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D5.1 Specifying and testing how externalities and disservices can be included in ecosystem accounts

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• Preface

This document is a Deliverable for the SELINA Project, involving a study on how ecosystem disservices and externalities can be aligned with ecosystem accounting following the UN System for Environmental Economic Accounting. The report reflects work in progress and will be used for various studies in the SELINA Demonstration Projects and test sites. Based on the outcomes of these studies, the report will be updated.

• Summary

Externalities and disservices are important in ecosystem and environmental management but these two concepts are not yet integrated in the System of Environmental Economic Accounting (SEEA) Ecosystem Accounting (EA) framework. The objective of SELINA Task 5.1, therefore, is to examine whether and how externalities and/or disservices can be connected to the SEEA EA methodology. This first version of Deliverable 5.1 presents and discusses the definitions of externalities and ecosystem disservices, overlaps and differences between the two concepts and how they are connected to ecosystem accounting. Based on this conceptual and methodological background, we propose that three categories of ecosystem disservices and negative externalities can be integrated in the SEEA EA: (1) disservices that are not the direct consequence of current human use or activity (i.e., they are not externalities), (2) disservices that occur, or are enhanced, as a consequence of current human use or activity (i.e., a negative externality of the activity), and (3) reductions in ecosystem services as a consequence of current human use or activity (i.e., a negative externality of the activity; not a disservice). We outline potential approaches for including disservices and externalities in ecosystem accounts, making a distinction between disservices that can be measured as the direct inverse of an ecosystem service and those that cannot. We also identify and propose solutions for challenges that may be encountered, such as how to record negative externalities arising from ecosystem type conversions, the recording of intermediate

disservices and double-counting issues, and monetary valuation approaches. Our proposals remain to be further tested in the SELINA test sites and Demonstration Projects, which take part in Task 5.1. The last section of this Deliverable report presents the scope of these Demonstration Projects and test sites, and how they will test the integration of disservices and negative externalities in ecosystem accounts. The Deliverable will be updated in June 2025 to reflect lessons learnt from test sites and Demonstration Projects.

List of abbreviations

EA	Ecosystem Accounting
CICES	Common International Classification of Ecosystem Services
CO_2	Carbon dioxide
EDS	Ecosystem Disservices
EO	Earth Observation
ES	Ecosystem Services
ESVD	Ecosystem Services Valuation Database
EU	European Union
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
LULC	Land Use Land Cover
MA	Millennium Ecosystem Assessment
N	Nitrogen
NESCS	National Ecosystem Services Classification System
NUTS	Nomenclature of Territorial Units for Statistics
NCP	Nature's Contribution to People
OECD	Organisation for Economic Cooperation and Development
SEEA	System of Environmental Economic Accounting
SEEA EA	System of Environmental Economic Accounting Ecosystem Accounting
SEEA CF	System of Environmental Economic Accounting Central Framework
SNA	System of National Accounts
TEEB	The Economics of Ecosystems and Biodiversity
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

Externalities and disservices are important in ecosystem and environmental management. Externalities include positive and negative side effects of economic activities, and may have major environmental implications e.g. in the form of emissions of pollution to air, water or soil. Whereas there is increasing attention for Ecosystem Services (ES) in environmental management, the negative contributions of ecosystems to human wellbeing (e.g. transmission of vector-borne diseases, loss of biodiversity due to invasive species, damage to crops and infrastructure by pests, emission of greenhouse gases, injury or mortality by dangerous species), also called disservices, have not received a comparable level of attention.

Furthermore, these two concepts (externalities and disservices) are not yet identified by and integrated in the System of Environmental Economic Accounting (SEEA) Ecosystem Accounting (EA) framework. Since accounting principally deals with services with positive (economic) value, it has proven complex to include externalities and disservices in the SEEA EA framework as discrete accounting elements. Therefore, the effects of externalities and disservices may be implicitly captured by ecosystem accounts, for instance in terms of change of ecosystem condition or flows of ES, but are not explicitly captured in specific accounting records.
At the same time, the SEEA Central Framework (SEEA CF) offers a methodology to account for discharges and emissions, and the SEEA CF is used globally to report emissions of, for instance, greenhouse gases and air pollutants such as particulate matter. The SEEA water account, part of the SEEA CF, allows monitoring and reporting pollutants to waterways. Nevertheless, given that SEEA EA aims to be a 'one-stop' comprehensive decision support system for ecosystem management, it is of interest to explore whether and how externalities and/or disservices can be included in SEEA EA. Even though SEEA EA is now a statistical standard (Edens *et al.*, 2022), the concept and application of EA is still evolving and further revisions of the SEEA EA, or future extensions of the way it is applied, are likely.

The objective of this concept note, therefore, is to examine whether and how externalities and/or disservices can be connected to the SEEA EA methodology. We build upon an earlier paper prepared for the UN statistics Division by Markandya *et al.* (2019), extending this earlier work with further analyses, examples and proposals. This first version presents the conceptual and methodological background, and makes several proposals for including the concepts in SEEA EA. This remains to be further tested in the test sites and Demonstration Projects of the SELINA project, in particular in Task 5.1.

This concept note should be seen as a living document for the duration of the SELINA project. This document is therefore preliminarily meant as a working paper, reflecting work-in-progress, of the SELINA project. At the end of SELINA, the concept note will be worked into a scientific publication with all contributors to Task 5.1 as co-authors.

2 Concepts and definitions

2.1 Definition of an externality

Externalities are unintended impacts of actions by producers, consumers or communities on other stakeholders in society. The OECD defines externalities as “situations when the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided” (Khemani and Shapiro, 1993). Externalities, in the economics literature, therefore require some agent (individual, household, enterprise or community body) to be responsible for the action that has an impact on the wellbeing of others (Markandya *et al.*, 2019). This means that natural phenomena that generate positive (or negative) effects on welfare without any human involvement are not externalities, even though in practice in many cases anthropogenic and natural causes can be hard to disentangle, e.g. in the case of forest fires that may be ignited by human actions or lightning, and spread faster as a consequence of climate change and human-induced changes in landscape flammability. Usually there is also a spatial dimension to externalities: the source area of the externalities and the impacted area can overlap or be spatially disjointed and linked by connectivity processes, for instance when water pollution resulting from an agricultural or industrial activity affects downstream water users. Analogous challenges often occur in the assessment of ESs, between areas where ecosystems provide ESs and areas where humans benefit from these ESs (Dworczyk and Burkhard, 2021). There may also be a temporal dimension, i.e., a time lag between the externality being generated and its impact on stakeholders. For example, alien species introduced deliberately to support a specific economic activity (e.g. water hyacinths used for pond/lake aesthetics), may become invasive over time and affect other economic activities, as externalities (e.g., river blockage for boats; suffocation of waterways).

Externalities can be both positive and negative. They are negative when they reduce the well-being of a third party. Positive externalities have an unintended positive impact on the well-being of others. For example, buyers of organic vegetables may do so for health reasons, but their actions lead to a positive externality because they reduce pesticide use and loss of biodiversity. Acknowledging that there are both positive and negative externalities, the focus of this paper is exclusively on negative externalities and how they can be included in ecosystem accounts, given that this is often of particular importance to ecosystem management (e.g., in dealing with emissions and discharges from ecosystems). Furthermore, importantly, positive externalities from activities that affect ecosystems can usually be captured in ecosystem accounts as the enhancement of ES. For instance, carbon sequestration in forests could be considered a positive externality of forest management aimed at timber production.

In the economics literature, building upon Coase (1960), there are several pathways to reduce externalities. For instance, actors affected by externalities may negotiate and pay for actions to reduce the externality. This works best when there is a well-understood connection between one or a limited number of polluters, and one or a limited number of actors incurring the externality. In practice, there may be many barriers to leaving it to stakeholders to deal with externalities – for example, in cases when there is incomplete understanding of the externality, the costs of mitigation are prohibitively high leading to competition effects of producers, or there is a lack of trust between actors to negotiate in good faith. Where externalities are considered an excessive burden on society, governments tend to step in with regulations.

