | 4.76 | |
| EE | 38 | 2.18 | 1.54 | 1.11 | 1.43 | 0.48 | 0.546 | 3.22 | 1.89 | 0.000 | 0.00000 | 14.87 | 10.87 | |
| EL | 36 | 2.85 | 3.53 | 1.19 | 4.12 | 0.05 | 0.924 | 3.01 | 5.04 | 0.000 | 0.00000 | 11.28 | 3.77 | |
| ES | 478 | 11.52 | 14.03 | 72.36 | 28.04 | 9.14 | 4.478 | 38.55 | 40.85 | 0.005 | 0.00336 | 160.29 | 98.90 | |
| FI | 804 | 10.43 | 4.86 | 30.82 | 15.34 | 0.00 | 1.104 | 45.28 | 31.33 | 0.003 | 0.00119 | 491.38 | 173.50 | |
| FR | 2,432 | 126.41 | 25.51 | 259.70 | 45.26 | 4.50 | 0.647 | 225.57 | 56.17 | 0.008 | 0.00109 | 1426.30 | 262.23 | |
| HR | 54 | 0.59 | 15.16 | 0.00 | 4.99 | 0.00 | 0.602 | 0.31 | 11.68 | 0.000 | 0.00003 | 0.28 | 20.48 | |
| HU | 156 | 26.60 | 5.12 | 9.98 | 1.85 | 1.72 | 0.283 | 14.86 | 2.94 | 0.002 | 0.00023 | 77.80 | 14.41 | |
| IE | 155 | 15.27 | 5.95 | 6.40 | 1.34 | 0.98 | 0.262 | 11.51 | 4.58 | 0.000 | 0.00001 | 79.08 | 29.52 | |
| IT | 501 | 20.26 | 4.74 | 86.77 | 15.24 | 1.17 | 0.377 | 53.05 | 10.71 | 0.000 | 0.00002 | 264.12 | 44.56 | |

| | Economic units | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Total*** | Agriculture | | Manufacturing & energy production | | Construction | | Transport | | Waste management | | Other tertiary and Households | | | |
| | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | | |
| LT | 190 | 6.71 | 4.02 | 11.65 | 6.46 | 0.43 | 0.349 | 6.99 | 3.87 | 0.001 | 0.00055 | 82.50 | 66.89 | | |
| LU | 166 | 1.28 | 0.16 | 11.51 | 1.42 | 0.00 | 0.000 | 15.53 | 2.01 | 0.000 | 0.00000 | 118.45 | 15.44 | | |
| LV | 331 | 7.12 | 6.45 | 24.32 | 15.30 | 4.83 | 2.031 | 11.77 | 8.23 | 0.000 | 0.00000 | 156.07 | 94.78 | | |
| NL | 935 | 71.47 | 2.71 | 108.38 | 3.93 | 84.47 | 3.235 | 104.02 | 3.98 | 0.002 | 0.00008 | 531.11 | 21.56 | | |
| PL | 1,456 | 66.45 | 27.14 | 76.42 | 21.89 | 5.51 | 1.062 | 45.52 | 18.84 | 0.012 | 0.00365 | 870.60 | 322.35 | | |
| PT | 66 | 1.19 | 4.43 | 1.91 | 4.56 | 0.01 | 2.429 | 3.40 | 11.83 | 0.000 | 0.00000 | 11.68 | 24.25 | | |
| RO | 199 | 12.16 | 5.22 | 10.75 | 5.51 | 0.29 | 0.166 | 7.59 | 3.71 | 0.000 | 0.00008 | 107.68 | 46.21 | | |
| SE | 1,303 | 13.47 | 8.06 | 90.11 | 38.44 | 0.71 | 1.062 | 46.12 | 66.47 | 0.000 | 0.00072 | 585.47 | 452.78 | | |
| SI | 106 | 3.00 | 0.95 | 16.00 | 5.19 | 0.14 | 0.039 | 14.08 | 5.33 | 0.000 | 0.00000 | 51.09 | 10.66 | | |
| SK | 127 | 5.19 | 0.73 | 16.92 | 2.50 | 0.72 | 0.104 | 8.32 | 1.38 | 0.000 | 0.00008 | 78.26 | 12.38 | | |
| UK | 692 | 27.13 | 4.76 | 88.51 | 13.71 | 2.09 | 0.318 | 34.02 | 6.18 | 0.003 | 0.00039 | 443.99 | 70.93 | | |
| | | | | | | | | | | | | | | | |
| EU | 16,127 | 621 | 183.1 | 1,754 | 393 | 133 | 23.42 | 1,026 | 366 | 0.059 | 0.015 | 9,132 | 2,495 | | |

