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OPEN EARTH MONITOR

D2.4 Report "Economic Assessment Framework Guidelines" 1st Version

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Contents

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1. Introduction

This report presents a first draft of the economic assessment framework for the HorizonEurope Open Earth Monitor Project. This project is aimed at developing cyberinfrastructure to accelerate uptake of environmental information and help build user communities at European and global levels. The specific objective of the project is to enable targeted end-users to monitor the status of natural resources at European and global scales, and production of environmental Business-2-Business solutions.

In the context of this project, there is a need to examine how spatial environmental data can be translated to economic information relevant for users. In specific cases, users are more accustomed to processing economic, rather than biophysical, metrics. However, converting biophysical to economic information is no easy task, given that economic valuation of environmental datasets is context dependent as well as requiring specific additional analyses and data. Furthermore, there are different concepts of economic value that are relevant in specific contexts and may be relevant for specific policy questions.

The objective of this document is to provide some initial clarity on how biophysical datasets can be used for economic assessments, either as (i) input into economic analysis, or (ii) through translating the spatial data itself into monetary values in the context of this project.

The report describes first the two main approaches to analysing environmental data (including spatial data) in monetary terms, i.e. (i) in Cost Benefit analysis and in (ii) natural capital accounting. Subsequently, the report presents some concrete recommendations and assessment options for spatial data relevant for the project.

This report presents an intermediate project output. The assessment approaching the report itself will be tested in the course of the project, and updated and enhanced mid-way through the project.

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2. Analysing the welfare implications of using natural resources

Environmental cost-benefit analysis (ECBA) (also called benefit-cost analysis) provides an organisational framework for identifying, quantifying, and comparing the costs and benefits (measured in a monetary unit) of a proposed investment or policy action. The final decision is informed (though not necessarily determined) by a comparison of the total costs and benefits. The costs are usually related to expenditure needed for investment. Measuring the benefits of the measures may be more complex, since many environmental benefits are not traded in a market. In addition to complicating the practice of cost-benefit analysis this raises ethical issues. Should we assign dollar values to undisturbed natural places? To the existence of blue whales? Clearly, economic assessment does not provide the sole criterion for decision making, and only part of the full value of the environment can be captured in economic metrics. With this limitation in mind, this section presents a brief description of how ECBA is relevant for economic assessments in the Open Earth Monitor Project. Specifically, this section explains the principles of ECBA, and the main difference in valuation approach with NCA.

A basic starting point for all ECBAs is a determination of whose benefits and costs should count (Aldy et al., 2021). For example, the residents of a country are usually the relevant population for policies that apply at the national level. ECBAs must also specify the planning horizon over which benefits and costs count, and the issue can be particularly important and consequential when it comes to long-term, intergenerational concerns like climate change. Future benefits and costs are discounted over the discounting period, at a given discount rate. Discounting provides the weights to facilitate intertemporal comparisons by converting all future costs and benefits into present values. The cost-benefit criterion is then a question of whether the present value of net benefits is positive.

Many environmental benefits and costs do not immediately translate into monetary values. The most common way for economists to measure an individual's or a household's value is willingness to pay (WTP). But for non-market ecosystem services and other environmental benefits , ECBA often requires the use of nonmarket valuation techniques, where the aim is to infer WTP for things that are not directly traded in markets. This can be done with revealed- or stated-preference techniques.

The *revealed preference* approaches use a link with a marketed good or service to indicate the willingness-to-pay for the service. There are two main types of revealed preference approaches:

- *Physical linkages.* Estimates of the values of ecosystem services are obtained by determining a physical relationship between the service and something that can be measured in the market. The main approach in this category is the damage-function (or dose-response) approach, in which the damages resulting from the reduced availability of an ecosystem service are used as an indication of the value of the service. This method can be applied to value, for instance, the hydrological service of an ecosystem.

- *Behavioural linkages.* In this case, the value of an ecosystem service is derived from linking the service to human behaviour – in particular people's expenditures to offset the lack of a service, or to obtain a service. An example of a behavioural method is the Averting Behaviour Method (ABM). There are various kinds of averting behaviour: (i) defensive expenditure (a water filter); (ii) the purchase of environmental surrogates (bottled water); and (iii) relocation. The travel cost method is another example of an indirect approach using behavioural linkages.

With *stated preference* approaches, various types of questionnaires are used to reveal the willingness-to-pay of consumers for a certain ecosystem service. The most important approaches are the Contingent Valuation Method (CVM) and related methods. It is the only valuation method that can be used to quantify the non-use values of an ecosystem in monetary terms. Information collected with well-designed CVMs has been found suitable for use in legal cases in the U.S. - as in the case of the determination of the amount of compensation to be paid after the Exxon Valdez oil spills. Nevertheless, various authors question their validity and reliability - both on theoretical and empirical grounds. There are two main points of criticism against CVM. First, CV estimates are sensitive to the order in which

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goods are valued; the sum of the values obtained for the individual components of an ecosystem is often much higher than the stated willingness-to-pay for the ecosystem as a whole. Second, CV often appears to overestimate economic values because respondents do not actually have to pay the amount they express to be willing to pay for a service.