The definition of externalities is an anthropocentric one and it is worth noting that there are alternative value systems (Pascual *et al.*, 2023). Social scientists make a distinction between the social value of a transaction and the market value, noting that the former may be much higher than the latter. Values in psychology relate to emotions and principles and goals which guide human behaviour. In environmental sciences, as well as in philosophy, values relating to the living environment are seen as endowing the latter with certain inalienable legal rights, which means that the living environment has value in and of itself, separate and independent from the benefits humans may derive from it for their own purposes (also referred to as intrinsic values) (Markandya *et al.*, 2019). Ecological value refers to the "perceived importance of an ecosystem, which is underpinned by the biotic and/ or abiotic components and processes that characterise that ecosystem" (Barton *et al.*, 2019). The use of the term externality as elaborated in this paper does not seek to deny these other perspectives but notes that its use as a tool of policy is mainly framed in economic terms and it is this definition that forms the basis of the discussion in this paper (cf. Markandya *et al.* (2019)).

2.2 Definition of ecosystem disservices

The literature on Ecosystem Disservices (EDS) has been growing since the 2000s. However, a widely accepted definition, conceptual framework and typology of EDS remain elusive (Campagne *et al.*, 2018). One difficulty is that there is a lack of consensus on what constitutes the distinction between EDS and externalities, and whether the concept should be restricted only to negative impacts which result directly from ecosystem structures, functions and processes (as with ES), or whether it should also include those impacts which may be mostly or entirely precipitated by human activity. The issue is compounded by the fact that discussion of EDS in the literature has largely come from the perspectives of ecological and ecosystem services sciences, despite the broad social and economic implications of EDS.

For the purposes of this report, we define EDS as "the ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing", after Shackleton et al. (2016). Examples often presented in the literature include transmissions of vector-borne diseases, loss of biodiversity due to invasive species, damage to crops by wildlife, damage to buildings by termites, emission of greenhouse gases, human morbidity due to parasites, and human injury or mortality by dangerous species. Recognizing that these examples are not always accepted as EDS and raise various scientific and policy issues, a health-focused commentary on EDS, externalities and ecosystem accounting is provided in the Appendix.

Building upon the ES conceptual framework, the IPBES recently came up with a new framework: Nature's Contributions to People (NCP). The IPBES reports highlight that contributions can be both positive and negative. Negative contributions are those perceived as detrimental or harmful by different (groups of) stakeholders or by the same stakeholders but in different socioeconomic, temporal or spatial contexts (Lliso et al 2022). In the IPBES framework, the terminology 'negative NCP' is used as a synonym of 'detriment' or 'detrimental contribution'. Those negative contributions should be deliberately defined, accounted for and valued to better identify social–ecological trade-offs (Lliso *et al.*, 2022).

While disservices have been part of the ES theoretical framework (Braat, 2018), the consideration of negative contributions of nature has been claimed as being more explicit in the definition of NCP (Díaz *et al.*, 2018). Yet, this claim might not be justified and the negative contributions in the IPBES framework are still loosely defined. Kadykalo *et al.* (2019) argued that theoretically the frameworks seem similar in terms of recognizing negative effects on human well-being. As a matter of fact, some scientific papers clearly mix both concepts (negative NCP and ecosystem disservice) and frameworks. The way IPBES defines negative NCP does not differ from disservices, reinforcing the idea that EDS and negative NCP are very much aligned. However, the NCP framework explicitly recognizes the fact that generally NCP are not inherently positive or negative and makes clear that the contributions can be defined and valued as negative, neutral or positive. The value of a NCP can be (understood as) either positive, neutral or negative, depending who perceives the NCP, when and where (Lliso *et al.*, 2022).

EDS are distinct from negative externalities in that there is no requirement for a disservice to be caused by human action. However, the occurrence of disservices is often related to a current or past human activity (see also commentary in Appendix), and it is therefore difficult to disentangle the underlying natural and human causes. For example, wildlife trampling of crops may occur after forests have been converted to croplands and the wildlife is faced with reduced habitat and food sources; or the decline of endemic species is due to the presence of invasive species that were intentionally or unintentionally introduced by humans. EDS may also be caused by a lack of risk awareness or risk acceptance on the part of humans, for instance by settling in flood-prone areas and volcanic areas (benefitting from fertile soils but with risk of volcano eruption). This challenge has a corollary in the assessment of ES and the separate quantification of the role of ecosystem inputs and human inputs in the production of goods and services. The disentanglement of underlying natural and human causes of disservices, particularly those with historical origins, is likely to be intractable and we therefore propose that disservices should be measured without attempting to attribute responsibility. Similarly, the identification of disservices that are of purely natural origin is rarely likely to be feasible, since all disservices involve people as recipients. Moreover, the distinction between purely natural and human influenced disservices is not necessarily useful for decision making. From the perspective of current ecosystem management, the measurement of the quantity and value of a disservice is arguably more relevant than the (historical) responsibility for its occurrence.

Conceptually, and from an accounting perspective, we propose to consider disservices as distinct from externalities. The key point of distinction is the role of human agency:

1. An ecosystem disservice is a negative contribution from an ecosystem to human wellbeing, irrespective of the role of human agency in the underlying processes.
2. A negative externality is an unintended negative consequence of human action on the wellbeing of a third party. In the context of EA, externalities can take two forms (see also Figure 1):
    a. An increase in the provision of an ecosystem disservice
    b. A reduction in the provision of an ecosystem service

The commentary in the Appendix further illustrates the distinction between externalities and disservices with the example of the emergence of Hendra virus disease, which though initially viewed as a problem caused by opportunistic fruit bats is now more fully understood as an externality from agricultural practice and habitat loss. This highlights how categorising a phenomenon as an EDS may be subject to change over time as the intricacies of disease ecology and human impacts on ecosystem functioning are more clearly understood, and how attempts to understand, assess, account for and respond to EDS benefit from multi-sector, transdisciplinary approaches.

2.3 Including disservices and externalities in ecosystem accounts

The purpose of including EDS and externalities in the accounts is to provide information to support environmental management. This purpose underpins the consideration of which disservices and externalities are potentially relevant. We propose that three categories of EDS and negative externalities can be integrated in the SEEA EA (see Fig. 1):

1. **Disservices that are the negative effects from ecosystems to human wellbeing** (i.e., without making a distinction between natural and human causation). The quantification of disservices in the accounts is potentially useful to inform, monitor and appraise environmental management aimed at mitigating such effects. Examples include the loss of biodiversity due to invasive species; spread of diseases by vector species; human injury/mortality due to snakes, dogs, sharks etc.; human morbidity due to parasites.
2. **Externalities that are increases in the flow of disservices attributable to specific human activities that take place during the accounting period**. An externality is therefore linked to the time period in which the causal human activity takes place. The quantification of such externalities is potentially useful to inform mitigation of, or compensation for, negative impacts. Examples include peatland drainage for agricultural use that increases the emissions of carbon (the disservice is the ongoing process of emission of carbon from peatland; the externality is the increase in emissions due to drainage activity); conversions of forest to agricultural land that reduce wildlife habitats and eventually lead to crop damage (the disservice is the wildlife damage to crops; the externality is the increase in damage due to forest conversion).
3. **Externalities that are reductions in the provision of ES attributable to specific human activities that take place during the accounting period (i.e., a negative externality of the activity; not a disservice)**. The quantification of such externalities is potentially useful to inform mitigation of, or compensation for, negative impacts. Examples include reduction in forest recreation due to logging; loss of biodiversity due to intensive tourism; reduction in carbon sequestration due to logging; loss of ES due to human-induced forest fires. ES flows recorded in ecosystem accounts already account implicitly for the effects of externalities, i.e. those ES flows are final flows, net of reductions due to externalities. However, in the current SEEA EA, these reductions are neither explicitly recorded nor attributed to human activities.