A.12.5 – Supply of flood control in physical terms (hectare), year 2012

| Economic unit | | | Type of ecosystem unit | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Economic sectors | Households | **Total** | Urban areas | Cropland | Grassland | Heathland and shrub | Woodland and forest | Sparsely vegetated land | Wetlands |
| *hectare* | | | | | | | | | | |
| AT | | | 75,566 | 20 | 2,733 | 12,982 | 2,427 | 57,151 | 6.86 | 247 |
| BE | | | 58,193 | 351 | 13,441 | 13,470 | 219 | 30,304 | - | 408 |
| BG | | | 62,979 | 35 | 6,294 | 6,349 | 413 | 49,576 | 3.94 | 308 |
| CZ | | | 59,562 | 37 | 5,692 | 9,564 | 46 | 44,043 | - | 181 |
| DE | | | 686,981 | 6,966 | 11,596 | 167,878 | 3,314 | 493,005 | 4.04 | 4,218 |
| DK | | | 6,874 | 210 | 1,739 | 254 | 153 | 4,284 | - | 234 |
| EE | | | 32,702 | 144 | 2,424 | 2,537 | 5 | 26,046 | - | 1,546 |
| EL | | | 36,259 | 5 | 4,030 | 3,532 | 4,857 | 23,750 | 24.01 | 61 |
| ES | | | 122,140 | 59 | 12,048 | 15,533 | 22,573 | 71,738 | 15.86 | 173 |
| FI | | | 105,842 | 157 | 3,505 | 34 | 724 | 95,907 | 0.24 | 5,516 |
| FR | | | 565,176 | 274 | 44,332 | 134,971 | 8,093 | 375,041 | 60.25 | 2,405 |
| HR | | | 140,567 | 12 | 25,282 | 6,821 | 308 | 107,787 | 0.56 | 357 |
| HU | | | 197,496 | 168 | 15,757 | 27,090 | 102 | 151,149 | 2.26 | 3,228 |
| IE | | | 65,765 | 18 | 3,455 | 43,338 | 310 | 8,517 | 0.46 | 10,127 |
| IT | | | 127,809 | 35 | 9,835 | 8,388 | 3,531 | 105,658 | 96.72 | 265 |
| LT | | | 85,047 | 912 | 19,075 | 7,547 | 37 | 55,880 | - | 1,596 |
| LU | | | 2,822 | 1.3 | 497 | 584 | 0.5 | 1,737 | - | 1.7 |
| LV | | | 132,883 | 756 | 18,427 | 17,857 | 3 | 91,521 | - | 4,319 |
| NL | | | 296,635 | 1,972 | 5,924 | 67,297 | 1,412 | 217,825 | 2.11 | 2,203 |
| PL | | | 760,552 | 13,040 | 73,056 | 117,662 | 283 | 549,443 | 6.53 | 7,061 |
| PT | | | 36,055 | 86 | 7,413 | 3,221 | 4,634 | 20,671 | 3.84 | 26 |
| RO | | | 225,412 | 114 | 19,612 | 32,777 | 1,410 | 170,306 | 10.87 | 1,181 |
| SE | | | 103,280 | 239 | 1,656 | 887 | 4,604 | 88,686 | 0.54 | 7,208 |
| SI | | | 23,558 | 1 | 1,232 | 765 | 273 | 21,240 | 3.04 | 43 |
| SK | | | 47,157 | 12 | 3,215 | 3,643 | 178 | 40,033 | - | 76 |
| UK | | | 112,246 | 614 | 1,320 | 62,031 | 12,122 | 21,638 | 0.71 | 14,520 |
| EU | | | 4,169,559 | 26,239 | 313,591 | 767,010 | 72,032 | 2,922,936 | 242.8 | 67,508 |

