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The role of forest ecosystem services to support the green recovery

Evidence from the Ecosystem Services Valuation Database

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Evidence from the Ecosystem Services Valuation Database

Background paper for State of the World's Forests 2022 report

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Acronyms

CBA	cost–benefit analysis
ESVD	Ecosystem Services Valuation Database
FAO	Food and Agriculture Organization of the United Nations
FES	forest ecosystem services
FSD	Foundation for Sustainable Development
GDP	gross domestic product
iCBA	integrated cost–benefit analysis
NPV	net present value
PES	payment for ecosystem services
SEEA	System of Environmental Economic Accounting
SEEA–CF	System of Environmental Economic Accounting – Central Framework
SEEA–EA	System of Environmental Economic Accounting – Ecosystem Accounting
SNA	System of National Accounts
SOFO	State of the World's Forests
TEEB	The Economics of Ecosystems and Biodiversity
TEV	total economic value

Executive summary

This paper is a background document developed for the Food and Agriculture Organization of the United Nations (FAO) report on The State of the World's Forests 2022 (SOFO 2022). It reflects the results of a collaboration between FAO and the Foundation for Sustainable Development (FSD) to update the Ecosystem Services Valuation Database (ESVD). The compilation of systematically reviewed and standardized economic values of forest ecosystem services (FES) consolidated in the ESVD includes value estimates for all FES in ten forest ecosystem types as per The Economics of Ecosystems and Biodiversity (TEEB) and the System of Environmental Economic Accounting (SEEA) classifications. This paper offers an improved understanding of the role of forests in sustainable development, and highlights the potential of forests to provide a pathway toward greater resilience and a green recovery.

Forests are an important component of the world's natural capital, and they deliver a broad range of ecosystem services that underpin human well-being socially, physically, mentally and economically. However, the extent and condition of forests in many parts of the world have declined dramatically over the past few decades due to their conversion to agriculture, forest fires, unsustainable timber harvesting, and urbanization. This has resulted in a reduction in FES. Conversely, the urgency to address such global challenges as climate change has increased the demand for FES and created greater awareness of their importance. It is critical, therefore, to improve our understanding of such services, and to properly estimate the value of forests to human well-being so that it can inform decision-making. There are many different conceptions of the value of forests and this publication focuses on the economic value. After updating forest value data for SOFO 2022, the ESVD now contains more than 2700 unique values for FES for ten forest types in all parts of the world. Summarizing these monetary estimates for each forest ecosystem service and forest type in a common set of units, such as international dollars per hectare per year, shows that there is now quite a lot of information on the economic value of some FES (e.g. food provisioning, air quality regulation, recreation) and some forest types (e.g. mangroves, tropical forests, temperate forests). The economic value of some FES is high, reaching annual values of more than USD 100 000 per hectare. Variation in the values of FES across forest types is also high, which might reflect differences in functions, conditions and socioeconomic contexts. Gaps remain in terms of the limited available information for some FES and some forest types, which can be filled through additional targeted investments in primary valuation studies.

Information on the economic values of FES from the ESVD can be used in several forest policy and management contexts to inform decisions promoting green recovery, including impact assessments, appraising green investments, price setting and sustainable financing, and natural capital accounting. Such information on the economic value of forests can support policymaking and can help to build the case for investments in forest conservation, restoration and afforestation and related economic development projects.

Our results highlight the need to look beyond narrow market values and to take the economic value of ecosystems into account. This not only makes for better informed decisions, it can also potentially provide many opportunities for innovative financing instruments and business opportunities. As illustrated by examples at the country- and local-levels in this paper, the ESVD provides a basis for conducting value transfers to inform forest policy and management decisions in a relatively low-cost and timely way, and it provides a way to take the economic value of nature into account in decision-making.

The following are the key observations made as part of the present work:

1. The economic value of some FES is high, reaching annual values of more than USD 100 000 per hectare. When adding the values of different FES across forest types, the highest annual estimates are attributed to urban parks and forests (401 746 international dollars per hectare) and mangroves (217 104 international dollars per hectare).
2. Although there is now quite a lot of information on the economic value of some FES (e.g. food provisioning, air quality regulation, recreation) and some forest types (e.g. mangroves, tropical forests, temperate forests), gaps remain for some other FES (e.g. regulation of water flows, biological control) and forest types (e.g. forested peatlands and wetlands). Such gaps can be filled through targeted investment in primary valuation studies.
3. Closer collaboration with the business community and with local and national governments as well as international organizations is needed to facilitate the dissemination of FES valuation estimates. This will further help to, first collect good practices on the integration of FES values in decision-making (which is critical to improving the adoption of valuation in public and private strategies, and investment decisions) and second, provide examples of how to use value information.

1. Introduction

Forests are an important component of our natural capital and deliver a broad range of ecosystem services that underpin human well-being (Dasgupta, 2021). Forests and forest-related biomes, ranging from mangroves to high mountain forest, cover approximately 30 percent of the terrestrial environment and provide habitat for the vast majority of terrestrial plant and animal species (Lawton *et al*., 1998).

In addition to this crucial habitat service, forests also provide a wide range of other benefits to humans including directly extracted resources such as wood and food (provisioning services), regulation of environmental processes such as water flows and carbon storage (regulating services) and non-material benefits that people obtain through spiritual enrichment, recreation and aesthetic experiences (cultural services) (Brander *et al*., 2012a; de Beenhouwer, Aerts and Honnay, 2013; Taye *et al*., 2021). Forests can also contribute to human physical and mental health as a component of our living environment (WHO, 2016; Bratman *et al*., 2019; UN Habitat, 2020; Saraev *et al*., 2021).

The extent and condition of forests in many parts of the world, however, have declined dramatically over the past few decades due to conversion to agriculture, unsustainable timber harvesting, forest fires and urbanization (FAO and UNEP, 2020). As the stock of this natural capital has been depleted, the supply of forest ecosystem services (FES) has also declined (Felipe-Lucia *et al*., 2018). At the same time, the demand for FES and recognition of their importance continues to grow, particularly in relation to climate change mitigation and adaptation. Forests can potentially play a major role in capturing and storing carbon dioxide from the atmosphere and in mitigating the impacts of droughts, floods and extreme temperatures (Canadell and Raupach, 2008; Grassi *et al*., 2017; Chow, 2018).

Given the current global environmental challenges, investment in forests and trees could potentially provide solutions, but making the best investments requires an understanding of the potential returns from alternative options. There is a need for information on the benefits of forest ecosystem services across the different biomes to guide decision-making on how to better harness their potential to support the green recovery.

This compilation of systematically reviewed and standardized economic values of FES is contained in the Ecosystem Services Valuation Database (ESVD), which is a global collection of economic value data with details on the type of ecosystem, ecosystem services, location, valuation method and beneficiaries (Brander *et al*., 2021a). The ESVD was updated in 2021 with a focus on forest ecosystem services as a contribution to the Food and Agriculture Organization of the United Nations (FAO) assessment of the potential for forests to support a green recovery, and the results were reported in The State of the World's Forests 2022 (SOFO 2022). The ESVD currently contains more than 2700 value records for FES for ten forest types in all parts of the world. This paper is structured as follows: Section 2 sets out the conceptual framework underlying the ESVD; Section 3 provides an overview and a summary of values for forest ecosystem services; Section 4 outlines how this information can be used to inform decision-making; and Section 5 provides conclusions.

2. Conceptual framework

The conceptual framework underlying the ESVD draws on both the ecosystem services approach (MA, 2005; TEEB, 2010) and the concept of total economic value (TEV) (Pearce and Turner, 1990). This framework builds on the conceptualization of nature as a productive asset (natural capital) which provides humanity with a flow of inputs into production and consumption (Dasgupta, 2021), but also recognizes that these inputs (benefits) should be seen as additional information in decision making and not as replacing the intrinsic value of nature.

2.1. ECOSYSTEM SERVICES

The concept of ecosystem services has been defined in numerous different ways but in general it is agreed that ecosystem services are the direct and indirect contributions of ecosystems to human well-being, and that ecosystem services comprise the following main categories:[1]

- *Provisioning services* are the products or resources that can be harvested or extracted from ecosystems (e.g. food and raw materials).
- *Regulating services* are the benefits obtained from ecosystem processes that maintain environmental conditions beneficial to individuals and society (e.g. climate regulation, air quality, flood protection, biological control).
- *Cultural services* are the experiential and intangible benefits related to the perceived or actual qualities of ecosystems (e.g. spiritual enrichment, cognitive development, recreation, aesthetic enjoyment, and the appreciation of the existence of diverse habitats and species).