We propose that the following cases of disservices and externalities should not be integrated in the SEEA EA, because they are considered not relevant for ecosystem management or are already captured in the SEEA CF:

- Emissions from machinery used in managing ecosystems, since this machinery is considered part of the economy in national accounting and those emissions are already captured by the SEEA CF;
- Negative externalities that impact people directly or through pathways that are not primarily related to ecosystem structure, processes, or functions (e.g. air pollution impacts on human health).

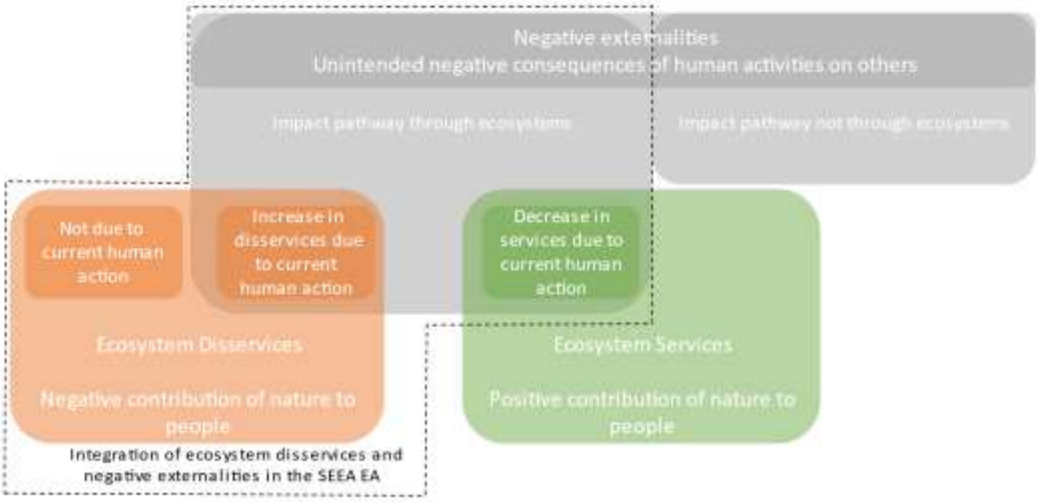

Figure 1: Integration of three categories of EDS and negative externalities in the SEEA EA.

In SELINA, we will focus on negative externalities of human activities that result in disservices or the reduction of ES (categories 2 and 3 above) and will not address the case of disservices that are not the consequence of human use or activity (category 1).

3 Approaches and challenges to including disservices and externalities in ecosystem accounts

In this section, we outline potential approaches for including disservices and externalities in ecosystem accounts, making a distinction between disservices that can be measured as the direct inverse of an ecosystem service and those that cannot. We also identify and propose solutions for challenges that may be encountered.

3.1 Disservices that are the inverse of an ecosystem service

In the case of disservices that are measured with the same metrics as ecosystem services, their inclusion may logically best be done in relation to the ES account. For instance, peatlands drainage leads to CO_2 emissions that reduce the net sequestration of CO_2 (and carbon storage) in all ecosystems at national scale (or may even lead to net negative sequestration, i.e. emissions, in all ecosystems at national scale). In other words, these disservices lead to an opposite effect – that can be measured with the same indicators of the carbon sequestration service in, say, growing forests. In this case, since the units with which the service and the disservice are measured are the same, the disservice can be connected or even deducted from the corresponding entry in the ecosystem service account. For example, if part of a forest ecosystem on peat is drained leading to CO_2 emissions, and the remainder of the forest is a net absorber of CO_2, then the ES account could, in principle, indicate the net CO_2 sequestration in this ecosystem asset or ecosystem type. Note that this does not conform to the SEEA EA, which proposes that only the positive (gross) sequestration is included in the account. However, it is policy-relevant to consider the net as well as the gross sequestration. Indeed, in the legal proposal for SEEA EA in the EU, currently under development, it is proposed to require measuring and reporting the net sequestration of carbon as the final indicator to be reported. This is also much more aligned with the greenhouse gas reporting principles of the UNFCCC, that require reporting of both emissions from and sequestration in ecosystems. In order to maintain alignment with SEEA EA, and to be transparent to the users of the account on the underlying data and models, it is important that it is clearly indicated what is the ecosystem service, and what comprises the ecosystem disservice (hence, both gross flows as well as the net flow should be reported).

An example of how a disservice with a corresponding service can be reported is provided in Table 1. Table 1 presents, using potentially realistic numbers, the service ‘carbon sequestration’ and the disservice ‘carbon emission’ resulting from drained peatlands. In drained peatlands, the organic matter in the peat soil is exposed to oxygen from the ambient air, after which it starts oxidising leading to CO_2 emissions of up to 50-100 tonnes CO_2/ha/year depending upon climate, drainage depth and land use. Note that the net service can be negative at the level of an individual ecosystem asset, an ecosystem type (e.g. grasslands) or even a country. Indeed, in the Netherlands, ecosystems are a net source of CO_2 emissions. Around 8% of the country is covered by peatlands and the large majority (>90%) of peatlands are drained and used as grassland for dairy farming. In total, each year, these emit some 7 million tonnes CO_2. The forests and other ecosystems of the Netherlands capture in total around 3.5 million tonnes CO_2 per year (Statistics Netherlands and WUR, 2017, 2022). Hence the disservice exceeds the service, and the net result is negative. Conceptually, this treatment does not violate the accounting principles of the SEEA EA, since the service itself (in the case of Table 1, the gross carbon sequestration) is always a positive number.

Table 1: Integrating services and disservices. The drained peatland used as grassland provides a disservice, i.e. CO_2 emission.

	Unit	Cropland	Grassland	Grassland	Forest	Forest	Forest	Heathland and Shrub	TOTAL Country
Soil type		mineral	mineral	peat (drained)	mineral	peat (undrained)	Plantation, mineral	mineral	
Area	(1000 ha)	1000	800	700	800	30	600	600	4530
Service									
Carbon sequestration/ha	(ton C/ha/year)	0.02	0.1	0.1	2	2	5	1.5	
Carbon sequestration	(1000 ton C/year)	20	80	70	1600	60	3000	900	5730
Disservice									
Emissions/ha	(ton C/ha)	0	0	14	0	0	0	0	
Emissions	(1000 ton C)	0	0	9800	0	0	0	0	9800
Net services									
1. Global climate regulation service/ha : Net sequestration/ha	(ton C/ha)	0.02	0.1	-13.9	2	2	5	1.5	
1. Global Climate regulation service: Net sequestration	(1000 ton C)	20	80	-9730	1600	60	3000	900	-4070

3.2 Disservices that are not the inverse of an ecosystem service

However, many disservices are not directly connected to an ecosystem service and therefore cannot be expressed in the same metrics as an ecosystem service. For example, the predation of surfers by sharks (a disservice) does not have a corresponding ecosystem service. In this case, a separate accounting table needs to be made. Given that disservices, in the same sense as ES, comprise a flow from the ecosystem to society, the recording of disservices is most logically connected to the ES account. Disservices can be recorded both in biophysical and monetary terms. Table 2 presents an example of a biophysical disservices accounting table.

Table 2: Disservices accounting table – example

	Unit	Ecosystem type 1	Ecosystem type 2	Ecosystem type 3	Total
Disservice account					
Disservice 1 (e.g. crop losses due to wildlife trampling)	1000 ton of paddy				
Disservice 2 (e.g. avian flu)	1000 poultry specimens affected				

It is worth noting that some disservices can, indirectly, be linked to a service. For instance, wildlife trampling of crops causes a reduction in crop provisioning. Care needs to be taken not to double count a disservice. Hence, crop losses due to wildlife trampling cannot be added (deducted from) to the actual crop production as recorded in the ES account since the account shows the net crop production inclusive of crop losses. A disservice, in this case, functions as an intermediate disservice – a negative effect from one ecosystem asset to another ecosystem asset. If the disservice and the service are both to be reported, a correction needs to be made, analogous to the example provided in Table 1 – showing gross crop production (before wildlife losses), wildlife related crop losses, and net crop production (see example in Table 3).