Welfare based analysis is usually conducted with regards to marginal changes in the supply of an ecosystem service or other environmental benefit (e.g., clean air). For instance, people may be asked to state their WTP for a certain improvement in air quality, or an increase with an ecosystem service (e.g. recreational opportunities) with a certain amount. The resulting change in economic value is a function of both the change in the consumer and the change in the producer surplus. This is explained in Annex 1. There are also various attempts to assess the welfare generated by natural capital at the national scale (i.e., not looking at marginal changes). Prime among these methods are inclusive and comprehensive wealth accounting. A challenge is, in these efforts, to assess the overall surplus generated by natural capital. Ultimately, the value of all natural capital combined may be close to infinite (i.e., only constrained by our ability to pay), since without food, water and oxygen humans would not be able to live. Consequently, ECBA is usually conducted for marginal assessments. For national scale analysis of the monetary value of ecosystem services and natural capital, a macro-economic approach using accounting values can be used (see Section 3 of this report). However, monetary values in natural capital (NC) accounts do NOT express welfare, but instead the value of the contribution of ecosystems to the economy, at price levels and based on pricing mechanisms reflecting current economic and institutional arrangements. Along these same lines, the exchange value (as used in NC accounting) may reflect prices with which water is delivered to people's houses by water companies, not the WTP of people for a change in the supply of water (which would be used in ECBA). The GDP of a country reflects the country's economic activity, not the welfare enjoyed by people living in the country (even though a relationship between the two measures of value can be established).

Policy questions you can answer with an ECBA looking at the welfare implications of a marginal change in welfare due to an intervention in the environment:

- Are the economic including environmental benefits of an investment project (e.g. an ecosystem restoration or a hydropower plant construction) larger than the costs?
- What is the most cost-efficient approach to enhance the water use efficiency in a watershed?

3. Natural capital accounting (using the SEEA EA)

The System of Environmental Economic Accounting – Ecosystem Accounting (SEEA EA), or, in short 'Ecosystem accounting' intends to provide comprehensive and up-to-date information on the state and use of ecosystems in order to support decision making in land use planning, economic, resource management and environmental policies that involve the use of, or have repercussions for ecosystems. The SEEA is connected to the System of National Accounts, used by statistical agencies world-wide to record economic production and consumption and derive macro-economic indicators like GDP. The SEEA consists of two parts. The SEEA Central Framework (SEEA CF) was published in 1993 and updated in 2012. It considers natural capital from the perspective of individual stocks of resources, and is generally used to measure non-renewable natural capital including water, oil, natural gas, and iron ore. The SEEA CF is not spatially explicit and thereby less relevant for this project. The SEEA Ecosystem Accounting (SEEA EA) was first published in 2014, and takes a spatial and integrated perspective to measuring ecosystems and the services they provide. The SEEA EA records ecosystem types, condition, ecosystem services supply and use and asset value, as well as biodiversity and carbon contained in ecosystems and changes therein. A specific property of the SEEA EA is that information is analysed and recorded both in the form of maps (of ecosystem types, a set of condition indicators, and a set of ecosystem services and asset indicators) and accounting tables.

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The SEEA has initially been developed to support natural capital accounting (NCA) in the public sector, i.e. by statistical offices. However it can be used at multiple scales, from local (e.g. a farm or an estate) to national. It is also useful to support NCA in the private sector: its conceptual framework and definitions, developed after a series of broad consultations with accountants, statisticians, scientists and users of accounts, is broadly applicable, including in corporate NCA. The SEEA CF can be used as a basis for recording emissions, for instance from degrading peatlands. However, the SEEA CF does not support the monetary valuation of emissions. Hence, the OEMC project will explore how emissions can be added to the monetary analysis of ecosystem datasets, in a way consistent with the valuation principles of accounting. The SEEA EA can be used to record ecosystem services, and does allow both the biophysical and the monetary quantification of these datasets. SEEA Ecosystem accounts consist of 5 different core accounts, and 4 thematic accounts. The core accounts are shown in Table 1 below. The focus of the current project is exclusively on the biophysical accounts. The general logic is that EO is useful for preparing the various biophysical accounts. In turn, the biophysical accounts provide the basis for the monetary accounts. Critical is that both the biophysical and the monetary accounts present a wide range of policy relevant information. The policy relevance of the biophysical accounts to be produced in this project is briefly elicited in this report.

Table 1. The SEEA EA accounts relevant for the project

Relevant accounts	Type of account	Examples of OEMC datasets
1. The extent account	SEEA EA Core account	Ecosystem cover in a country or region
2. The condition account	SEEA EA Core account	NPP, standing stock of biomass, water quality
3. The physical ecosystem services use and supply account	SEEA EA Core account	carbon sequestration, water regulation (by forests)
4. The biodiversity account	SEEA EA Thematic account	species occurrence
5. The carbon account	SEEA EA Thematic account	carbon stocks and flows
6. The urban ecosystem account (potentially)	SEEA EA Thematic account	air quality, air filtration
7. The ocean account (potentially)	SEEA EA Thematic account	water quality indicators
8. Emissions account	SEEA Condition account and the SEEA CF account	carbon, NH4, CH4 emissions from ecosystems

The SEEA EA can be used to answer, for instance, the following questions:

- How has a country's natural capital stock changed over time?
- At the level of the country, or a province, which ecosystem services are under the highest stress? And which have increased? Is this increase due to a better ecosystem condition, or due to more intense harvesting?
- What is the share of GDP dependent upon ecosystems?