[1] Here we use the definitions developed in the TEEB initiative. Recent classifications, including the Common International Classification of Ecosystem Services (CICES) and the System of Environmental Economic Accounting – Ecosystem Accounting (SEEA–EA) reference list, use these three main categories. The Millennium Ecosystem Assessment included a fourth category, Supporting Services, to highlight the importance of maintaining basic ecological processes. Examples include photosynthesis, nutrient cycling, soil formation and primary production. Similarly, the classification developed by the TEEB study included a fourth category, Habitat Services, defined as the benefits provided by protecting a minimum area of natural ecosystems to allow the proper functioning of evolutionary processes needed to maintain a healthy gene pool, and by providing essential habitats in the life cycle of migratory species, many of which have commercial value elsewhere.

As with the concept of ecosystem services, there are also many alternative classifications, including those of Costanza *et al.* (1997), Daily (1997), MA (2005), TEEB (2010), Haines-Young and Potschin (2012, 2018), Landers and Nahlik (2013), US EPA (2015), Diaz *et al.* (2018), and most recently UNSD (2021). These classification systems share many similarities but also reflect different perspectives and purposes. The main points of variation are in terms of inclusion or exclusion of abiotic services, intermediate services, non-use values, disservices, overlapping categories, hierarchies and the identification of beneficiaries. The applicability of each classification system is dependent upon the specific biophysical, socioeconomic and decision-making context in which it is applied. Any ecosystem service assessments may apply or further, and justifiably, adapt a classification system to suit their specific needs.

2.2. ECONOMIC VALUE

Economic value is a measure of the welfare that individuals and societies gain from the production and consumption of goods and services. It is the quantified net benefit that people derive from a good or service, whether there is a market and monetary transaction for the good or service or not. Economic valuation is one way to quantify and communicate the importance of something (e.g. environmental damage, changes in resource availability, ecosystem services) to decision makers, and it can be used in combination with other forms of information (e.g. biophysical indicators and social impacts). The comparative advantage of economic valuation is that it conveys the importance of environmental change directly in terms of human welfare and uses a common unit of account (i.e. money) so that values can be directly compared across other goods, services, investments and impacts in the economy.

The economic value of ecosystem services can be usefully framed by the concept of TEV, which describes the comprehensive set of utilitarian values derived from a natural resource (Pearce and Turner, 1990). It is useful for identifying the different types of value that may be derived from an ecosystem.

Economic value is distinct from economic activity (also known as financial or exchange value), which is generally a measure of cash flows and can be observed in markets. While economic activity from market transactions is often used to calculate economic value, economic activity is not in and of itself a measure of human benefit. The system of national accounts (SNA) that is used to calculate gross domestic product (GDP) and other economic statistics uses the concept exchange value. For national accounting purposes, this approach to valuation enables a consistent and convenient recording of transactions between economic units since the values for supply and use of products are the same. In the context of natural capital accounting under the System of Environmental Economic Accounting – Ecosystem Accounting

(SEEA–EA) (see Section 4.5), which is consistent with the SNA, it is necessary to value the flow of ecosystem services at the market prices that would have occurred if the services had been freely traded and exchanged. That is, it is necessary to measure exchange value and not welfare value. Annex 1 provides a more extensive explanation of value concepts.

3. Ecosystem services valuation database

Over the past 40 years, researchers have made a considerable effort to estimate the economic value of ecosystem services provided by all forms of natural capital (MA, 2005; TEEB, 2010; IPBES, 2018). The ESVD provides a global collection of the results of economic valuation studies with details on the type of ecosystem, ecosystem services, location, valuation method and beneficiaries (Brander *et al.*, 2021a).[2]

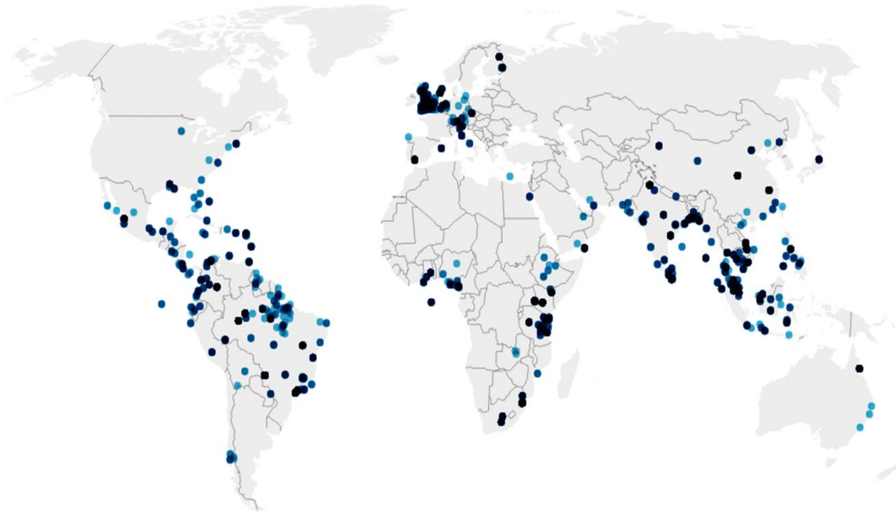
For SOFO 2022, 916 additional forest values were included in the ESVD, for a total of 2 746 value estimates. These data are from studies spanning the time period 1973–2021. The data update was targeted at forest biomes and ecosystems that had relatively few value estimates (i.e. forested wetlands, forested peatlands, plantations, orchards/agroforestry, high mountain forest, woodland and shrubland, and urban parks and forests). This update of the ESVD for SOFO 2022 added substantially to the amount of data on forested peatlands and forested wetlands; specifically, the added data comprises 89 and 81 percent respectively of the value estimates for these forest types in the ESVD.

3.1. DATABASE

The ESVD now contains 2 746 unique value records from FES for ten forest types in all parts of the world. The forest types classified in the ESVD are Mangroves, Peatland, Forested wetland, Forested tropical forests, Temperate forests, Woodland and shrublands, High mountain and polar forests, Plantations, Orchards/agro-forestry, and Urban parks and forests. Figure 1 represents the locations of forest valuation study sites. Figure 2 through Figure 5 represent the number of FES estimates by continent, forest type, ecosystem service and valuation method.

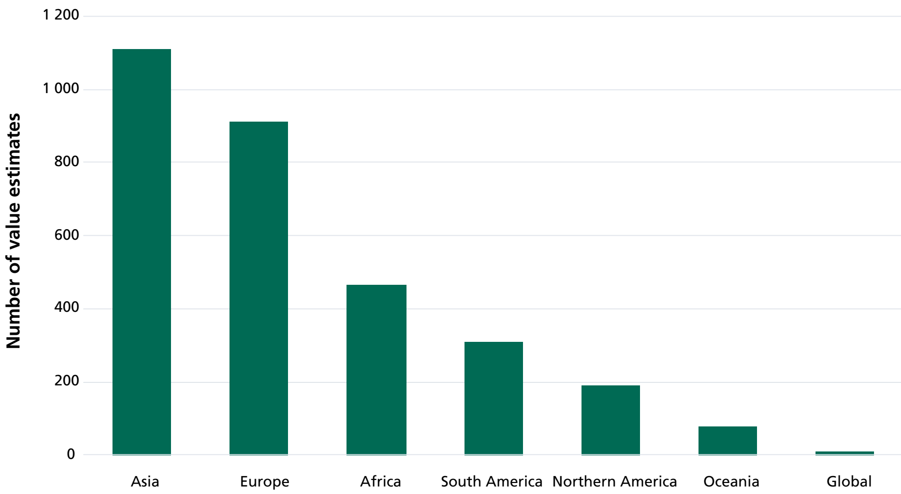
[2] The ESVD was originally developed under the TEEB initiative in 2010. It has since been hosted, maintained and developed by the Ecosystem Services Partnership (www.es-partnership.org), the Foundation for Sustainable Development (www.fsd.nl) and Brander Environmental Economics (http://lukebrander.com). The ESVD is free to access at www.esvd.info

Figure 1 Locations of forest valuation study sites included in the ESVD. Colour depth indicates the number of value estimates.