In the case of Avian flu, recording is simpler since there is no corresponding entry in the ES accounts, and recording following Table 2 suffices (Note, however, that avian flu does function as an intermediate disservice in the production of poultry, and the net production of poultry is recorded in the SNA).

Table 3: Intermediate disservices accounting table – example

	Unit	Cropland	Forest	Total
Gross service: Crop production	1000 ton of paddy	5600		5600
Intermediate disservice : crop losses due to wildlife trampling	1000 ton of paddy	-500	500	
Net service : crop losses due to wildlife trampling	1000 ton of paddy	5100		5100

3.3 Challenges in recording disservices including negative externalities from ecosystem management in the accounts

3.3.1 Land use conversions

Negative externalities may also arise because of conversions between ecosystem types, for instance the conversion of a natural forest to e.g. an agricultural field. In such cases, negative externalities include the disservices generated by the newly created agricultural field (e.g. N emissions), but also the loss of ES that the cleared forest was providing (e.g. carbon sequestration, water flow regulation, habitat for biodiversity, protection from wind and mass flows, water filtration, pest and disease regulation (see Appendix)). Disservices generated by the newly created agricultural field can be treated as proposed in previous sections 5.1 and 5.2, as disservices that are the inverse of an ecosystem service (e.g. CO_2 emissions) or as disservices not connected to an ecosystem service (e.g. N emissions). However, the loss of services that were provided by the forest cannot be attributed directly to the newly created agricultural field.

Therefore, we propose that negative externalities arising from land use conversions should be compiled as distinct complementary information to SEEA EA accounts. Complementary accounting tables could present flows of ES and disservices associated to ecosystem types before and after land use change. Such information can be derived from time series of ecosystem extent accounts, which record ecosystem conversions in mapping units and link these conversions to economic sectors, combined with ES and disservices supply tables. Based on policy needs, negative externalities from ecosystem type conversions in these mapping units can then be aggregated at different scales: land properties, administrative/biophysical regions or national, and be used to capture trade-offs associated with those conversions. Such time series will need to consider foregone future ES flows due to land use conversions.

3.3.2 Recording intermediate disservices

As is the case of ES, disservices can be intermediary. For example, the supply of final ES (e.g. crop provisioning) can be negatively affected by ecosystem processes (e.g. pest species in agricultural land) and such processes can be regarded as intermediate EDS. Care should be taken to avoid double counting. When a disservice is a pollution source in an ecosystem type, another ecosystem type can be a sink of this pollutant where it is broken down. Take N emissions to water. One could record a disservice flow from agricultural fields (N emissions). This would reduce the recreational services provided by downstream lakes, e.g. the number of days a lake is accessible for bathing (effects of algae blooms). The service provided by the lake is lower compared to the situation without the agricultural run-off, i.e. the disservice. If the disservice is included in the account, double counting of the negative effect may occur. Hence, in this case, the disservice needs to be recorded as an intermediate disservice. Double counting needs to be avoided. Hence if the disservice N runoff is included as a negative when accounting for the service provided by the agricultural field, in theory the services of the downstream lake would have to be increased by a similar amount (akin to the treatment of intermediate ES in SEEA EA). In practice this is not likely to be feasible in most cases, since it would involve considerable effort and result in potentially unrealistically high, theoretical ES supply in the lake.

Hence, it is proposed to pursue one of two options depending upon environmental and policy context – to be further tested in the SELINA test sites and Demonstration Projects:

- Option 1. Only include intermediate disservices in cases for which there is a specific need to bring out the interactions between ecosystems in the ecosystem accounts. Of course, not all disservices are intermediate, i.e. all disservices that directly affect people (e.g. by causing negative health effects) are final disservices. Greenhouse gas emissions can also be considered a final disservice, since their effect occurs in the long term and much of the consequences of current emissions are not fully reflected in current ES supply.
- Option 2. Include all disservices including intermediate services in physical terms, but exclude intermediate disservices from valuation to avoid double counting. We note that N emissions to air and water have both an effect on ecosystems and ES supply and an effect on human health (nitrate in drinking water, Particulate Matter precursor). Only recording the N flows that are final disservices may not be feasible in most cases since it is difficult to separate final and intermediate parts of the N flows. In this option, we would record all N emissions in the physical account (they are also very relevant for policy) and, in monetary accounts, only include the value of final disservices (human health cost) and exclude the value of intermediate disservices to avoid double counting.

These two options are to be further tested and discussed during SELINA implementation.

3.3.3 Monetary valuation

We suggest that the following list of principles is adhered to when performing monetary valuation for EDS, reduction of ES and externalities:

- Valuation of disservices and negative externalities should conform to the general guidance on monetary valuation in the SEEA EA (2021). This means the measurement of exchange values and not welfare values or other value concepts.
- Conceptually, prices for disservices and externalities could be framed in terms of markets to avoid negative impacts or reduction of output from services priced in (simulated) markets. This includes implicit prices that are revealed through

transactions in related markets (e.g. hedonic pricing of reductions in air pollution or flood risk in residential and agricultural property markets).

- It may also be possible to obtain proxy prices for disservices and negative externalities using prices for the inverse and equivalent positive impact. For example, the value of a reduction in recreational activity due to degradation of a coral reef could be measured using information on the price of a recreational visit (dive fee). This approach potentially ignores the implications of loss aversion and associated asymmetry of values for gains and losses of ES (although this is perhaps less relevant for exchange values than it is for welfare values).
- For disservices that are the direct inverse of an ecosystem service (e.g. carbon emissions and carbon sequestration), the same valuation methods should be applied as for the ecosystem service (e.g. damage costs measured by carbon credit prices).
- Value transfer methods are applicable to generate spatially variable value estimates at large geographic scales across multiple ecosystem service providing units. The potential for using value transfers for EDS may be limited, however, due to limited primary valuation research on the value of disservices. We note that most major classifications of ES (e.g. CICES, MA, TEEB, NESCS) and databases of valuations (e.g. ESVD) do not include EDS.
- Many disservices and negative externalities impact human health. It has long been established, however, that the national accounts do not place a direct value on health outcomes and instead the focus is placed on measuring the inputs to human health, e.g., outputs related to doctors and hospitals (cf. SEEA EA 2021, p225, 12.26 (UN et al., 2021)). The value of health impacts represents an important area of analysis that is broader than the ecosystem accounts. Regarding the economic valuation of health impacts resulting from disservices and externalities, there is an extensive and well-developed literature on the valuation of (both positive and negative changes in) health endpoints than could be drawn on. To a large extent, the methods used to value health endpoints (e.g. loss of productivity, cost of treatment) are consistent with the general guidance on monetary valuation in the SEEA EA (UN et al., 2021).

4 Demonstration project and test sites

4.1 Externalities from peatland management in the Netherlands

Around 8% of the Netherlands is covered by peatlands and the large majority (>90%) of Dutch peatlands are drained and used as grassland for dairy farming (Fig. 2). In total, each year, these emit some 7 million tonnes CO_2. The drainage of peatlands also leads to soil subsidence of up to 1 cm per year, with associated damages to infrastructure, houses and nature. Negative externalities from dairy farming on peatland also include emissions from energy use (for drainage), methane emissions from dairy cows and impacts on meadow bird habitats. In this test site, we will assess and map externalities from peatland management and test how to integrate these externalities to the Dutch ecosystem accounts. Conceptually, CO_2 emissions are the inverse of the CO_2 sequestration ecosystem service and can be integrated in the carbon sequestration supply and use table of ES accounts (cf. section 3.1). On the contrary, damages from soil subsidence are disservices that are not the inverse of an ecosystem service. Damages from soil subsidence may be recorded in separate disservices accounting table in the ES accounts (cf. section 3.2). Emissions from energy use (for drainage) and from livestock are part of the economy and already captured by the SEEA CF, hence not in the scope of SEEA EA in principle. However, methane emissions from dairy cows fit in the SEEA EA thematic account on climate change. Negative impacts on meadow bird habitats may be conceptualised as a reduction of ES provided by grasslands, or may be connected to the SEEA EA thematic account on biodiversity. We will test and discuss these different options to integrate negative externalities of dairy farming on peatland using the SELINA test site as a case study.