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4. Translating biophysical datasets into economic datasets

One key way in which the Open Earth Monitoring project can contribute to economic assessments is by translating some of the datasets in monetary terms. This can be done in two ways:

1. **Support or implement an ECBA**. Where specific policy questions are being addressed, and in particular specific potential investments are being assessed, the project may attempt to assess changes in producer and consumer surplus (see Annex 1) as a function of this intervention of investment option. However – this requires specification of the use case scenarios, e.g. policy options or investments. It may be most relevant where the project supports specific stakeholders in specific case studies. There are several use cases in the OEMC project that mention the ecosystem accounting tool (T3.10) as one of the required building blocks: (1) Biodiversity monitoring and reporting tool; (2) forest management and tracking tool for Croatia; (3) soil carbon accounting system for world mangroves, and this option will be discussed together with project partners including but not limited to those in the three use cases mentioned above. Where such options exist, an assessment is needed of which economic valuation techniques to use, the data needs, project scope, discounting period and discount rate, etc. It is noted that this approach cannot be applied to translate spatial datasets as such into monetary indicators, a specific policy or investment option needs to be defined.

2. **Compile monetary ecosystem accounts of spatial datasets**. Contrary to the previous option, this does not require defining a specific policy intervention or investment option. The SEEA EA is a macro-economic framework that relates values to the valuation framework of the SNA (as explained in Section 3 of this report). Specifically, ecosystem services or ecosystem assets can be analysed in monetary terms, following the SEEA EA. The most relevant for this project is looking at ecosystem services indictors – since ecosystem assets require the aggregation of discounted flows values of service flows over time, i.e the whole basket of ecosystem services provided by an ecosystem asset needs to be understood and valued in order to calculate the ecosystem asset value – having such a broad set of data seems unlikely in the scope of the project, at present. Annex 2 presents a list of ecosystem services, and Annex 3 presents an overview of valuation techniques that can be used to value ecosystem services for SEEA EA accounting. In the next step of this project, it is recommended for partners to identify which of the services mentioned in Annex 2 are of particular relevance for monetary valuation in the context of this project. For this evaluation of the relevance, the following criteria can be used:
    a. Is it feasible? (biophysical data availability, potential to conduct the data required for valuation, resources in project partner)
    b. Is it policy relevance? (will there be a strong stakeholder interest in the dataset?)
    c. Is it innovative? (i.e., is similar monetary data, of comparable quality not already available from other sources).
    d. Other criteria may be added by each partner depending upon local needs and interests.

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5. Facilitating the use of project datasets for economic analysis

A second approach for the project to support economic analysis is to prepare and make datasets available that can support SEEA Ecosystem accounting in various countries undertaking such account compilation. It is relevant, in this context, that the EU is preparing legislation that, if adopted, would make it compulsory to compile ecosystem accounts as of 2026 (first reporting year: 2024). The proposal has been published by the European Commission and can be found here[1]: "Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulation (EU) No 691/2011 as regards introducing new environmental economic accounts modules". In its current development phase, the proposal includes several extent, condition and ecosystem services indicators. Where these could be mapped in European countries with EO datasets, this would be extremely helpful in supporting the EU MS states and other countries that could follow the proposal, such as Norway, with their accounting efforts. The indicators are shown in table 2 below. However, it needs to be emphasised that this is a draft proposal that still is being discussed in the European council and the European parliament. Hence, it is work in progress and that the indicators may well change. Also, the legal proposal may not be accepted, in which case accounting efforts would remain solely a national, rather than a national as well as a European, topic.

Table 2. SEEA EA indicators of particular relevance in Europe (for guidance to project partners)

Account	Indicator
Ecosystem extent	Ecosystem cover, following the proposed EU Ecosystem typology (Annex 4)
Ecosystem condition	
(i) In cities	- Green areas in cities, as defined in Regulation (EU) 2017/2391, to be reported in m^2/inhabitant - Concentration of particulate matter with a diameter up to 2.5 µm
(ii) for croplands:	- Soil organic carbon content in topsoil shall be reported in tonne/ha, as a national average for the reporting period
(iii) for grasslands:	- Soil organic carbon content in topsoil shall be reported in tonne/ha, as a national average for the reporting period
(iv) for forests and woodlands:	- Dead wood shall be reported in m3/ha, as a national average for the reporting period [the originally proposed unit was tonne/ha] - Tree cover density shall be reported in %, as a national average for the reporting period :
(vi) for coastal wetlands, beaches and dunes:	- Artificial impervious area cover shall be reported in %, as a national average for the reporting period
Ecosystem services	Crop provision, defined as the ecosystem contributions to the growth of cultivated plants that are harvested by economic units for various uses including food and fibre production, fodder and energy, to be reported in tonnes of agricultural crops, by type of crop
	Pollination, defined as the ecosystem contributions by wild pollinators to the fertilisation, to be reported in tonnes of pollinator-dependent crops that can be attributed to wild pollinators, by type of crop for the main types of pollinator-dependent crops comprising fruit trees, berries, tomatoes, oilseeds and 'other'

1 https://op.europa.eu/en/publication-detail/-/publication/ddb7c711-010b-11ed-acce-01aa75ed71a1/language-en/format-PDF/source-search