A.12.6 – Use of flood control in physical terms (hectare), year 2012

| | Type of economic unit | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Total** | Agriculture | Manufacturing & energy production | Construction | Transport | Waste management | Other tertiary and Households | **Ecosystem types** |
| *hectare* | | | | | | | | |
| AT | 75,566 | 58,277 | 893 | 59 | 11,104 | 12 | 5,221 | |
| BE | 58,193 | 48,414 | 854 | 70 | 4,723 | 22 | 4,110 | |
| BG | 62,979 | 56,956 | 678 | 3 | 4,050 | 20 | 1,272 | |
| CZ | 59,562 | 48,662 | 1,409 | 24 | 5,585 | 216 | 3,667 | |
| DE | 686,981 | 599,288 | 9,357 | 316 | 47,662 | 168 | 30,190 | |
| DK | 6,874 | 6,275 | 32 | 1 | 227 | - | 340 | |
| EE | 32,702 | 29,567 | 144 | 29 | 2,296 | - | 666 | |
| EL | 36,259 | 33,324 | 222 | 68 | 2,329 | - | 317 | |
| ES | 122,140 | 101,823 | 1,934 | 360 | 14,702 | 200 | 3,120 | |
| FI | 105,842 | 79,395 | 771 | 44 | 18,760 | 60 | 6,812 | |
| FR | 565,176 | 492,368 | 7,436 | 103 | 49,620 | 114 | 15,535 | |
| HR | 140,567 | 133,526 | 347 | 12 | 6,120 | 1 | 562 | |
| HU | 197,496 | 187,622 | 512 | 85 | 6,842 | 41 | 2,393 | |
| IE | 65,765 | 62,339 | 167 | 4 | 2,417 | 2 | 836 | |
| IT | 127,809 | 109,572 | 1,734 | 86 | 13,358 | 7 | 3,052 | |
| LT | 85,047 | 77,050 | 691 | 61 | 4,305 | 38 | 2,901 | |
| LU | 2,822 | 1,580 | 48 | 9 | 865 | - | 319 | |
| LV | 132,883 | 115,574 | 2,046 | 211 | 8,161 | - | 6,891 | |
| NL | 296,635 | 262,568 | 2,075 | 1,509 | 21,919 | 50 | 8,514 | |
| PL | 760,552 | 694,104 | 4,919 | 493 | 29,642 | 574 | 30,819 | |
| PT | 36,055 | 32,024 | 178 | 113 | 3,325 | - | 415 | |
| RO | 225,412 | 212,792 | 1,303 | 20 | 6,674 | 22 | 4,599 | |
| SE | 103,280 | 71,330 | 1,475 | 37 | 20,453 | 28 | 9,958 | |
| SI | 23,558 | 19,089 | 234 | 8 | 3,557 | 0 | 669 | |
| SK | 47,157 | 41,551 | 597 | 53 | 3,366 | 19 | 1,570 | |
| UK | 112,246 | 96,282 | 1,652 | 47 | 7,147 | 50 | 7,069 | |
| | | | | | | | | |
| EU | 4,169,559 | 3,671,353 | 41,710 | 3,825 | 299,210 | 1,645 | 151,817 | |
| | | | | | | | | |