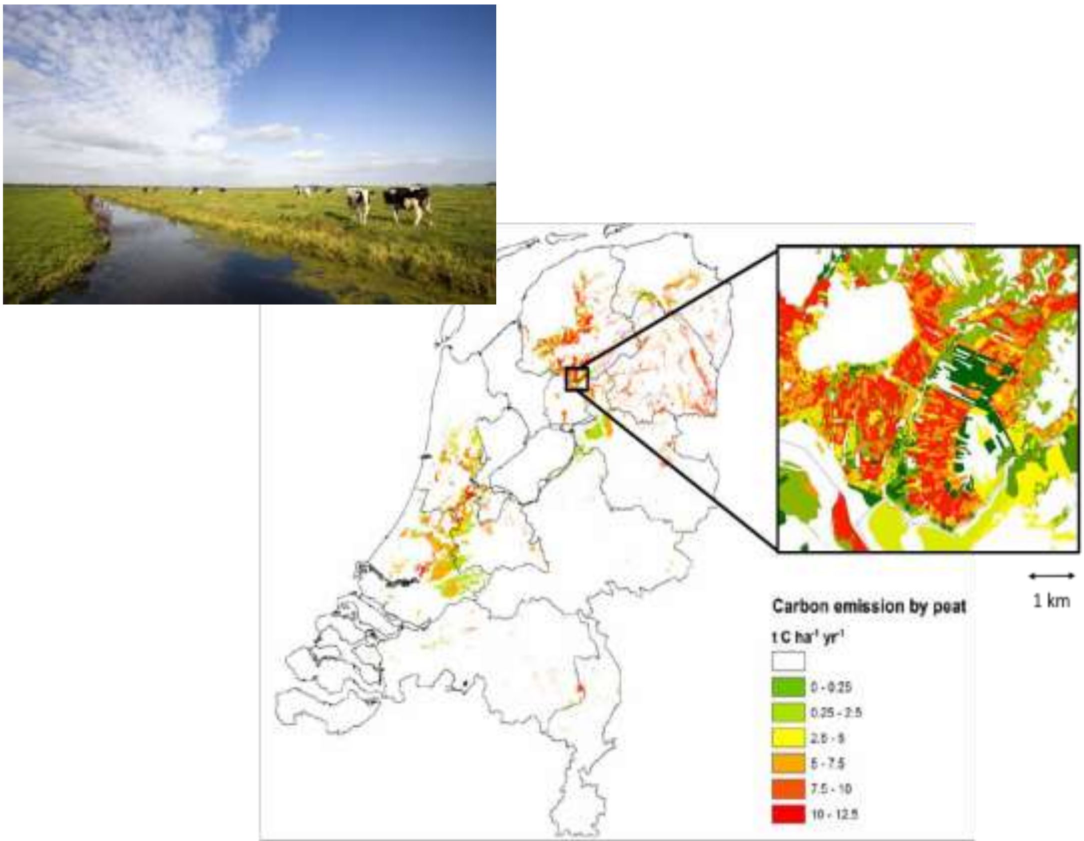

Figure 2: Netherlands test site. Most Dutch peatlands are managed as grassland for dairy farming.

4.2 Negative externalities from forest fires in Portugal

Background: Fire is an ecological process that occurs across different terrestrial ecosystems, whether due to natural- or human-caused ignitions, with varied socio-ecological effects (McLauchlan et al. 2020). In many ecosystems, fire is important to sustain biodiversity and habitat heterogeneity (Kelly et al. 2020) and to support ecosystem functions and services. For example, fires control landscape fuel built-up and connectivity, thereby preventing catastrophic wildfires, or foster carbon sink in soils and belowground biomass (Pausas and Keeley 2019). However, anthropogenic factors, such as land use and land cover (LULC) changes and/or fire exclusion policies, fostered fuel hazard in many fire-prone landscapes, such as the Euro-Mediterranean region (Mantero et al. 2020; Moreira et al. 2020). In these highly fire-prone environments, fuel built-up, vertical and horizontal fuel continuity or the increase of the proportion of highly flammable species together with longer and drier climate conditions is disrupting contemporary fire regimes (Rogers et al. 2020). Consequently, the frequency of high-intensity wildfires is growing (Rodrigues et al. 2022) with increasing ecological and socio-economic damages (Meier et al. 2023; UNEP 2022). For example, in Portuguese forests, fire regime shifts can be attributed to modifications in the landscape flammability and ignition patterns from human-influenced LULC changes together with favourable fire-weather conditions (Fernandes et al. 2014). In this sense, acknowledging the ecological, social, and economic dimensions of fire and anticipating its positive and negative impacts requires incorporating fire under an ES-EDS framework (Sil et al. 2019) which allows decision-makers to have a more balanced perspective of fire and its effects on socio-ecological systems.

Table 4: ES and targeted negative externalities (reduced ES and disservices) derived from forest fires in the Northern Portugal test site.

Ecosystem Service			Negative externalities	
			Reduced Ecosystem Service	Ecosystem Disservice
Provisioning	Fibres and other materials from cultivated plants	Timber provision: the volume of woody biomass in forests (i.e., potentially harvestable).	Degradation of timber provision: due to losses in the volume of woody biomass in areas burned at high/very high fire severity.	N.A.
Regulating & Maintenance	Regulation of chemical composition of atmosphere and ocean	Carbon storage: the amount of carbon stored by above- and belowground biomass and dead organic matter in forests and shrublands.	Carbon storage reduction: due to losses in carbon stocks in burned areas according to different levels of fire severity.	N.A.
	Control of erosion rates	Soil retention: the amount of soil retained by forests and shrublands.	Soil retention reduction: due to vegetation losses in burned areas according to different levels of fire severity.	Soil erosion: soil loss/deterioration in burned areas according to different levels of fire severity.

Cultural	Physical and experiential interactions with natural environment	Nature-based tourism: the number of visitors in forested landscapes.	Decrease in nature-based tourism: due to loss in the number of visitors in burned forested landscapes.	Unpleasant landscapes: burned landscapes perceived as unpleasant by people.

* N.A. – Not applicable.

Aim: This test site will focus on uncontrolled forest fires in Northern Portugal, which can be seen as negative externalities associated with changes in socio-economic activities in the agricultural and forest sectors (e.g., promoting increased fuel accumulation due to the gradual cessation of traditional land use practices). Concurrently, forest fires also promote EDS directly affecting people, for instance, human safety, health and infrastructures (Augusto et al. 2020; Ribeiro et al. 2020) or disrupting ecosystems functioning by promoting soil erosion (Vieira et al. 2023). Furthermore, forest fires can affect pre-existing ES, for example, by reducing the supply of biomass, altering carbon stocks, or promoting recreation potential losses (Sil et al. 2019). Therefore, our goal is to demonstrate how reduced ES and disservices derived from forest fires (Table 4) can be accounted for, using the NUTS II - Northern Portugal as the focal area.