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	Timber provision, defined as the ecosystem contributions to the growth of trees and other woody biomass in forest available for wood supply, to be reported as net increment in thousand m^3 overbark.
	- Air filtration, defined as ecosystem contributions to the filtering of air-borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components, particularly trees, that mitigates the harmful effects of the pollutants, to be reported in tonnes of fine particulate matter (PM2.5) absorbed.
	- Soil erosion control, defined as the ecosystem contributions, particularly the stabilising effects of vegetation, that reduce the loss of soil (and sediment) due to run-off and support use of the environment (e.g., agricultural activity, water supply), to be reported in tonnes of soil retained.
	- Global climate regulation, defined as the ecosystem contributions to reducing concentrations of greenhouse gases in the atmosphere through the removal (net sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. The contributions are to be reported in terms of tonnes of net sequestration of carbon and tonnes of carbon stored in ecosystems including above ground and below ground in the first 2 meters of the soil (including in peatlands).
	- Local climate regulation, defined as the ecosystem contributions to the regulation of ambient atmospheric conditions (including micro and mesoscale climates) in urban areas through the presence of vegetation that improves the living conditions for people and supports economic production, shall be expressed and reported as the reduction of temperature in cities, due to the effect of urban vegetation in degrees Celsius on days exceeding 30 degrees Celsius.
	- Flood protection, which includes:
	(i) the ecosystem contributions of linear vegetation elements (e.g. riparian forest, dunes) which provide structure and a physical barrier to high water levels and thus mitigate the impacts of floods on local communities, and
	(ii) the ecosystem contributions to the regulation of river flows and groundwater and lake water tables, derived from the ability of ecosystems to absorb and store water, and hence mitigate the effects of flood and other extreme water-related events, shall be expressed and reported as the reduction of residential, industrial and commercial area, and infrastructure flooded within a-once-in-100-years flood category due to the presence of natural water retention measures, in 1000 ha.
	- Recreation and tourism-related services, defined as the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment shall be reported in number of overnight stays in hotels, hostels, camping grounds, etc., that can be attributed to visits to ecosystems.

However, it needs to be noted that countries outside the EU may have different priorities in account compilation. Hence, global datasets could focus on entirely different ecosystem services, extent or condition indicators (noting that some countries may use the IUCN Global Ecosystem Typology for extent accounting).

6. Next steps (proposed)

1. The draft of the economic assessment framework (this report) is to be shared among project partners for comments and suggestions for clarification. The report will, hopefully, also provide some clarification on economic assessment to project partners.

2. A workshop to be held to discuss with those project partners that are interested in either: (i) compiling biophysical datasets that are directly relevant for accounting efforts (i.e. on ecosystem extent, condition and/or services, where possible following the definitions of the SEEA EA and in time series); and/or (ii)

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compiling economic datasets following the SEEA EA (Section 3 of this report) or the ECBA approach (Section 2). With these partners, the specific datasets to be compiled can be identified, and workflows and data requirements can be established for the economic analysis.

3. Work (by the project partners, with some support from Wageningen University) on compiling biophysical SEEA EA and/or economic indicators

4. Evaluation of these datasets in terms of technical accuracy and innovation, compliance with accounting requirements, and user relevance (with involvement of various project partners and external stakeholders, procedure to be established). Where relevant, recommendations form the evaluation can be used to revise and enhance the datasets

5. Making the datasets available to the user, using the Open Earth Monitoring data sharing (and other?) platforms.

References

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UN, 2017. SEEA Experimental Ecosystem Accounting: Technical Recommendations. UN New York, 2017.

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Annex 1. Consumer and producer surplus in welfare analysis

Analyzing the welfare implications of the use of natural resources requires understanding the consumer and the producer surplus that are generated by the use of that resource. These two concepts are explained below.

(i) The consumer surplus. The concept of consumer surplus was explained by Marshall (in 1920): 'The excess of price which a consumer would be willing to pay rather than go without the thing, over that what he actually pays is the economic measure of this surplus of satisfaction'. In other words, the consumer surplus equals the willingness-to-pay of a consumer for a good minus the market price the consumer faces for that good. Estimation of the consumers surplus, which sums the surpluses obtained by different consumers, generally requires the construction of a demand curve that reflects people's willingness to purchase a good or service at different price levels.

(ii) The producer surplus*.* The producer surplus indicates the amount of net benefits a producer gains, given his production costs and the (market) price he receives for his products. In the valuation of ecosystem services, the producer surplus needs to be considered if there are costs related to "producing" the ecosystem good or service, such as for example the costs related to collecting or harvesting forest products. In case an ecosystem services approach is used to analyze activities such as agriculture or fisheries, clearly, the full production costs of the fisherman (boat, equipment, labor, etc.) or farmer (land, machinery, inputs, labour, etc.) need to be accounted for. The estimation of the producers surplus generally requires the construction of a supply curve indicating production costs for all producers in a market. For public ecosystem services, supply curves can be seen as reflecting the costs of measures to restore and conserve the supply of services. For these services, a supply curve is often difficult to construct and the producers surplus is difficult to establish.