A.12.7 – Supply of flood control in monetary terms (million euro), year 2012

| **Economic units** | | | **Ecosystem types** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Economic sectors | Households | ***Total*** | Urban areas | | Cropland | | Grassland | | Heathland and shrub | | Woodland and forest | | Sparsely vegetated land | | Wetlands | |
| *million euro* | | | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC |
| AT | | | 955 | 0.21 | 0.034 | 29.84 | 4.72 | 141.74 | 22.40 | 26.50 | 4.19 | 624.02 | 98.61 | 0.075 | 0.0118 | 2.70 | 0.43 |
| BE | | | 709 | 3.75 | 0.529 | 143.46 | 20.25 | 143.76 | 20.29 | 2.33 | 0.33 | 323.42 | 45.66 | - | - | 4.36 | 0.62 |
| BG | | | 66 | 0.02 | 0.012 | 4.43 | 2.15 | 4.46 | 2.17 | 0.29 | 0.14 | 34.86 | 16.96 | 0.003 | 0.0013 | 0.22 | 0.11 |
| CZ | | | 429 | 0.23 | 0.038 | 35.26 | 5.75 | 59.23 | 9.66 | 0.28 | 0.05 | 272.79 | 44.48 | - | - | 1.12 | 0.18 |
| DE | | | 3,728 | 31.09 | 6.716 | 51.75 | 11.18 | 749.25 | 161.86 | 14.79 | 3.20 | 2,200.31 | 475.33 | 0.018 | 0.0039 | 18.83 | 4.07 |
| DK | | | 22 | 0.50 | 0.170 | 4.17 | 1.41 | 0.61 | 0.21 | 0.37 | 0.12 | 10.28 | 3.47 | - | - | 0.56 | 0.19 |
| EE | | | 40 | 0.10 | 0.076 | 1.70 | 1.28 | 1.78 | 1.34 | 0.00 | 0.00 | 18.28 | 13.71 | - | - | 1.08 | 0.81 |
| EL | | | 39 | 0.00 | 0.003 | 2.05 | 2.23 | 1.80 | 1.96 | 2.48 | 2.69 | 12.11 | 13.15 | 0.012 | 0.0133 | 0.03 | 0.03 |
| ES | | | 509 | 0.15 | 0.097 | 30.54 | 19.66 | 39.37 | 25.34 | 57.21 | 36.83 | 181.82 | 117.04 | 0.040 | 0.0259 | 0.44 | 0.28 |
| FI | | | 809 | 0.86 | 0.339 | 19.24 | 7.56 | 0.19 | 0.07 | 3.97 | 1.56 | 526.49 | 206.75 | 0.001 | 0.0005 | 30.28 | 11.89 |
| FR | | | 2,442 | 0.99 | 0.190 | 160.84 | 30.68 | 489.69 | 93.42 | 29.36 | 5.60 | 1,360.70 | 259.57 | 0.219 | 0.0417 | 8.72 | 1.66 |
| HR | | | 55 | 0.00 | 0.005 | 0.21 | 9.68 | 0.06 | 2.61 | 0.00 | 0.12 | 0.91 | 41.28 | 0.0000 | 0.0002 | 0.00 | 0.14 |
| HU | | | 161 | 0.12 | 0.022 | 10.83 | 2.04 | 18.63 | 3.51 | 0.07 | 0.01 | 103.93 | 19.57 | 0.002 | 0.0003 | 2.22 | 0.42 |
| IE | | | 156 | 0.03 | 0.012 | 5.98 | 2.21 | 74.95 | 27.67 | 0.54 | 0.20 | 14.73 | 5.44 | 0.001 | 0.0003 | 17.51 | 6.46 |