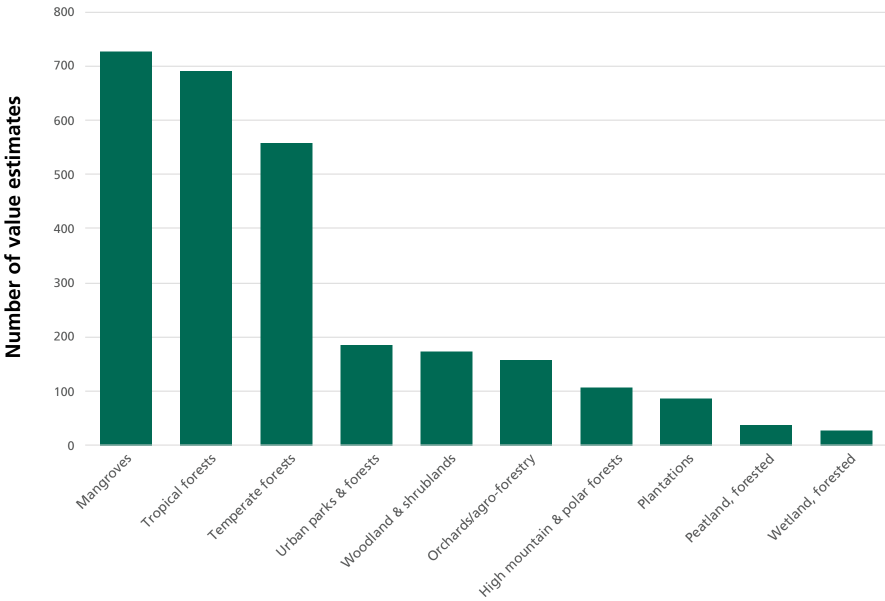
Source: Authors' own elaboration (map adapted to Map No. 4170 Rev. 19 UNITED NATIONS October 2020)

Figure 2 Number of forest ecosystem services (FES) value estimates by continent



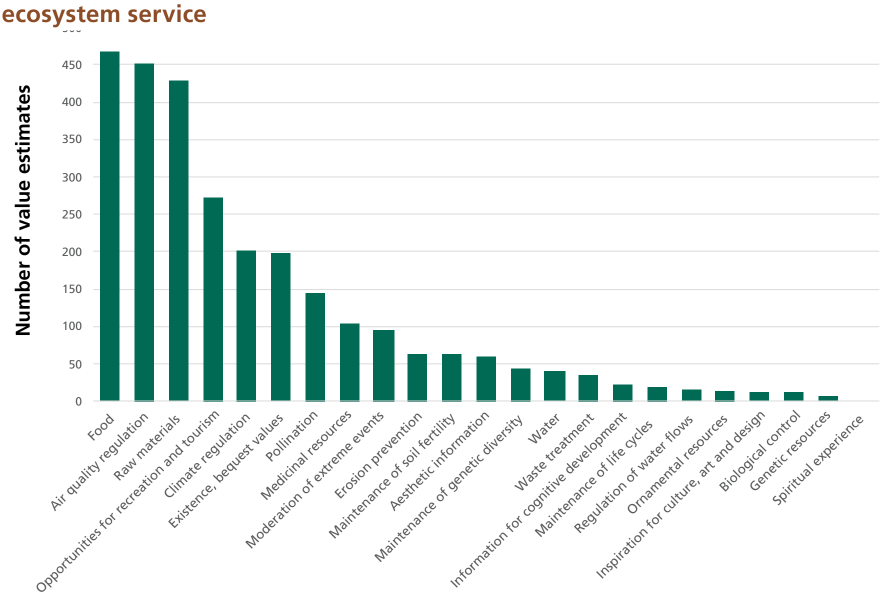
Source: Adapted from FSD. 2021. Ecosystem Services Valuation Database 1.0 (ESVD). In: ESVD. [Cited 1 September 2021]. www.esvd.net

Figure 3 Number of forest ecosystem services (FES) value estimates by forest type



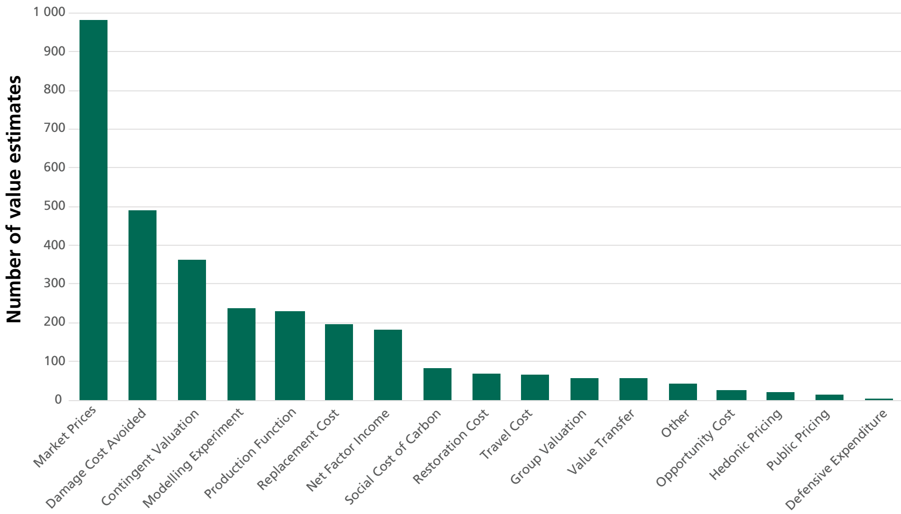
Source: Adapted from FSD. 2021. Ecosystem Services Valuation Database 1.0 (ESVD). In: ESVD. [Cited 1 September 2021]. www.esvd.net

Figure 4 Number of forest ecosystem services (FES) value estimates by ecosystem service



*Source:*Adapted from FSD. 2021. Ecosystem Services Valuation Database 1.0 (ESVD). In: ESVD. [Cited 1 September 2021]. www.esvd.net

Figure 5 Number of forest ecosystem services (FES) value estimates by valuation method



Source: Adapted from FSD. 2021. Ecosystem Services Valuation Database 1.0 (ESVD). In: ESVD. [Cited 1 September 2021]. www.esvd.net

To enable comparisons and summaries of the forest value data, recorded values have been standardized to a common set of units: "international dollars" per hectare per year at 2020 prices levels.[3] The standardization process involves five steps, addressing the following five dimensions: price level, currency, spatial unit, temporal unit and beneficiary unit. Details on the standardization methods can be found in Brander *et al*. (2021b). This standardization process ensures that values are expressed in the same measurement unit but does not adjust for biophysical or socioeconomic influences that might affect the value. It should also be noted that it is not possible to standardize all valuation results to this common set of units primarily because of missing data (e.g. on the total number of beneficiaries of a forest ecosystem service) or the incompatibility of spatial units (e.g. linear features such as avenues of trees cannot be meaningfully converted into hectares). Values that cannot be standardized are kept in the database since the information recorded in the originally reported units is still potentially useful.

3.2. FOREST VALUATION RESULTS

Table 1 provides an overview of the average monetary value per service for each forest ecosystem/biome. FES are defined using the 23 ecosystem service types in the TEEB classification. The value estimates summarized in Table 1 are for single ecosystem services and single biomes, i.e. value estimates for bundles of services and/or multiple biomes are excluded from the summary. We also excluded values

[3] International dollar is a hypothetical currency that has the same purchasing power parity as the US dollar in the United States of America at a specified point in time. Conversion of other currencies to international dollars involves adjusting for differences in prices levels (purchasing power) across countries.

derived through value or benefit transfer (the secondary use of valuation results from other study sites), outliers (outside 1.5 times the interquartile range of log of transformed values) and a small number of estimates that were considered to be non-representative of the biome-ecosystem service combination. Note that an empty cell in the table does not necessarily mean that the forest type does not provide that ecosystem service, but rather that no value records were available to calculate an average value. In a small number of cases, the summary values are based on a very limited number of available estimates and should be treated with caution. In general however, these values do not form a large proportion of the total economic value for any biome and so do not have a disproportionately large influence on the total values.