The concepts of consumer and producer surplus are illustrated with the example of the pollination service. Insect pollination is required for a range of crops including apples, oranges, almonds, etc. (see e.g. Klein et al., 2007 for a full overview). Insect pollination can be achieved by bringing in bee hives, or can be performed by naturally occurring bees or, for some crops, other animals. In the latter case, pollination is an ecosystem service, in particular, a regulating service required for agricultural production. In the valuation of pollination, it is necessary to consider the scale at which pollination is studied. For instance, in case the value of pollination in one particular farm is studied, there will probably be no price effects since the production of this farmer is likely to be small compared to the overall market supply. In this case, changes in the producer surplus can be estimated on the basis of multiplying physical changes in ecosystem services supply with net revenues generated per unit of ecosystem service. For example, Rickets et al. (2004) relate the value of the pollination service supplied by forest patches on a Costa Rican coffee farm (which serve as habitat for pollinating bees) to the impact of pollination on the coffee yields, the total area of coffee plants pollinated, and the net benefits obtained from the sale of coffee (off-farm price minus variable production costs).

However, in case pollination declines at the national scale, price effects for pollinated crops become increasingly likely, because the supply of the affected crops is reduced while demand, presumably, is not affected. Valuation of pollination services at the national scale, therefore, needs to consider that prices may not be constant. In this case, demand and supply curves have to be constructed to analyse changes in the producers and consumers surplus as a function of changes in the supply of the pollination service. This is illustrated in the figure 3 below, that shows that a decline in the pollination service may reduce agricultural production, and shift the supply curve of the affected crops to the left, from *S* to *S'*. This shift reflects that farmers will obtain a lower harvest at relatively higher production costs. Consequently, a new market equilibrium (*E2*) is reached, at a higher food price and with a lower quantity of food traded in the market.

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Consequently, the producers surplus changes from S_0AE_1 to $S_0'BE_2$ and the consumer surplus from D_0AE_1 to D_0BE_2. From Figure 3, it is clear that all consumers will be affected by the decline in pollination. With regards to the producers surplus, there may also be producers that are not affected by a decline in the pollination service and that may benefit by obtaining a higher price for their crops, for example producers in the part of the country not affected by a reduction in pollination services (if any) or producers growing substitute crops that are less dependent on pollination. Hence, the producers surplus may increase or decrease when pollination services are affected, depending on the shape of the demand and supply curves.

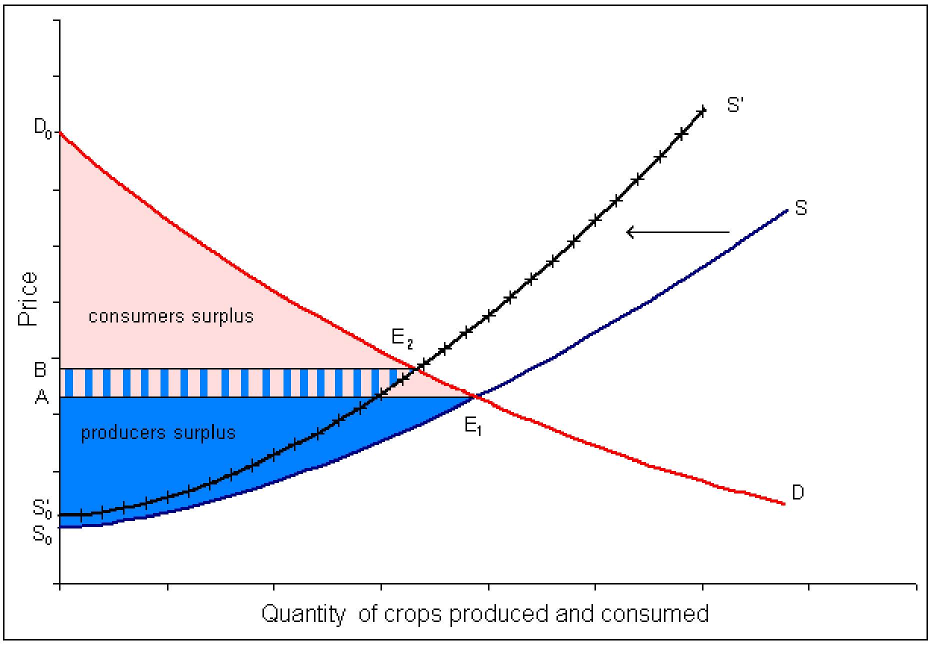

Figure A1. Changes in the consumers and producers surplus in case pollination losses affect agricultural production (see text above for explanation).

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Annex 2. Reference list of ecosystem services

From UN et al., 2021: The SEEA EA.