| Economic units | | | Ecosystem types | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Economic sectors | Households | ***Total*** | Urban areas | | Cropland | | Grassland | | Heathland and shrub | | Woodland and forest | | Sparsely vegetated land | | Wetlands | |
| *million euro* | | | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC |
| IT | | | 504 | 0.12 | 0.021 | 32.92 | 5.88 | 28.08 | 5.01 | 11.82 | 2.11 | 353.66 | 63.13 | 0.324 | 0.0578 | 0.89 | 0.16 |
| LT | | | 190 | 1.17 | 0.875 | 24.38 | 18.31 | 9.65 | 7.24 | 0.05 | 0.04 | 71.42 | 53.64 | - | - | 2.04 | 1.53 |
| LU | | | 165 | 0.07 | 0.009 | 25.67 | 3.34 | 30.16 | 3.92 | 0.02 | 0.00 | 89.71 | 11.67 | - | - | 0.09 | 0.01 |
| LV | | | 343 | 1.21 | 0.739 | 29.60 | 18.02 | 28.69 | 17.46 | 0.01 | 0.00 | 147.02 | 89.49 | - | - | 6.94 | 4.22 |
| NL | | | 1,046 | 6.70 | 0.258 | 20.11 | 0.78 | 228.49 | 8.81 | 4.79 | 0.18 | 739.58 | 28.51 | 0.007 | 0.0003 | 7.48 | 0.29 |
| PL | | | 1,455 | 18.24 | 6.717 | 102.17 | 37.64 | 164.56 | 60.61 | 0.40 | 0.15 | 768.44 | 283.05 | 0.009 | 0.0034 | 9.88 | 3.64 |
| PT | | | 68 | 0.04 | 0.120 | 3.73 | 10.35 | 1.62 | 4.50 | 2.33 | 6.47 | 10.41 | 28.85 | 0.002 | 0.0054 | 0.01 | 0.037 |
| RO | | | 199 | 0.07 | 0.031 | 12.04 | 5.29 | 20.12 | 8.83 | 0.87 | 0.38 | 104.52 | 45.90 | 0.007 | 0.0029 | 0.72 | 0.32 |
| SE | | | 1,301 | 1.70 | 1.314 | 11.76 | 9.10 | 6.30 | 4.88 | 32.68 | 25.30 | 629.60 | 487.42 | 0.004 | 0.0030 | 51.17 | 39.61 |
| SI | | | 106 | 0.00 | 0.001 | 4.40 | 1.16 | 2.73 | 0.72 | 0.98 | 0.26 | 75.87 | 19.95 | 0.011 | 0.0029 | 0.15 | 0.040 |
| SK | | | 128 | 0.03 | 0.004 | 7.55 | 1.18 | 8.56 | 1.34 | 0.42 | 0.07 | 94.06 | 14.70 | - | - | 0.18 | 0.028 |
| UK | | | 685 | 3.23 | 0.517 | 6.94 | 1.11 | 326.09 | 52.28 | 63.73 | 10.22 | 113.75 | 18.24 | 0.004 | 0.0006 | 76.33 | 12.24 |
| EU | | | 16,312 | 71 | 19 | 782 | 233 | 2,581 | 548 | 256 | 100 | 8,883 | 2,506 | 0.7 | 0.18 | 244 | 89.42 |

A.12.8 – Use of flood control in monetary terms (million euro), year 2012

| | Economic units | | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Total*** | Agriculture | | Manufacturing & energy production | | Construction | | Transport | | Waste management | | Other tertiary and Households | | | |
| | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | | |
| *million euro* | | | | | | | | | | | | | | | |
| AT | 955 | 18.65 | 2.78 | 67.74 | 11.07 | 4.40 | 0.585 | 72.96 | 11.65 | 0.001 | 0.0001 | 661.33 | 104.30 | | |
| BE | 709 | 10.95 | 1.57 | 91.51 | 11.99 | 2.46 | 0.391 | 25.55 | 3.70 | 0.002 | 0.0003 | 490.61 | 70.03 | | |
| BG | 66 | 2.55 | 1.54 | 10.63 | 4.61 | 0.02 | 0.006 | 4.24 | 2.70 | 0.000 | 0.0001 | 26.84 | 12.69 | | |
| CZ | 429 | 8.26 | 1.26 | 81.68 | 11.81 | 0.45 | 0.098 | 20.85 | 3.29 | 0.009 | 0.0012 | 257.66 | 43.71 | | |
| DE | 3,728 | 147.12 | 30.28 | 593.39 | 120.76 | 12.25 | 2.772 | 207.03 | 47.08 | 0.007 | 0.0012 | 2106.25 | 461.46 | | |
| DK | 22 | 1.04 | 0.36 | 0.42 | 0.09 | 0.00 | 0.007 | 0.58 | 0.21 | 0.000 | 0.0000 | 14.44 | 4.91 | | |
| EE | 40 | 2.18 | 1.52 | 1.02 | 1.32 | 0.23 | 0.342 | 3.26 | 1.91 | 0.000 | 0.0000 | 16.25 | 12.12 | | |
| EL | 39 | 2.83 | 3.51 | 1.26 | 5.69 | 0.17 | 2.120 | 2.96 | 5.00 | 0.000 | 0.0000 | 11.26 | 3.77 | | |
| ES | 509 | 11.46 | 13.94 | 82.15 | 37.94 | 9.09 | 4.838 | 37.98 | 40.22 | 0.005 | 0.0041 | 168.88 | 102.33 | | |
| FI | 809 | 10.39 | 4.85 | 30.02 | 15.28 | 0.04 | 1.115 | 45.34 | 31.35 | 0.003 | 0.0007 | 495.24 | 175.58 | | |
| FR | 2,442 | 125.80 | 25.39 | 268.46 | 46.93 | 3.77 | 0.675 | 223.90 | 55.70 | 0.008 | 0.0011 | 1428.60 | 262.47 | | |
| HR | 55 | 0.59 | 15.14 | 0.00 | 6.35 | 0.00 | 0.233 | 0.31 | 11.57 | 0.000 | 0.0000 | 0.28 | 20.54 | | |
| HU | 161 | 26.89 | 5.14 | 13.34 | 2.47 | 1.55 | 0.305 | 15.25 | 3.06 | 0.002 | 0.0002 | 78.76 | 14.59 | | |
| IE | 156 | 15.28 | 5.93 | 6.36 | 1.33 | 0.15 | 0.044 | 11.53 | 4.60 | 0.000 | 0.0000 | 80.43 | 30.08 | | |
| IT | 504 | 20.04 | 4.69 | 88.22 | 15.64 | 3.06 | 0.870 | 52.16 | 10.48 | 0.000 | 0.0001 | 264.32 | 44.68 | | |