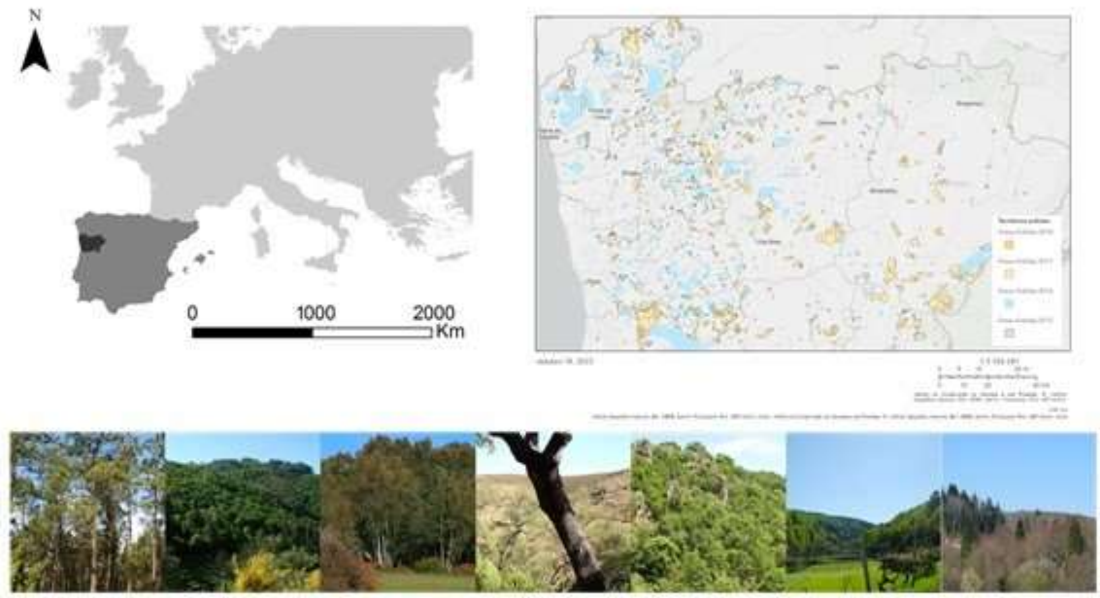

Figure 3: Northern Portugal test site. Left panel: Northern Portugal (NUTS-II EU) test site. Right panel: area burned in Northern Portugal between 2015 and 2018. Bottom panel: forested landscapes in Northern Portugal.

Study area: The test site is in Northern Portugal (NUTS-II EU administrative region) and covers a surface area of ca. 21 515 km^2 (Figure 3). The area is part of the Eurosiberian-Mediterranean regions and comprises a wide range of conditions (e.g., elevation: 0 - 1545 m; mean annual rainfall: ca. 400-2500 mm). Protected areas represent 25% of the total surface. Forests (37%), agriculture (29%) and shrublands (22%) are the main LULC types in the test site. Fire activity in Northern Portugal is high, with 9,630 fires/year affecting mostly forests and shrublands whose combined burned area is ca. 49,000 ha/year (2010 – 2011).

4.3 Negative externalities resulting from tourism and agricultural development in Peloponissos, Greece

Greece is one of the most visited destinations in the EU, especially in the summer months, with the vast majority of tourism and related infrastructure concentrated along the country's coastline. Simultaneously, Greece is one of the most biodiverse countries in the EU, with 27.3 % of its terrestrial and 19.6 % of its marine area, respectively, included in the Natura 2000 protected areas Network. The objective of the test site (Figure 4), is to map and assess externalities related (a) to tourism and (b) agriculture and how these externalities can be quantified and integrated in the SEEA EA framework. More precisely, we will identify and assess tourism infrastructure and agricultural activities spatial patterns using photo interpretation and remote sensing methods, based on EO data, with special focus in areas belonging to National parks and Natura 2000 protected areas. Moreover, specific objectives deal with the development of relevant, standardised indicators for NCA, including the important task of the categorization of tourism and agricultural activities as generating externalities, disservices or ES. For instance, ecosystems with tourism activities within the limit of the protected areas' carrying capacity should be treated as providing cultural ES and this type of activities should not be treated as generating externalities and/or disservices. This also applies to traditional cultivations of e.g. olive groves and vineyards. The impact of wildfires, including the megafires of 2007, and subsequent fire events that occurred in the same areas during the last twenty years, will also be evaluated combined with the potential of ecosystem recovery and impact from the identified externalities. A main task will be the wildfire impact on current ES at all types of ecosystems, that may transform them or not from ES to disservices or externalities for the fire affected area (e.g. cropland ES provided by specific agricultural land use patterns, may be externalities in the post fire conditions).

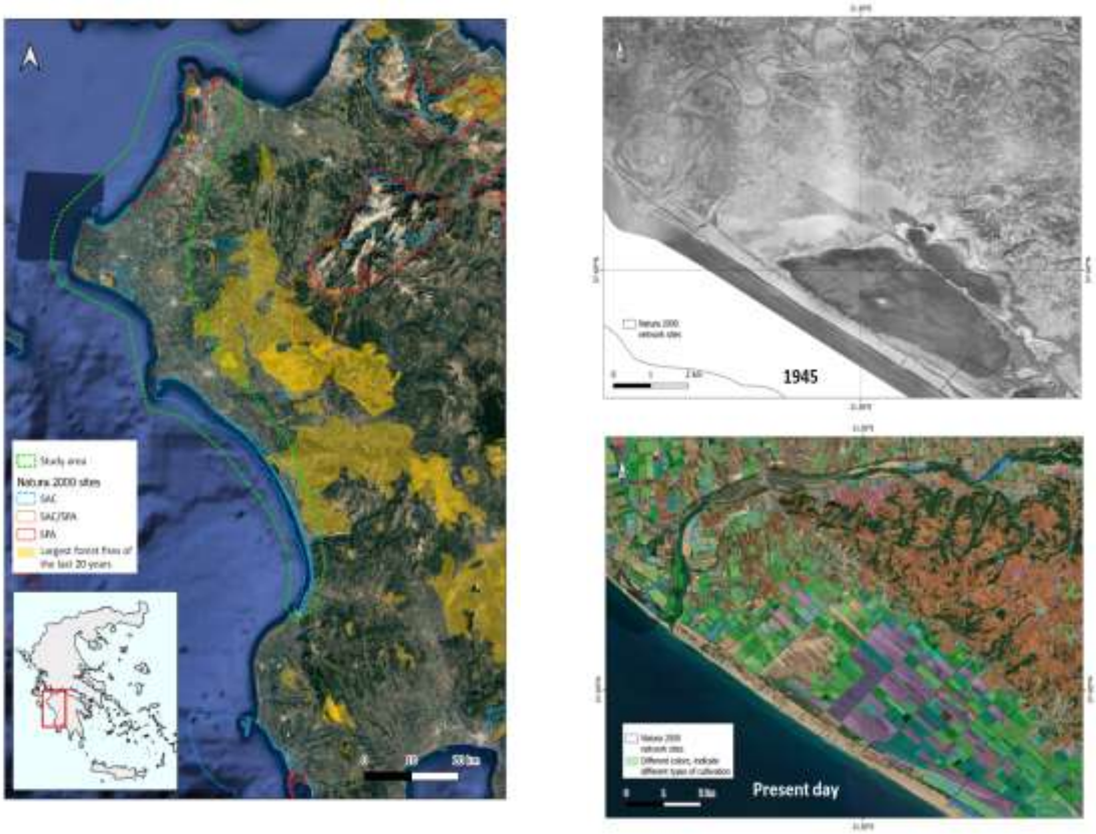

Figure 4: Peloponissos test site. Left panel: study area. Right panel (top and bottom): Characteristic example of agricultural activities affecting ecosystems and their services. In the upper right panel, the severe modification of the river route and its riparian ecosystems is observed, alongside the loss of the river deltaic system. Former wetlands and riparian areas are now covered by intensive agricultural activities (lower, right panel).

In Figure 4, a characteristic part of the study area is presented depicting how agricultural activities and infrastructure transformed ecosystems, landscapes and land uses, from 1945 to present day. Additionally, externalities from the development of an extensive network of solar parks related to agricultural and natural ecosystems will be assessed to identify potential indicators for accounting.