ECOSYSTEM SERVICE		DESCRIPTION
Provisioning services		
Biomass provisioning services	Crop provisioning services*	Crop provisioning services are the ecosystem contributions to the growth of cultivated plants that are harvested by economic units for various uses including food and fibre production, fodder and energy. This is a final ecosystem service.
	Grazed biomass provisioning services*	Grazed biomass provisioning services are the ecosystem contributions to the growth of grazed biomass that is an input to the growth of cultivated livestock. This service excludes the ecosystem contributions to the growth of crops used to produce fodder for livestock (e.g., hay, soybean meal). These contributions are included under crop provisioning services. This is a final ecosystem service but may be intermediate to livestock provisioning services.
	Livestock provisioning services*	Livestock provisioning services are the ecosystem contributions to the growth of cultivated livestock and livestock products (e.g., meat, milk, eggs, wool, leather), that are used by economic units for various uses, primarily food production. This is a final ecosystem service. No distinct livestock provisioning services to be recorded if grazed biomass provisioning services are recorded as a final ecosystem service.
	Aquaculture provisioning services	Aquaculture provisioning services are the ecosystem contributions to the growth of animals and plants (e.g., fish, shellfish, seaweed) in aquaculture facilities that are harvested by economic units for various uses. This is a final ecosystem service.
	Wood provisioning services	Wood provisioning services are the ecosystem contributions to the growth of trees and other woody biomass in both cultivated (plantation) and uncultivated production contexts that are harvested by economic units for various uses including timber production and energy. This service excludes contributions to non-wood forest products. This is a final ecosystem service.
	Wild fish and other natural aquatic biomass provisioning services	Wild fish and other natural aquatic biomass provisioning services are the ecosystem contributions to the growth of fish and other aquatic biomass that are captured in uncultivated production contexts by economic units for various uses, primarily food production. This is a final ecosystem service
	Wild animals, plants and other biomass provisioning services	Wild animals, plants and other biomass provisioning services are the ecosystem contributions to the growth of wild animals, plants and other biomass that are captured and harvested in uncultivated production contexts by economic units for various uses. The scope includes non-wood forest products (NWFP)[69] and services related to hunting, trapping and bio-prospecting activities; but excludes wild fish and other natural aquatic biomass (included in previous class). This is a final ecosystem service
Genetic material services		Genetic material services are the ecosystem contributions from all biota (including seed, spore or gamete production) that are used by economic units, for example (i) to develop new animal and plant breeds; (ii) in gene synthesis; or (iii) in product development directly using genetic material. This is most commonly recorded as an intermediate service to biomass provisioning.
Water supply*		Water supply services reflect the combined ecosystem contributions of water flow regulation, water purification, and other ecosystem services to the supply of water of appropriate quality to users for various uses including household consumption. This is a final ecosystem service.
Other provisioning services		

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ECOSYSTEM SERVICE		DESCRIPTION
Regulating and maintenance services		
Global climate regulation services		Global climate regulation services are the ecosystem contributions to reducing concentrations of GHG in the atmosphere through the removal (sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems. These services support the regulation of the chemical composition of the atmosphere and oceans. This is a final ecosystem service.
Rainfall pattern regulation services (at sub-continental scale)		Rainfall pattern regulation services are the ecosystem contributions of vegetation, in particular forests, in maintaining rainfall patterns through evapotranspiration at the sub-continental scale. Forests and other vegetation recycle moisture back to the atmosphere where it is available for the generation of rainfall. Rainfall in interior parts of continents fully depends upon this recycling. This may be a final or intermediate service.
Local (micro and meso) climate regulation services		Local climate regulation services are the ecosystem contributions to the regulation of ambient atmospheric conditions (including micro and mesoscale climates) through the presence of vegetation that improves the living conditions for people and supports economic production. Examples include the evaporative cooling provided by urban trees ('green space'), the role of urban water bodies ('blue space') and the contribution of trees in providing shade for humans and livestock. This may be a final or intermediate service.
Air filtration services		Air filtration services are the ecosystem contributions to the filtering of air-borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components, particularly plants, that mitigates the harmful effects of the pollutants. This is most commonly a final ecosystem service.
Soil quality regulation services		Soil quality regulation services are the ecosystem contributions to the decomposition of organic and inorganic materials and to the fertility and characteristics of soils, e.g., for input to biomass production. This is most commonly recorded as an intermediate service.
Soil and sediment retention services	Soil erosion control services	Soil erosion control services are the ecosystem contributions, particularly the stabilising effects of vegetation, that reduce the loss of soil (and sediment) and support use of the environment (e.g., agricultural activity, water supply). This is may be recorded as a final or intermediate service.
	Landslide mitigation services	Landslide mitigation services are the ecosystem contributions, particularly the stabilising effects of vegetation, that mitigates or prevents potential damage to human health and safety and damaging effects to buildings and infrastructure that arise from the mass movement (wasting) of soil, rock and snow. This is a final ecosystem service.
Solid waste remediation services		Solid waste remediation services are the ecosystem contributions to the transformation of organic or inorganic substances, through the action of micro-organisms, algae, plants and animals that mitigates their harmful effects. This is may be recorded as a final or intermediate service.
Water purification services (water quality regulation)	Retention and breakdown of nutrients	Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health. This may be recorded as a final or intermediate ecosystem service.
	Retention and breakdown of other pollutants	
Water flow regulation services	Baseline flow maintenance services	Water regulation services are the ecosystem contributions to the regulation of river flows and groundwater and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods through evapotranspiration and hence secure a regular flow of water. This may be recorded as a final or intermediate ecosystem service.
	Peak flow mitigation services	Water regulation services are the ecosystem contributions to the regulation of river flows and groundwater and lake water tables. They are derived from the ability of ecosystems to absorb and store water, and