Table 1 shows that there is high variation in the values of FES across forest types, with very high values for some FES. When adding the different FES across forest types, the highest values are by far attributed to urban parks and forests (401 746 international dollars/ha/year) and mangroves (217 104 international dollars/ha/year). Urban parks and forests have high mean values for air quality regulation and recreation; mangroves have high mean values for the provision of food (by supporting adjacent fisheries) and raw materials, and for moderation of extreme events (by mitigating coastal flooding). Other biomes with high mean values (above 10 000 international dollars/ha/year) are plantations for provision of raw materials and wood, and shrubland for provision of food. Tropical forests have lower mean values when compared to the forest types previously mentioned, with highest values of tropical forests being attributed to medicinal resources (2 328 international dollars/ha/year), climate regulation by sequestering and storing carbon (1 812 international dollars/ha/year), provision of raw materials (1 773 international dollars/ha/year) and pollination (1 094 international dollars/ha/year).

The estimates also provide indicative information on the relative importance of different FES categories within each forest biome. For instance, provisioning and regulating ecosystem services provided by tropical forests are of approximately equal value: 47.3 percent and 49.3 percent of total value respectively (see Table 2). In contrast, regulating and cultural services from temperate forests are of similar importance: 42.6 percent and 44 percent of total value, with regulation of water flows and opportunities for recreation and tourism presenting the highest values, 6 084 and 4 972 international dollars/ha/year, respectively. High mountain forests are overwhelmingly recognized for their regulating services, which account for 86.9 percent of their attributed value.

The number of value estimates by forest type and by forest ecosystem service also merits discussion as they are an indication of research gaps. Mangroves, tropical forests and temperate forests are by far the forest biomes with the highest number of value estimates, individually exceeding 500 entries, while all other forest biomes individually have fewer than 200 entries (Figure 3). Considering the potential importance of sustainable agroforestry and plantations for delivering regulating ecosystem services (Kuyah *et al.*, 2017), the low number of value estimates for these forest types indicate an important research gap.

TABLE 1

Mean values per ecosystem service/biome combination and number of value estimates in parentheses (international dollars per hectare per year, 2020 price level; outlier exclusion inter–quartile range (IQR) 1.5 of log of transformed values)

Ecosystem services/ Biomes	High mountain forest	Mangroves	Orchards/ agroforestry	Peatland, forested	Plantations	Temperate forests	Tropical forests	Urban parks and forests	Wetlands, forested (on alluvial soils)	Woodland and shrubland
Food	229 (15)	13 071 (189)	697 (11)			2 287 (7)	194 (46)		259 (1)	10 710 (3)
Water	94 (2)					175 (8)	82 (3)			96 (3)
Raw materials	264 (23)	14 593 (110)	222 (23)		14 407 (21)	364 (30)	1 733 (34)	419 (1)	25 (3)	8 372 (14)
Genetic resources				60 (4)			16 (1)			
Medicinal resources	31 (1)				9 (2)		2 328 (29)			2 (1)
Ornamental resources	12 (1)						1 (1)			280 (1)
Air quality regulation	1 927 (1)	1 323 (2)	1 867 (4)		4 076 (3)	1 617 (306)	515 (3)			1 664 (3)
Climate regulation	1 699 (7)	5 998 (38)	1 239 (7)		57 (1)	761 (28)	1 812 (17)	479 (1)		828 (6)
Moderation of extreme events	419 (2)	96 550 (33)				39 (2)	177 (12)			49 (2)
Regulation of water flows		3 (1)				6 084 (4)	682 (3)			115 (1)
Waste treatment		3 756 (16)				270 (4)	12 (2)		144 (1)	
Erosion prevention	165 (1)	8 475 (17)	64 (4)			116 (8)	181 (7)			420 (4)

Ecosystem services/ Biomes	High mountain forest	Mangroves	Orchards/ agroforestry	Peatland, forested	Plantations	Temperate forests	Tropical forests	Urban parks and forests	Wetlands, forested (on alluvial soils)	Woodland and shrubland
Maintenance of soil fertility		1 062 (5)			106 (34)	43 (7)	13 (4)			
Pollination							1 094 (4)			
Biological control			840 (8)				14 (1)			
Maintenance of life cycles		4 624 (9)					19 (1)			
Maintenance of genetic diversity		7 373 (9)					13 (2)			
Aesthetic information		334 (1)	185 (1)			35 (1)		119 751 (4)		38 (2)
Opportunities for recreation and tourism	5 (6)	28 796 (54)				4 972 (14)	71 (14)	279 595 (8)		124 (1)
Existence, bequest values		15 689 (15)		60 (8)		1 391 (13)	226 (17)	1 502 (6)		2 (1)
Inspiration for culture, art and design		3 890 (1)					4 (2)			214 (6)
Spiritual experience										
Information for cognitive development		11 567 (4)				2 827 (6)	14 (1)			214 (1)
Total	4 845 (59)	217 104 (504)	5 114 (59)	120 (12)	18 655 (61)	20 981 (438)	9 201 (204)	401 746 (20)	428 (5)	23 128 (49)

Source: Adapted from FSD. 2021. Ecosystem Services Valuation Database 1.0 (ESVD). In: ESVD. [Cited 1 September 2021]. www.esvd.net

Notes: The summary values reported in this table are intended for illustration and to identify data gaps. These summary statistics reflect the underlying ecological and socioeconomic contexts of diverse, but not necessarily globally representative, study sites. For the purposes of value transfer, users are advised to select value estimates from the ESVD that match the characteristics of their policy site(s) since FES values are highly context dependent.

To reduce the effect of outliers on estimated mean values, we exclude value estimates that fall outside 1.5 of the inter–quantile range of the log–transformed values in each FES-biome subset.

The colour code indicates provisioning services (blue), regulating services (green) and cultural services (yellow).

TABLE 2

Estimated mean values of ecosystem service categories by biome, in percentage of total value

Ecosystem service categories/ Biomes	High mountain forest	Mangroves	Orchards/ agroforestry	Peatland, forested	Plantations	Temperate forests	Tropical forests	Urban parks and forests	Wetlands, forested (on alluvial soils)	Woodland and shrubland
Provisioning	13.0	12.7	18.0	50.0	77.3	13.5	47.3	0.1	66.4	84.1
Regulating	86.9	59.5	78.4	0.0	22.7	42.6	49.3	0.1	33.6	13.3
Cultural	0.1	26.2	3.6	50.0	0.0	44.0	3.4	99.8	0.0	2.6

Source: Adapted from FSD. 2021. Ecosystem Services Valuation Database 1.0 (ESVD). In: ESVD. [Cited 1 September 2021]. www.esvd.net

Note: Mean values of ecosystem services were grouped from Table 1 in this table according to the three categories of ecosystem services used by SEEA: provisioning (blue), regulating (green) and cultural (yellow).

3.3. LIMITATIONS

The data included in the ESVD and underlying the summary table are carefully screened, coded and reviewed to ensure robustness. Nevertheless, several caveats and limitations should be kept in mind when using these data.

1) Limited value data for some biomes and ecosystem services

Although ESVD now contains more than 6 500 unique value records, of which 2 746 are on forests, there remain gaps or limited information for some biomes and ecosystem services. Table 1 includes information on the number of value estimates underlying each summary value. For some forest types and ecosystem services, there are many data but for others there are few or no value estimates available. Mean values (in Table 1) for a given combination of forest type and ecosystem services that are based on few value estimates may be less robust than mean values that can rely on a much broader empirical basis of values. Furthermore, due to missing values for some FES, the total values computed for each forest type in Table 1 are likely to be underestimated and will increase as more data become available and the gaps can be filled.

2) Language

The ESVD predominantly contains results from studies published in English. Effort has been made to include studies in other languages but the bias towards English language publications is likely to have consequences for the representation of data from countries that publish in other languages.

3) Representativeness

The ESVD is a global database containing value observations for all biomes and all ecosystem services. In the most recent update for SOFO 2022, we have focused on adding data on forest ecosystem services and increasing the representation of regions with relatively little data. The data are not, however, globally representative and the current sample of values reflects the availability of valuation studies, the interests of funding organizations and the thematic expertise of the researchers involved. As such, the summary values cannot be treated as representative of each biome–ecosystem service combination. Indeed, it is not possible for a single unit value to represent an entire biome given the natural variation in supply and demand for ecosystem services across locations.