4.4 Shark risk disservices and coastal ecosystem services in Réunion Island

A normal level of ecosystem-mediated risk, i.e. socially acceptable both in terms of probability of danger occurrence and severity of damages, is a key condition to experience in-situ cultural ES. In Réunion Island, in the context of a rapidly changing marine-coastal ecosystem, the iconic ES of “sea bathing and surfing” has been abruptly interrupted by increased shark bite incidence since the early 2010s. While understanding the ecosystem drivers and patterns of large predators (e.g. sharks), risk for humans is critical for public safety and management purposes, the causal attribution of increased shark risk remains speculative so far. Here, we basically assume that an increasing likelihood of shark bite events is associated with higher shark presence. As a starting point, we conceptualise shark risk as a) an increase in ecosystem disservice (predator-related risk for humans) that is concomitant to ii) a decrease in ecosystem service both in terms of offer (public safety) and demand (due to lower attendance combined or not with legal access restrictions). In this case, the disservice is the direct opposite (symmetrical) of the service. Human actions to reduce shark risk-linked disservices in Réunion Island can therefore be considered as a revelator of the value of mirror ES.

La Réunion (2500 km^2) is a French volcanic island located in the tropical Southwest Indian Ocean, 900 km East of Madagascar. The island is characterised by an overall conic shape (3059 m summit), a narrow insular shelf, and a steep topography. Major marine coastal habitats include fringing coral reefs on the leeward dry west coast (~25 km long), rocky shore and soft bottom coastal sediments on the wet east coast. Over the last three decades, La Réunion has been characterised by rapid land-use changes and intensification of human activities, fuelled by demographic growth and planned economic development in a post-colonial context. From 1980 to 2022, the human population in La Réunion increased from 500,000 to 870,000 inhabitants and urban areas expanded 4-fold from 70 km2 to 300 km^2. Meanwhile, the gravity centre of the economy of the island shifted from production to services. Tourism grew from 200,000 tourists in the early 1980s to 500,000 since the mid-2010s (+150%). Moreover, ocean-based activities also expanded, including coastal fishing and a wide range of sea-based leisure activities. Coastal tourism and leisure activities are concentrated on the leeward side of the island (west). Since 2007, 80% of fringing coral reefs located along the western and southern coast are protected within the *Réserve Naturelle Nationale Marine de La Réunion* (RNNMR).

Surfers, bathers, and spear-fishers are among the ocean-user groups most exposed to the potential shark bite risk. Imported during the 1960s in La Réunion, surfing is practised across approximately 50 distinct surf spots, most of them being located within the boundaries of the marine reserve. The surfer population was estimated at 10,000 in the 2010s. Between 2011 and 2019, 26 cases of shark bites on humans (or their personal equipment) were recorded, of which 19 involved surfers, resulting in 11 deaths (i.e. a fatality rate of 42%) and 11 injured victims. The annual incidence of shark bite accidents increased 3-fold from the 1980-2010 period (1 case per year) to the 2010-2020 period (3 cases per year). In fact, after normalising the incidence by the number of sea-users, Lagabrielle et al. (2018) measured a 23-fold increase of shark bite incidence rate over the 2005–2016 period. Most shark bites on humans in Réunion have been attributed to bull sharks. The average instantaneous number of surfers at sea decreased 10-fold from 2010 to 2013.

Faced with this sudden increase of shark risk, public authorities in Réunion Island were pressed to rapidly develop, test and implement a set of shark risk reduction actions under the guidance of the Shark Security Centre, a public boundary organisation initiated in 2016. Collective risk reduction measures included a total ban of sea bathing activities - e.g. surfing - still in place since 2013, a fishing programme targeting potentially dangerous shark since 2014 (Niella et al. 2021) and other measures such as the creation of shark detection patrols and shark nets. No shark bite accident has been recorded on the island since 2019.

In Réunion Island, the causal attribution of the increased shark risk has been the core of heavy debates about i) the diagnosis of the increased shark bite phenomenon (What should be measured and compared?) ii) the problem (Is it a normal or abnormal risk? If abnormal, is it a societal problem?), iii) its causes (natural or human-induced? At what scale of space and time do the drivers of the risk operate? If human-induced, what activities caused the increased risk?) and iv) its solutions (What public shark risk reduction policy should be implemented?). Intense public debates and controversies fuelled with emotions and uncertainties, amplified by media and social media have developed around each of those four items.

Through our investigations in WP 5.1 and 5.3, we do not aim to answer the core question of causal attribution of increased shark risk in Réunion, but rather to measure what does it imply (in monetary terms) to ignore or to consider shark risk in ES accounting, whether as i) an increased disservice (induced by human action or not), or ii) a decrease in ecosystem service (induced by human action). This research will contribute to guide a shark risk reduction public policy, part of maritime strategy and plan (Shabtay et al. 2020), that has to balance: sustainability, transparency, uncertain and incomplete knowledge, the value of human life, people's freedom to access coastal ES, and the potential externalities resulting from shark risk reduction actions. While aiming to achieve shark risk reduction, a negative externality of potentially dangerous shark fishing is the catch of sharks and non-targeted species (by-catch). However, shark risk reduction policy measures (implementation of shark nets) enabled a bathing service in new sites where bathing was not practised before.

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● Appendix: Health-related perspectives on ecosystem disservices and negative externalities

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C.E. Kretsch, Cohab Initiative Secretariat

○ Introduction

In presenting definitions of externalities and ecosystem disservices (EDS), this report has recognised that as yet there is no general scientific consensus on a definition, typology or conceptual framework for addressing or assessing EDS. A related difficulty is that arguments and perspectives on EDS tend to come from a relatively narrow scientific and cultural perspective, typically from "ecosystem services" science and adjacent disciplines; for example, discussions of EDS frequently focus on the negative impacts which nature, or interaction with nature, can have on human health, and yet perspectives coming directly from epidemiology or other health sciences or from public health planning or policy are rarely included in these discussions. This means that crucial understanding of the mechanisms by which such health threats arise and the degree to which they may be deemed risks at all is overlooked.

Some authors have suggested that various ecosystem functions, without human influence, can pose threats to human health (e.g. Lytimaki and Sipila, 2009; Dunn, 2010), without giving appropriate consideration to the often highly complex interactions between people and ecosystems which might not only determine the actual existence of such threats, but also the spatial and temporal occurrences and flows of related EDS. This issue has a correlate in the sphere of health policy, where assumptions of a simplistic habitat-pathogen-disease paradigm have sometimes led to poorly informed interventions involving destruction of natural habitats without fully considering the negative consequences of such actions on ES which support human well-being. This underscores the need for transdisciplinary approaches to the identification, assessment and management of EDS to ensure that trade-offs and externalities are appropriately considered.

Here, we discuss the issue of EDS from a human health perspective in order to highlight some of the gaps in current conceptual frameworks and discussions on EDS in the literature, whilst also arguing that accounting for EDS and negative externalities - regardless of how they are framed - as part of a comprehensive system of environmental economic accounts is important in order to facilitate mainstreaming of biodiversity and ecosystem services into the health sector and to more completely inform decision making on conservation and sustainable use of the natural environment.

○ The importance of linking biodiversity, ecosystem services and health

There are several reasons why the health sector represents a key area for mainstreaming biodiversity, ecosystem services and natural capital concepts. Firstly, the varied and intricate relationships between nature and health are increasingly well understood and have been explored in detail in scientific literature (see for example WHO-CBD 2015), and have become of increasing concern to governments and citizens throughout the EU and worldwide. Recent experience of the Covid-19 pandemic has provided clear examples of the connections between the health of the environment, human health and the health of other species (IPBES, 2020). Second, investments in health and healthcare account for a significant amount of public expenditure at regional, national and local levels, with an EU average investment equivalent to approximately 11% of GDP and 20% of gross national budgets, as well as being a key area of household expenditure for individuals and families. Furthermore, the health sector directly or indirectly encompasses a broad diversity of scientific disciplines, policy sectors and areas of economic activity; as such, the health sector may be seen as an important instrument of economic policy (Jagrič et al., 2020). Third, health is recognised as a significant component of well-being, influencing individual and societal metrics on quality of life, lived experience, personal development and social interaction (e.g. Ruggeri et al., 2020) and therefore should factor explicitly in assessments of nature's contribution to people.