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ECOSYSTEM SERVICE		DESCRIPTION
		hence mitigate the effects of flood and other extreme water-related events. Peak flow mitigation services will be supplied together with river flood mitigation services in providing the benefit of flood protection. This is a final ecosystem service.
Flood control services	Coastal protection services	Coastal protection services are the ecosystem contributions of linear elements in the seascape, for instance coral reefs, sand banks, dunes or mangrove ecosystems along the shore, in protecting the shore and thus mitigating the impacts of tidal surges or storms on local communities. This is a final ecosystem service.
	River flood mitigation services	River flood mitigation services are the ecosystem contributions of riparian vegetation which provides structure and a physical barrier to high water levels and thus mitigates the impacts of floods on local communities. River flood mitigation services will be supplied together with peak flow mitigation services in providing the benefit of flood protection. This is a final ecosystem service.
Storm mitigation services		Storm mitigation services are the ecosystem contributions of vegetation including linear elements, in mitigating the impacts of wind, sand and other storms (other than water related events) on local communities. This is a final ecosystem service.
Noise attenuation services		Noise attenuation services are the ecosystem contributions to the reduction in the impact of noise on people that mitigates its harmful or stressful effects. This is most commonly a final ecosystem service.
Pollination services		Pollination services are the ecosystem contributions by wild pollinators to the fertilization of crops that maintains or increases the abundance and/or diversity of other species that economic units use or enjoy. This may be recorded as a final or intermediate service.
Biological control services	Pest control services	Biological control services are the ecosystem contributions to the reduction in the incidence of species that may prevent or reduce the effects of pests on biomass production processes or other economic and human activity. This is may be recorded as a final or intermediate service.
	Disease control services	Disease control services are the ecosystem contributions to the reduction in the incidence of species that may prevent or reduce the effects of species on human health. This is most commonly a final ecosystem service.
Nursery population and habitat maintenance services		Nursery population and habitat maintenance services are the ecosystem contributions necessary for sustaining populations of species that economic units ultimately use or enjoy either through the maintenance of habitats (e.g., for nurseries or migration) or the protection of natural gene pools. This service is an intermediate service and may input to a number of different final ecosystem services including biomass provision and recreation-related services.
Other regulating and maintenance services		
Cultural services		
Recreation-related services		Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. This includes services to both locals and non-locals (i.e., visitors, including tourists). Recreation-related services may also be supplied to those undertaking recreational fishing and hunting. This is a final ecosystem service.
Visual amenity services*		Visual amenity services are the ecosystem contributions to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual. This service combines with other ecosystem services, including recreation-

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ECOSYSTEM SERVICE		DESCRIPTION
		related services and noise attenuation services to underpin amenity values. This is a final ecosystem service.
Education, scientific and research services		Education, scientific and research services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use the environment through intellectual interactions with the environment. This is a final ecosystem service.
Spiritual, artistic and symbolic services		Spiritual artistic and symbolic services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that are recognised by people for their cultural, historical, aesthetic, sacred or religious significance. These services may underpin people's cultural identity and may inspire people to express themselves through various artistic media. This is a final ecosystem service.
Other cultural services		
Flows related to non-use values		
Ecosystem and species appreciation		Ecosystem and species appreciation concerns the wellbeing that people derive from the existence and preservation of the environment for current and future generations, irrespective of any direct or indirect use.

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Annex 3. Valuation techniques

Adapted from: UN et al., 2017: Technical Recommendations for SEEA EEA.

Valuation method	**Description**	**Comments**	**Suitability for ecosystem accounting**
Unit resource rent	Prices determined by deducting costs of labour, produced assets and intermediate inputs from market price of outputs (benefits).	Estimates will be affected by the property rights and market structures surrounding production. For example, open access fisheries and markets for water supply often generate low or zero rents.	In principle this method is **appropriate** but consideration of market structures is required.
Production function, cost function and profit function methods	Prices obtained by determining the contribution of the ecosystem to a market based price using an	In principle analogous to resource rent but generally focused on the valuation of regulating services. May be difficult to estimate the functions.	**Appropriate** provided the market based price being decomposed refers to a product rather than an asset – e.g. value of housing services rather

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	assumed production, cost or profit function.		than the value of a house.
Payment for Ecosystem Services (PES) schemes	Prices are obtained from markets for specific regulating services (e.g. in relation to carbon sequestration)	Estimates will be affected by the type of market structures put in place for each PES (see SEEA EEA 5.88-94)	**Possibly appropriate** depending on the nature of the market structures.
Hedonic pricing	Prices are estimated by decomposing the value of an asset (e.g. a house block including the dwelling and the land) into its characteristics and pricing each characteristic through regression analysis	Very data intensive approach and separating out the effects of different characteristics may be difficult, unless there are large sample sizes.	**Appropriate** in principle. Heavily used in the pricing of computers in the national accounts.

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Replacement cost	Prices reflect the estimated costs of replacing specific ecosystem services using produced assets and associated inputs.	This method requires an understanding of the ecosystem function underpinning the supply of the service and an ability to find a comparable “produced” method of supplying the same service.	**Appropriate** under the assumptions (i) that the estimation of the costs reflects the ecosystem services being lost; (ii) that it is a least-cost treatment; and (iii) that it would be expected that society would replace the service if it was removed. (Assumption (iii) may be tested using stated preference methods.)

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Damage costs avoided	Prices are estimated in terms of the value of production losses or damages that would occur if the ecosystem services were reduced or lost due to ecosystem changes (e.g. as a result of pollution of waterways).	May be challenging to determine the value of the contribution/impact of individual ecosystem services.	**Appropriate** under the assumptions (i) that the estimation of the damage costs reflects the specific ecosystem services being lost; and (ii) that the services would be not be replaced or treated. If the service can be replaced, ánd if the costs of replacing the service are lower than the damage costs, then the replacement cost method is more appropriate.