4) Methodological and quality variation

The ESVD contains values derived from a wide variety of valuation methods (see Figure 5) that estimate various value concepts, including exchange values, consumer surplus, producer surplus, cost–based proxies of welfare values and others. The consistency across different value concepts is limited. Moreover, the robustness with which valuation methods are applied varies greatly across studies, which has consequences for the quality of the data. Defining a consistent measure of the quality of data from diverse valuation methods is challenging and currently the ESVD does not contain such a measure.

5) Some records have not yet been externally reviewed

The data contained in the ESVD is subject to an ongoing review process by invited expert reviewers. Over the course of the most recent update, the proportion of value records that have been reviewed has greatly increased and 57 percent of forest value data have been reviewed. The review status of each value record is indicated in the database and will be updated as the review process continues.

6) Sustainable use

The value estimates included in the ESVD pertain to levels of use of forests that may or may not be sustainable. The individual study contexts from which value data are obtained represent a spectrum of use intensities, including those that exceed sustainable levels. The summary values therefore represent an *average* of use intensity across study sites and do not necessarily represent sustainable use.

7) Trade-offs between ecosystem services

In computing total values from each forest type (Table 1), we assume that all FES can be supplied and used simultaneously. In practice, there are likely to be trade-offs between some FES. In many cases, the level of sustainable activity for one ecosystem service may not be compatible with the sustainable level of another. For instance, there is a likely trade-off between harvesting timber and use for recreational activities. Such trade-offs introduce further complexity to any analysis, since it becomes necessary to consider how the use of one ecosystem service affects other potential uses and values. This has not been possible in the computation of the summary values presented here.

8) Average and marginal values

The ESVD contains data on the value of the annual flow of FES (average values) as well as data on *changes* in the annual value of FES (marginal values). Changes in annual values are typically due to a change in ecosystem extent, condition, or both. Average and marginal values have been summarized jointly, but it should be noted that the ESVD contains information to distinguish between the two.

9) Need for meta-regression analysis

Accounting for location-specific differences in biophysical, socioeconomic and cultural conditions, and for methodological differences across studies, may allow for more robust value transfer.

4. Using forest ecosystem service values to support the green recovery

Information on the economic value of ecosystem services can be useful in many policy and decision-making contexts to support the green recovery. The purpose of this section is first to explain in general terms how information from the ESVD can inform decision-making, and then to provide examples of applications on: impact assessment, appraisal of green investments, price setting and sustainable financing, and natural capital accounting.

4.1. VALUE TRANSFER TO INFORM DECISION-MAKING

Value transfer is the use of research results from existing primary studies at one or more sites or policy contexts (study sites) to predict welfare estimates or related information for other sites or policy contexts (policy sites). Value transfer can be used to inform decisions regarding impacts on ecosystems that are of current interest and for which new primary valuation research would be time-consuming and expensive. Even in cases where some primary valuation research is available for the ecosystem of interest, it is often necessary to extrapolate or scale up this information to a larger area or to multiple ecosystems in the region or country (also referred to as ecosystem services value mapping). Primary valuation studies tend to be conducted for specific ecosystems at a local scale whereas the information required for decision-making, including natural capital accounting, is often needed at a regional or national scale. Value transfer, therefore, provides a means to obtain information for the scale that is required.

Value transfer can be used potentially to estimate values for any ecosystem service, provided that there are primary valuations of that ecosystem service from which to transfer values. Value transfer methods have been employed widely in national and global ecosystem assessments, value mapping applications and policy appraisals. The use of value transfer is widespread but requires careful application (Brander, 2013). Please see Annex 1 for alternative methods of conducting value transfer.

Box 1 provides an example application of meta-analytic value transfer to estimate the economic value of mangrove ecosystem services in southeastern Asia.

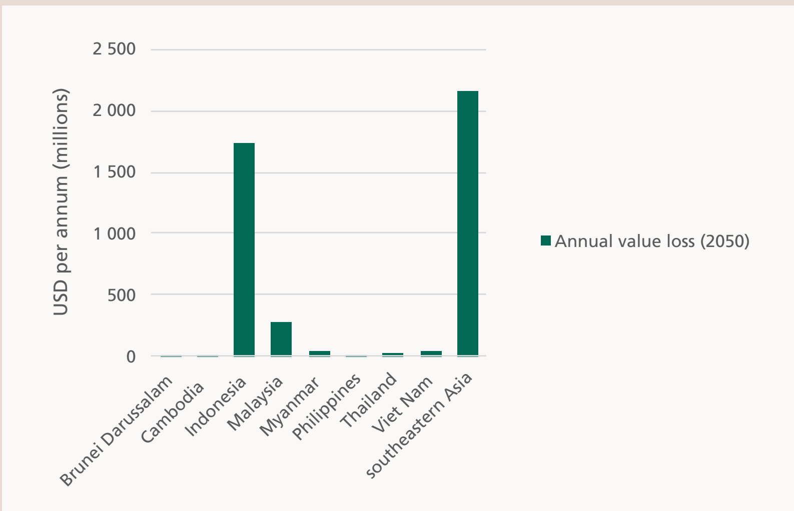
Box 1
Value of mangroves in southeastern Asia

Data contained in the ESVD has been used to estimate the value of ecosystem services provided by mangroves in southeastern Asia for the period 2000–2050.

Brander *et al.* (2012a) applies a meta-analytic value transfer approach using 48 studies to obtain 130 value estimates of mangrove ecosystem services from across the world. The ecosystem services represented in the collected studies include both provisioning and regulating services. These data are used in a meta-regression analysis to estimate a function that relates the value per hectare of mangrove to its biophysical characteristics (size, fragmentation, scarcity) and socioeconomic context (population and income). This function is then combined with spatial data on individual mangrove ecosystems in southeastern Asia to produce site specific values, which are aggregated to the country level.

Brander *et al.* (2012a) uses this approach to estimate the annual value of declining mangrove area and lost ecosystem services in southeastern Asia for the period 2000–2050. The study estimates the lost annual value to be approximately USD 2.16 billion in 2050 (2007 prices), with a 95 percent prediction interval of USD 1.58 – 2.76 billion. The figure shows the values of foregone mangrove ecosystem services aggregated to the country level.

Figure: Value of foregone mangrove ecosystem services in 2050



Source: Authors' own elaboration based on Brander, L.M., Bräuer, I., Gerdes, H., Ghermandi, A., Kuik, O., Markandya, A., Navrud, S. et al. 2012b. Using meta-analysis and GIS for value transfer and scaling up: Valuing climate change induced losses of European wetlands. Environmental and Resource Economics, 52(3): 395–413. https://doi.org/10.1007/s10640-011-9535-1

4.2. IMPACT ASSESSMENT

Policies and investments can have both positive and negative impacts on the extent and condition of natural capital and flow of ecosystem services. Regarding forest biomes, a land use change in the form of converting forests to agriculture or plantation has major impacts on FES, but many other decisions or investments have impacts on forests including mining, urban development, transport infrastructure and protection status. Information on the full economic impact of investment decisions, including on non-market FES is necessary for guiding those decisions, regulating activities, and setting compensation for unmitigated impacts.

Quantifying changes in the economic value of FES is also useful for understanding the distribution of impacts across different groups in society. The distribution of impacts (costs and benefits) has both practical and ethical consequences. In practical terms, it is important to assess the burden of costs and benefits received by local stakeholders, as they often have a strong influence on the success of an investment implementation. For example, it is often the case when establishing protected areas that it will not be possible to prevent local stakeholders from accessing an environmental resource unless the benefits of conservation have first been shared with them. Understanding who gains and who loses from each policy and investment option can provide important insights into the incentives that different groups have to support or oppose each project. This approach can provide useful information for designing appropriate responses and increasing the success of implementing projects and plans.

In terms of ethical considerations, the analysis of the distribution of costs and benefits is important to ensure that environmental management does not harm vulnerable groups within society. Identifying and estimating the distribution of costs and benefits across different groups is the first step in designing measures to avoid a disproportionate or undesirable allocation of impacts, compensation mechanisms or payment schemes between those who gain and those who lose. Box 2 provides an example application of ESVD data to assess the economic impact of land use change in North Sumatra and Aceh, Indonesia.