| | Economic units | | | | | | | | | | | | | Ecosystem types |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Total*** | Agriculture | | Manufacturing & energy production | | Construction | | Transport | | Waste management | | Other tertiary and Households | | |
| | | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | NC+ | NC | |
| *million euro* | | | | | | | | | | | | | | |
| LT | 190 | 6.65 | 3.99 | 11.54 | 6.41 | 0.70 | 0.330 | 6.98 | 3.87 | 0.001 | 0.0005 | 82.83 | 67.04 | |
| LU | 165 | 1.27 | 0.16 | 9.79 | 1.27 | 1.38 | 0.170 | 15.46 | 2.00 | 0.000 | 0.0000 | 117.82 | 15.36 | |
| LV | 343 | 7.07 | 6.38 | 24.32 | 15.38 | 2.80 | 0.752 | 11.74 | 8.19 | 0.000 | 0.0000 | 167.53 | 99.23 | |
| NL | 1,046 | 70.23 | 2.66 | 138.57 | 4.74 | 81.89 | 3.114 | 103.03 | 4.00 | 0.002 | 0.0001 | 613.45 | 24.31 | |
| PL | 1,455 | 66.21 | 27.05 | 78.51 | 22.51 | 7.74 | 2.049 | 45.25 | 18.79 | 0.013 | 0.0037 | 865.97 | 321.39 | |
| PT | 68 | 1.17 | 4.34 | 1.87 | 4.51 | 0.41 | 5.506 | 3.33 | 11.69 | 0.000 | 0.0000 | 11.38 | 24.27 | |
| RO | 199 | 12.03 | 5.19 | 11.20 | 5.68 | 0.17 | 0.117 | 7.49 | 3.67 | 0.000 | 0.0001 | 107.44 | 46.10 | |
| SE | 1,301 | 13.45 | 8.05 | 90.26 | 39.74 | 0.75 | 0.872 | 46.24 | 66.91 | 0.000 | 0.0007 | 582.51 | 452.06 | |
| SI | 106 | 3.00 | 0.95 | 15.95 | 5.18 | 0.14 | 0.039 | 14.05 | 5.32 | 0.000 | 0.0000 | 51.03 | 10.65 | |
| SK | 128 | 5.19 | 0.73 | 17.92 | 2.67 | 1.18 | 0.166 | 8.33 | 1.39 | 0.000 | 0.0001 | 78.18 | 12.36 | |
| UK | 685 | 27.05 | 4.75 | 86.18 | 13.12 | 2.09 | 0.403 | 33.87 | 6.15 | 0.003 | 0.0004 | 440.88 | 70.18 | |
| | | | | | | | | | | | | | | |
| EU | 16,312 | 617 | 182.1 | 1,822 | 415 | 137 | 27.92 | 1,020 | 364 | 0.056 | 0.015 | 9,220 | 2,506 | |

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