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Costs of treatment	Prices are estimated in terms of the costs that would be incurred to change production processes in the event of ecosystem services being reduced or lost due to ecosystem changes (e.g. as a result of pollution of waterways).	This method requires understanding how changes in ecosystems due to human factors lead to a change in the supply of ecosystem services. May be challenging to determine the contribution/impact of an individual ecosystem service.	**Appropriate** under the assumptions (i) that the estimation of the costs reflects the costs of treating the ecosystem ; (ii) that it is a least-cost treatment; and (iii) that it would be expected that the services would be replaced through treatment. The latter would generally be the case if the costs of treatment (e.g. pollution control) are lower than the costs of replacing the services and the avoided damage costs related to the loss of services.
Averting behaviour	Prices are estimated based on individuals willingness to pay for	Requires an understanding of individual preferences and may be difficult to	Likely **inappropriate** since it relies on individuals being aware of the impacts arising

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	improved or avoided health outcomes.	link the activity of the individual to a specific ecosystem service.	from environmental changes.
Restoration cost	Refers to the estimated cost to restore an ecosystem asset to an earlier, benchmark condition. Should be clearly distinguished from the replacement cost method.	The main issue here is that the costs relate to a basket of ecosystem services rather than a specific one. More often used as a means to estimate ecosystem degradation but there are issues in its application in this context also.	**Inappropriate** since it does not determine a price for an individual ecosystem service.

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Travel cost	Estimates reflect the price that consumers are willing to pay in relation to visits to recreational sites.	Key challenge here is determining the actual contribution of the ecosystem to the total estimated willingness to pay. There are also many applications of this method with varying assumptions and techniques being used with a common objective of estimating consumer surplus. Finally, some travel cost methods include a value of time taken by the household which would be considered outside the scope of the production boundary used for accounting purposes.	**Possibly appropriate** depending on the actual estimation techniques and whether the approach provides an exchange value, i.e. excludes consumer surplus.

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Stated preference	Prices reflect willingness to pay from either contingent valuation studies or choice modelling.	These approaches are generally used to estimate consumer surplus and welfare effects. Within the range of techniques used there can be potential biases that should be taken into account.	**Inappropriate** since does not measure exchange values
Marginal values from revealed demand functions	Prices are estimated by utilising an appropriate demand function and setting the price as a point on that function using (i) observed behaviour to reflect supply (e.g. visits to parks) or (ii) modelling a supply function.	This method can use demand functions estimated through travel cost, state preference, or averting behaviour methods. The use of supply functions has been termed the simulation exchange method (Campos & Caparros, 2011)	**Appropriate** since aims to directly measure exchange values. However, the creation of meaningful demand functions and estimating hypothetical markets may be challenging.

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Annex 4. Ecosystem extent typology, proposed for Europe.

EU ecosystem typology: level 1	EU ecosystem typology: level 2
1. Settlements and other artificial areas	1.1 Continuous settlement area
	1.2 Discontinuous settlement area
	1.3 Infrastructure
	1.4 Urban greenspace
	1.5 Other artificial areas
2. Cropland	2.1 Annual cropland
	2.2 Rice fields
	2.3 Permanent crops
	2.4 Agro-forestry areas
	2.5 Mixed farmland
	2.6 Other farmland
3. Grassland (pastures, semi-natural and natural grasslands)	3.1 Sown pastures and fields (modified grassland)
	3.2 Natural and semi-natural grassland
4. Forest and woodlands	4.1 Broadleaved deciduous forest
	4.2 Coniferous forests
	4.3 Broadleaved evergreen forest
	4.4 Mixed forests

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EU ecosystem typology: level 1	**EU ecosystem typology: level 2**
	4.5 Transitional forest and woodland shrub
	4.6 Plantations
5. Heathland and shrub	5.1 Tundra
	5.2 Heathland and (sub-) alpine shrub
	5.3 Sclerophyllous vegetation
6. Sparsely vegetated ecosystems	6.1 Bare rocks
	6.2 Semi-desert, desert and other sparsely vegetated areas
	6.3 Ice sheets, glaciers and perennial snowfields
7. Inland wetlands	7.1 Inland marshes on mineral soil
	7.2 Mires, bogs and fens
8. Rivers and canals	8.1 Rivers
	8.2 Canals, ditches and drains
9. Lakes and reservoirs	9.1 Lakes
	9.2 Artificial reservoirs
	9.3 Geothermal pools and wetlands (Iceland)
10. Marine inlets and transitional waters	10.1 Coastal lagoons
	10.2 Estuaries and bays
	10.3 Intertidal flats

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EU ecosystem typology: level 1	EU ecosystem typology: level 2
	10.4 Deepwater coastal inlets (fjords)
11. Coastal beaches, dunes and wetlands	11.1 Artificial shorelines
	11.2 Coastal dunes, beaches and sandy and muddy shores
	11.3 Rocky shores
	11.4 Coastal saltmarshes and salines
12. Marine ecosystems	12.1 Marine macrophytes
	12.2 Coral reefs
	12.3 Shellfish beds and reefs
	12.4 Subtidal sand beds and mud plains
	12.5 Subtidal rocky substrates
	12.6 Continental and island slopes
	12.7 Deepwater benthic and pelagic ecosystems
	12.8 Sea ice