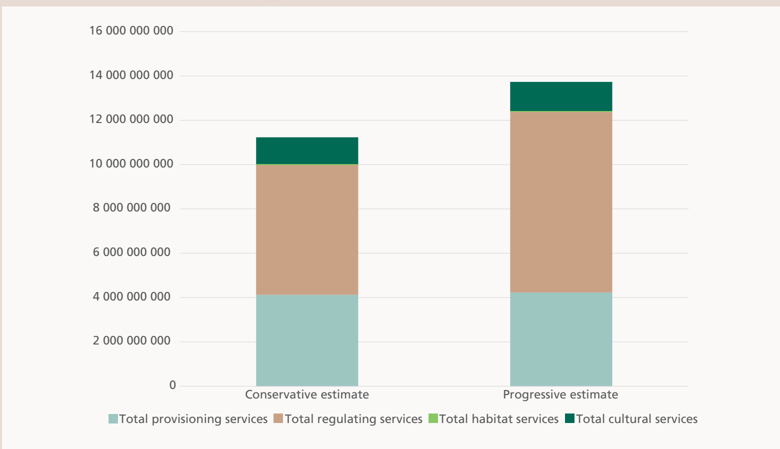
Box 2
Deforestation in North Sumatra and Aceh, assessed by the Satelligence company using the ESVD to value the loss of services and the value of the maintained forest areas

FSD (2021b) provides an example of how the ESVD can be used within an impact assessment of land use change. The study was conducted on behalf of a financial institution to examine changes in land use in Aceh and North-Sumatra over the last 20 years. The goal of this impact assessment was to estimate the benefits and losses of ecosystem services in monetary terms as a result of a land-use change.

Data from the ESVD on the value of ecosystem services provided by different land-use classes in Indonesia were used to estimate the values of original and converted ecosystems. Standardized values were multiplied by the area of the original and converted ecosystems to obtain the total economic value under alternative land-use scenarios. The results reveal that there are substantial benefits flowing from the remaining forested areas towards society, in the order of USD 10 billion per year (see the figure). These are direct benefits such as the provisioning of food or recreational use as well as indirect benefits such as erosion prevention.

In addition, the comparison of land-use scenarios shows that it is not beneficial to convert forests to other land uses, with a negative monetary value ranging from USD 48 million to almost USD 200 million per year. At a site-specific level, it can be beneficial to convert forests into rice plantations, but the analysis highlights that this is only the case when provisioning ecosystem services only are considered.

Figure: Total economic value in USD million/year for entire remaining forested areas (3 211 319 ha), including mangroves (3 928 ha), tropical forests (3 079 883 ha) and peat forests (127 507 ha)



Source: FSD (Foundation for Sustainable Development). 2021b. Make nature count. Aligning satellite data and ecosystem services valuation for better insights. Report for the Dutch Enterprise Agency (RvO).

4.3. APPRAISAL OF GREEN INVESTMENTS

Making decisions between alternative investments, projects or policies that affect the provision of ecosystem services often involves weighing and comparing multiple costs and benefits that are measured in different metrics and are incurred at different locations and points in time. For example, establishing a new protected area might involve costs in terms of purchasing land, compensating local communities, ongoing maintenance and enforcement costs, as well as benefits in terms of biodiversity conservation, recreational use and enhanced fish stocks. These costs and benefits are likely to be measured in different units, be incurred at different locations by different groups of stakeholders and have different time profiles. Organizing, comparing and aggregating information on such a complex array of impacts, and subsequently choosing between alternative options with different impact profiles, requires a structured approach. Economic methods for assessment, evaluation or appraisal of complex decision contexts provide systems for structuring the information and factors that are relevant to a decision.

There are many economic assessment methods available to help decision-makers to structure the information and there are factors that are relevant to a decision and a selection among alternative investments, projects or policies. The choice of which assessment method to use will largely be determined by the type of decision problem and the availability and nature of information related to each potential option. One of the most widely applied economic assessment methods is cost–benefit analysis (CBA), which involves summing up the value of the costs and benefits of each option and comparing options in terms of their net benefits (i.e. the extent to which benefits exceed costs). However, conventional CBA is focussed on market values and ignores most of the so-called externalities (positive and negative) of many ecosystem services, notably the regulating services. Box 3 provides an example of an integrated CBA (iCBA) of landscape restoration options, using ESVD data. Chapter 3.2 of FAO (2022) provides a review of CBA of landscape restoration.

4.4. PRICE SETTING AND GREEN FINANCING

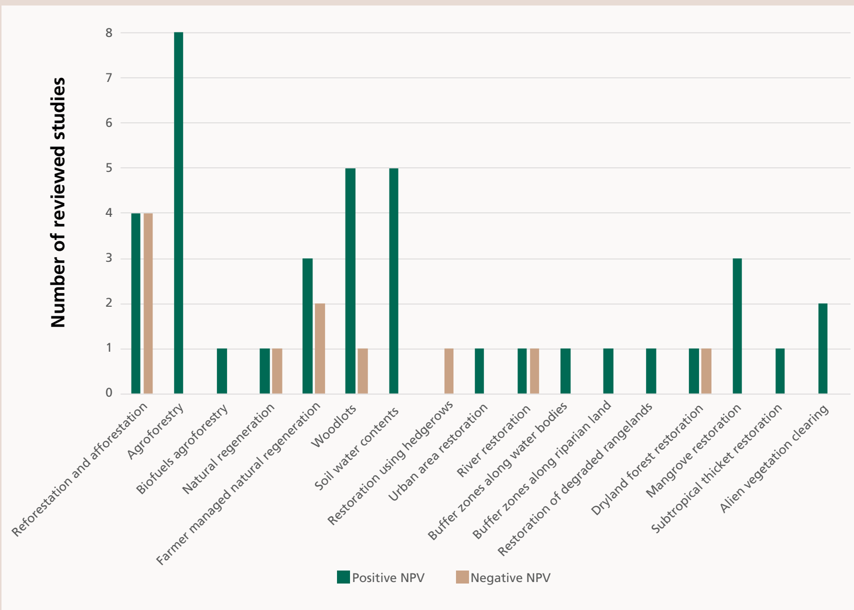
Sustainable financing mechanisms include a wide range of approaches for raising long-term funding flows for environmental management, as opposed to conventional donor- or project-financing that is usually time limited. Sustainable financing mechanisms include conservation trust funds, debt for nature swaps, green bonds and payment for ecosystem services (PES). PES covers a broad set of mechanisms through which incentives for the provision of ecosystem services are established. In a PES scheme, providers of an ecosystem service (e.g. upstream farmers who conserve forests that control water flow) are given some form of payment or compensation. The latter may be paid by the beneficiaries of the service (e.g. downstream farmers

Box 3
Overview of an integrated cost–benefit analysis of landscape restoration

The ESVD provides value estimates that can be included in economic evaluations of landscape restoration. This case is about the systematic review of cost–benefit analysis for different types of landscape restoration options and strategies. Wainaina *et al.* (2020) examines the extent and coverage of existing studies, as well as gaps, to help prioritize the investment of scarce resources.

This systematic review included 31 publications that were either entirely focused on cost–benefit analysis of landscape restoration or were included as a component of it. The publications included in the review detailed research that was conducted in about 20 countries distributed across five regions. Wainaina *et al.* (2020) uses the value estimates provided in the ESVD as a source of information to assess the benefits of landscape restoration. The figure presents reported net present value (NPV) – positive or negative – by various iCBA studies for different landscape restoration options.

Figure: Reported net present value (NPV) for various landscape restoration types, weighted by the number of reviewed cost–benefit analysis studies



Source: Wainaina, P., Minang, P.A., Gituku, E. & Duguma, L. 2020. Cost-benefit analysis of landscape restoration: a stocktake. Land, 9(11), 465. https://doi.org/10.3390/land9110465 who benefit from lower exposure to flooding) to incentivize the providers. PES schemes attempt to provide incentives for the continued or enhanced provision of services and to address the commonly observed problem that markets do not exist for ecosystem services (Wunder, 2015; Engel, Pagiola and Wunder, 2008). Creating a system of incentives is crucially important since the provider of an ecosystem service may otherwise be better off using the ecosystem resource in another way (e.g. an upstream farmer might convert forest area to agricultural land).