While the significance of biodiversity and ecosystems to health is well established, it is important to note also that the health sector itself can, through various policies, programmes and practices, have negative impacts on biodiversity, ecosystems and ES (e.g. Boxall and Kretsch, 2015). Where these impacts threaten the sustainability of ES which contribute positively to health or other elements of well-being, or potentially increase negative externalities, it is important that they be recognised, understood, and appropriately accounted for in the development, assessment and review of related policies.

Various barriers to mainstreaming in the health sector have been discussed in the literature (e.g. Kretsch, 2016; Campbell-Lendrum, 2005). Historically, one difficulty has been a perception within the health sector, or in government agencies in various countries, that biodiversity and ecosystems are a source of significant health threats and therefore options for the management of those risks should include ecosystem degradation or culling of wild species. Examples include policies on the destruction of wetlands in many countries as a means of combating malaria (Keiser et al., 2005) and calls for the widespread culling of wild birds and removal of their preferred habitats as a means of preventing the spread of avian influenza (Cromie et al, 2011; Cook and Karesh, 2012). Although the term EDS is not necessarily used in such contexts, these concerns clearly correlate with the idea that biodiversity and ecosystems can pose inherent threats to human health which should be accounted for when developing strategies for management of the natural environment. If such strategies in turn pose a threat to the sustainability of ES associated with the targeted biodiversity and ecosystems, then the ultimate impacts on human health and well-being may be negative – in addition to the fact that these actions may often be counter-productive (Miguel et al., 2020).

Although the relationships between elements of biodiversity or certain ecosystems and health are in some cases clearly identified, the exact mechanisms and pathways through which ecosystems influence health outcomes are sometimes poorly understood, or are highly case specific, depending upon, for example, climate, geography, and cultural perspectives and behaviours (IPBES, 2020; Clark et al., 2014). In order to give an accurate economic account of the relationships between ecosystems and health, and therefore to produce accounts that can better inform decision making, it is important that these pathways (linking ecosystem structure and function and health-related services, disservices, benefits, costs or values) are carefully examined. This is particularly important for complex systems where a full understanding of which aspects of biodiversity or ecosystem functioning can or should be managed to address health issues requires careful consideration of the interaction between ecosystem health and the health of animals, plants and humans, as well as of the past, present or future role of human activity and behaviour in driving those health issues (Ostfeld and Keesing, 2017).

This requires a nuanced approach to EDS and a conceptual framework for EDS accounting that can facilitate a better assessment of health risks, pathways, and responses. Such a framework has not yet been established for either ES or EDS related to health, and though it is beyond the scope of this short report it will be addressed in other tasks within SELINA. For the purposes of this deliverable, some examples of the complexities involved are provided in the following section.

Health threats from nature: disservices, reduced services, or externalities? Or does it matter?

The notion of EDS, as with ES, involves some degree of human agency identifiable at one or more stages of the ES (or EDS) cascade – e.g. anthropogenic impacts on ecosystem structures or functions, specific behaviours resulting in contact with biodiversity, societal or personal perceptions on benefits or disbenefits, or specific views on impacts and values. Whether perceived health risks associated with ecosystems are classified as EDS or externalities, or as a result of reductions in ES stocks or flows, or as primarily driven by ecological processes or by human influence on those processes, is of material relevance to the development of interventions intended to effectively alleviate those risks. Whilst this classification is not necessarily of relevance to the process of accounting – i.e., knowledge of the root causes of an emerging disease outbreak does not necessarily inform an assessment of the immediate human cost of that outbreak - the outputs of accounting efforts can help to prioritise and promote more detailed investigations into the scale and determinants of negative human-nature interactions, and provide an economic argument for enhanced transdisciplinary approaches to ecosystem assessment and management.

Recent research into emerging infectious diseases have highlighted some of the difficulties involved in attributing health risks to ecosystem structures, processes or functions. The case of Hendra virus disease in Australia, which causes acute respiratory infection in humans and horses, is a useful example. Although virological studies have since indicated that Hendra virus has circulated in Australian flying foxes (fruit bats) since before the arrival of Europeans, it only came to public health attention when it caused fatal disease outbreaks in horses and the humans who interacted with them in 1994 in eastern Australia, with bats being identified as the reservoir by 2000 (Halpin et al., 2000). Outbreaks were not recorded between 1996 and 2002, however from 2003 bat behaviour and the number of outbreaks changed rapidly. The proximate causes of the outbreaks relate to increased occurrence of bats in urban and agricultural lands; however, the primary root cause was a change in the roosting and feeding behaviour of fruit bats in response to habitat loss (by 1996, the bats' primary forest habitat had been cleared by over 70% of its pre-colonial extent) exacerbated by climate change associated with El Nino events which impact on the flowering and fruiting periods of the bats' preferred food trees. Bats which had historically been resident in their home forest habitats adapted to food shortages by becoming nomadic, moving closer to human settlements and farms to avail of other sources of food, placing them in contact with horses, which passed infections on to humans and pets. A comprehensive picture of how the emergence of Hendra was the result of largely anthropogenic changes in bat ecology was not ascertained until 2023 (Eby et al., 2023).

Similar patterns have been identified in the emergence of other infectious diseases over the past several decades, with the risk of several disease outbreaks (in humans, livestock or wildlife) relating to changes in the ecology of pathogens or vectors driven by human influence on landscapes and biodiversity. In the case of Hendra, prior to recent insights into the social-ecological dynamics involved the disease was largely framed as an issue of human-livestock-wildlife conflict, with bats being increasingly regarded by the public and health authorities as pests – a source of EDS. The current understanding, based on a more integrated scientific approach, frames the issue largely as an externality from agricultural expansion and deforestation, with significant implications for future disease management, outbreak prediction, and habitat management. In many cases, the precise drivers, proximate causes and root causes of disease emergence are not identified until many years after the disease is first reported.

The existence of pathogens and parasites, and by extension any potential they may have to cause disease in humans or in other species of economic importance, should not alone be sufficient to class an ecosystem or species as being a source of EDS, since the positive and often essential role of pests and pathogens in ecosystem functioning must also be taken into account. Indeed, from an ecosystem management perspective, since they shape host population dynamics, alter interspecific competition, influence energy flow and appear to be important in the maintenance of biodiversity, conserving populations of pathogens and other species potentially harmful to humans may be essential to the sustainability of ES as well as the reduction of other EDS (Fischhoff et al, 2020; Hatcher et al., 2012; Delaux and Schornack, 2021) – again dependent upon context. Whilst it may arguably be in the best interests of human well-being to eradicate certain pathogens – smallpox and the malaria parasite being cases in point – such valuations taken in the absence of a comprehensive account of likely ES trade-offs and potential externalities will be incomplete at best, leading to uncertainties around the sustainability of related interventions.
Similar issues arise across several other proposed classes of EDS presented in the literature. For example: risks of attack by wild animals may be an EDS or an externality due to human encroachment on habitats or loss of predators' food resources (IUCN, 2023); the risks of antibiotic resistance, proposed as an EDS by some authors, are largely driven by pollution and human over-use of antimicrobial compounds (Boxall and Kretsch, 2015); and the increasing occurrence of harmful algal blooms in many aquatic and marine ecosystems is associated with pollution and anthropogenic climate change (Gilbert, 2020).

The key take-away here is that while economic accounting of negative aspects of biodiversity and ecosystems is essential in order to build a comprehensive and balanced picture of nature's contributions to people, the utility of such assessments can be severely limited by narrowly-defined or silo-based determinations of EDS. From a public health perspective, identifying a particular ecosystem-related health threat as being a disservice or an externality may be less important in the face of urgent health risks than unpacking the complex drivers, pathways, responses and trade-offs involved. Nevertheless, ensuring that the results of ecosystem economic accounting speak substantively to the data needs of the health sector whilst avoiding confusion and also providing appropriate direction for policy and practical responses – for biodiversity conservation, ecosystem service sustainability, and health - requires that the conceptual frameworks used for EDS and externalities are based on careful consideration of how such risks are framed and communicated.

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