One of the main attractions of PES as a policy instrument is that it can, in principle, be self-financing in the case that payments by beneficiaries cover all associated costs (transaction costs as well as opportunity costs of the provider of the ecosystem services). A further attraction of this policy instrument is that it can, in principle, result in an efficient allocation of resources. The observed disadvantages of this policy instrument are: possible *windfall profits* where ecosystem service providers may be compensated for services that they provide anyway; the high transaction costs involved in establishing and operating a PES scheme; the institutional requirements for setting, collecting and disbursing payments; and the information requirements to monitor the activities of participants. Box 4 provides an example application of information from the ESVD to inform price setting in a PES scheme.

4.5. NATURAL CAPITAL ACCOUNTING

Natural capital is the stock of renewable (e.g. forests, fish, water) and non-renewable resources (e.g. minerals, aggregate, natural gas) resources that can be used to yield a flow of benefits to people. The benefits provided by natural capital may be used in combination with other forms of capital (e.g. financial, manufactured, social and human capital) to produce goods and services for consumption.

Natural capital accounting frameworks aim to provide a structured way of measuring the economic significance of nature that is consistent with existing macroeconomic accounts. They can help to identify trends and drivers of ecosystem change within the wider economy and society. By linking to the System of National Accounts (SNA), they can provide comprehensive, integrated and consistent data sets to support national decision-making. In the case of forests, natural capital accounting can be used to quantify the contribution of FES to the national or regional economy.

The SEEA provides detailed methodological guidance on how to prepare environmental economic accounts. The SEEA includes three volumes: the Central Framework, Experimental Ecosystem Accounts, and Applications and Extensions. The SEEA Central Framework (SEEA–CF) was adopted as an international statistical standard for environmental economic accounting by the United Nations Statistical Commission at its 43rd session in 2012.

Box 4
Payments for forest ecosystem services generate double dividends

A comprehensive example of the use of the ESVD in price setting can be observed in Phan *et al.* (2018). This study investigates the extent to which Viet Nam's move to PES has helped to protect forest ecosystems and to improve local livelihoods as well as income inequality.

To quantify the environmental and socioeconomic impacts for the analysis, Phan *et al.* (2018) makes use of rural household interviews and changes in forest cover, using satellite images over a period of 15 years. The ESVD can assist in this type of analysis by creating insights into the economic impacts for the specific forest ecosystem services. More specifically, the ESVD can provide information from similar study sites to quantify the economic value underlying a price setting mechanism.

The results of the study in Phan *et al.* (2018) show that farmers or people with experience in forestry activities contribute significantly to conserving the forest, improving local livelihoods and reducing income inequality. The environmental impacts of payments for forest ecosystem services show a significant 4.9 percent increase in the average percentage of tree cover after the introduction of PES. The figure shows the comparison of mean tree cover during the pre-PES and PES periods. Phan *et al.* (2018) also reveals that the absolute and relative changes in income proved to be significantly higher for participating households than non-participating households (see Figure). Moreover, the average income level of participating households has increased by 45 percent since the introduction of PES in Viet Nam.

Figure: Comparison of mean Landsat vegetation continuous fields (VCF) tree cover in the study area between the pre-PES period (blue) and during the PES period (green)

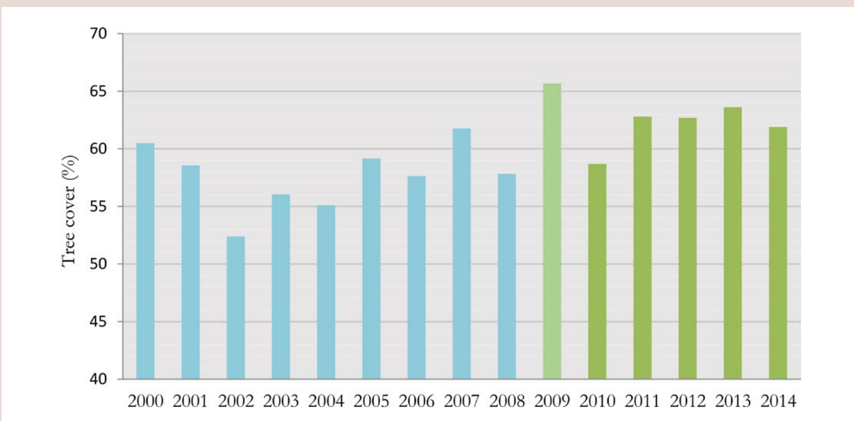
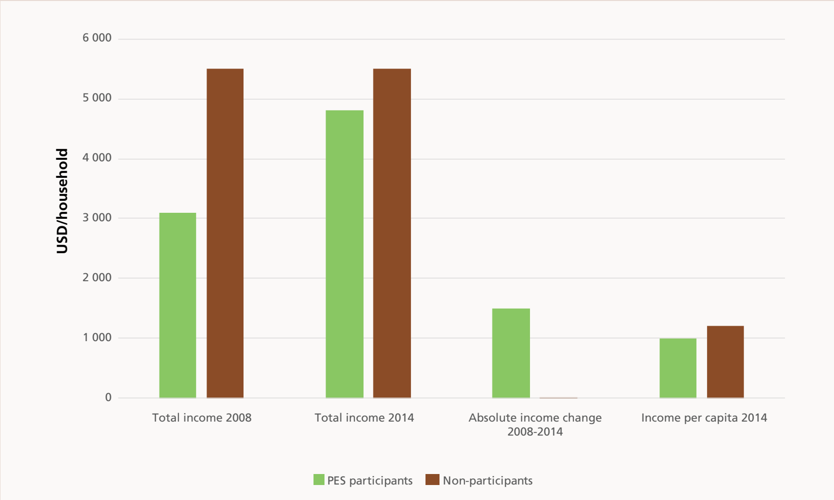


Figure: Comparison of income and income change between payment for ecosystem services (PES) participants and non-participants



Source: Phan, T.H.D., Brouwer, R., Hoang, L.P. & Davidson, M.D. 2018. Do payments for forest ecosystem services generate double dividends? An integrated impact assessment of Vietnam's PES program. PloS one, 13(8), e0200881. https://doi.org/10.1371/journal.pone.0200881

It provides an accounting framework that is consistent and can be integrated with the structure, classifications, definitions and accounting rules of the SNA; thereby enabling the analysis of the changes in natural capital, its contribution to the economy and the impacts of economic activities on it. SEEA–CF focuses on the stock of natural resources and the flows that cross the interface between the economy and the environment.

The recently published SEEA–EA is a spatially-based integrated statistical framework for organizing biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets, and linking this information to measures of economic and human activity. It was developed to respond to a range of policy demands and challenges with a focus on making visible the contributions of nature to the economy and people (UNSD, 2021).

The SEEA–EA offers a synthesis of the current knowledge of ecosystem accounting and serves as a platform for developing it at national and sub-national levels. It provides a common set of terms, concepts, accounting principles and classifications, as well as an integrated accounting structure for ecosystem services and characteristics of ecosystem condition, in both physical and monetary terms (UNSD, 2021). In the context of monetary valuation, the SEEA–EA applies the SNA concept of exchange values. While estimates based on this value concept are useful in many contexts, there are some limitations. In particular, an exchange value does not include consumer surplus, which can be a dominant component of the economic value of non-marketed ecosystem services (e.g. outdoor recreation). A large proportion of the value information in the ESVD could be compatible with the exchange value concept used in the SEEA–EA and potentially be used in natural capital accounting applications (Brander *et al.*, 2022). Box 5 provides an example application of forest accounts for Guatemala.

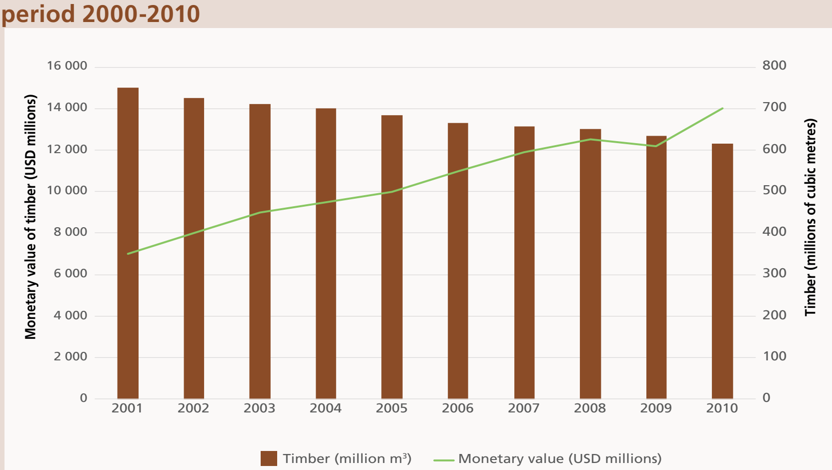
Box 5
Forest accounts in Guatemala

Studies of forest accounts can potentially make use of valuable information from the ESVD. This is illustrated by World Bank (2017), a case study of forest accounts in Guatemala, showing how the country has rapidly lost a valuable asset and how that loss has substantially affected the monetary value of the forest (see the figure).

This research follows the SEEA, expanding on information from the land accounts. For this, it is necessary to estimate the monetary value of forestry land in terms of timber assets and ecosystem services. The ESVD provides a source of information to produce this estimation and account for the ecosystem services benefits that forests provide.

World Bank (2017) shows that forestry activities contribute 2.5 percent of GDP, which is higher than the 1 percent currently recorded by the (conventional) national accounts. However, the massive disparity between reported activities and actual forest change shows that as much as 96 percent of forest use is illegal. As a result of these accounts, policymakers were able to better understand the flows through the entire timber sector. In response, Guatemala is designing a new strategy to prevent illegal logging.

Figure: Volume of timber in Guatemala and its monetary value over the period 2000-2010



Source: World Bank. 2017. Forest Accounting Sourcebook: Policy applications and basic compilation. Washington, DC. http://documents.worldbank.org/curated/en/772391580132234164/Forest-Accounting-Sourcebook-Policy-Applications-and-Basic-Compilation

5. Discussion and conclusions

Forests deliver a broad range of ecosystem services that are crucial to human well-being. This paper provides an overview of the available case studies on the economic value of forest ecosystem services, which can inform decision-making regarding forest management, conservation and restoration. This evidence base is substantial and continues to grow. The ESVD provides the most comprehensive global collection of economic valuation studies. As a result of the update conducted for SOFO 2022, it now contains more than 2 700 unique value records from forest ecosystem services for ten forest types in all parts of the world. This data provides a basis for conducting value transfers to inform forest policy and management decisions in a relatively low-cost and timely way.

The following are the key observations made over the present work:

1. Although there is now quite a lot of information on the economic value of some FES (e.g. food provisioning, air quality regulation, recreation) and some forest types (e.g. mangroves, tropical forests, temperate forests), gaps remain for some other FES (e.g. regulation of water flows, biological control) and some forest types (e.g. forested peatlands and wetlands). These gaps can be filled through additional targeted investment in primary valuation studies.
2. The economic value of some FES are high, reaching annual values of more than USD 100 000 per hectare. When adding the different FES across forest type, the highest annual values are attributed to urban parks and forests (401 746 international dollars per hectare) and mangroves (217 104 international dollars per hectare).
3. Information on the economic values of FES from the ESVD can be effectively used in several forest policy and management contexts including impact assessment, appraisal of green investments, price setting and sustainable financing, and natural capital accounting.
4. Closer collaboration with the business community and local, national and supra-national governments is needed to facilitate the dissemination of FES valuation estimates. Collecting good practices on the integration of FES values in decision-making is critical to improve the adoption of valuation in public and private strategies and investment decisions, and to provide examples on how to use value information.
5. The accuracy and reliability of the data presented in this study may be challenging to evaluate due to the diverse sources, hence it is important

to exercise caution when conducting inter-comparisons. While the data provided offers valuable insights, it should be viewed as indicative of magnitudes rather than being entirely precise.

To support informed forest policy and management decisions, the ESVD continues to build the evidence base on the economic value of ecosystem services and to make this information widely and freely available. This is a perpetual process that is gaining momentum from the increasing demand for economic analysis to support sustainable use of natural capital from the full spectrum of stakeholders.

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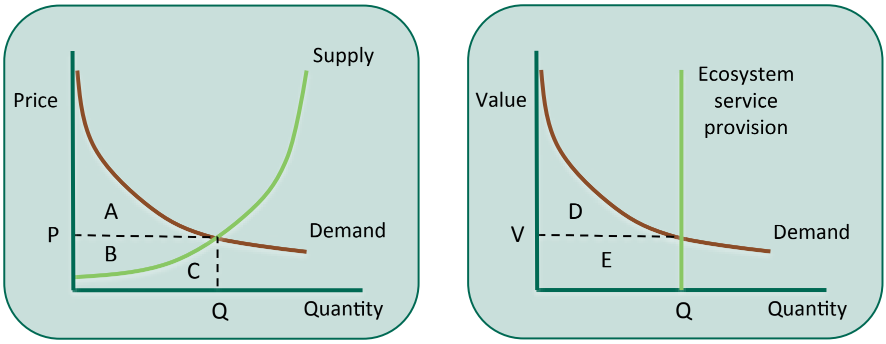
Annex 1. Economic value and value transfer

This annex provides the definitions of the various concepts of economic value that are relevant to the assessment of forest ecosystem services, as well as value transfer methods.

Economic value is a measure of the human welfare derived from the use or consumption of goods and services. Economic valuation is one way to quantify and communicate the importance of something (e.g. environmental damage, changes in resource availability, ecosystem services) to decision-makers and can be used in combination with other forms of information (e.g. biophysical indicators and social impacts). The comparative advantage of economic valuation is that it conveys the importance of environmental change directly in terms of human welfare, using a common unit of account (money) so that values can be directly compared across other goods, services, investments and impacts in the economy.

In neo-classical welfare economics, the economic value of a good or service is the monetary measure of the well-being associated with its production and consumption. In a perfectly functioning market, the economic value of a good or service is determined by the demand for and supply of that good or service. Demand for a good or service is determined by the benefit, utility or welfare that consumers derive from it. Supply of a good or service is determined by the cost to producers of producing it. Figure 12 Panel 1 provides a simplified representation of demand (marginal benefit) and supply (marginal cost) for a good traded in a market at quantity (Q) and price (P).

Figure A1.1 Demand and supply curves for marketed goods and services (Panel 1, left) and non-marketed goods and services (Panel 2, right)



Source: Brander, L.M., van Beukering P., Balzan, M., Broekx, S., Liekens, I., Marta-Pedroso, C., Szkop, Z. et al. 2018. Report on economic mapping and assessment methods for ecosystem services. Deliverable D3.2 EU Horizon 2020 ESMERALDA Project, Grant agreement No. 642007.
Note: See text for explanation of symbols.

In Figure A1.1 Panel 1, area A represents the *consumer surplus*, which is the gain obtained by consumers because they are able to purchase a product at a market price that is less than the highest price that they would be willing to pay (which is related to their benefit from consumption and represented by the demand curve). The *producer surplus*, depicted by B, is the amount by which producers benefit by selling at a market price that is higher than the lowest price that they would be willing to sell for (which is related to their production costs and represented by the supply curve). The area C represents production costs, which may differ among producers and over the scale of production. The sum of areas A and B is the total surplus in this market, and is interpreted as the net economic gain or welfare resulting from production and consumption with a quantity of Q at price P.

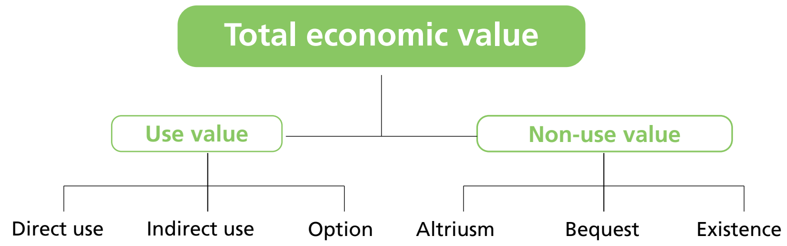
In the case that goods and services are not traded in a market (as is the case for many ecosystem services such as climate regulation, flood regulation and biodiversity), the interpretation of the welfare derived from their provision can also be represented in terms of surplus. Figure A1.1 Panel 2 represents the supply and demand of a non-marketed service. In this case, the service does not have a supply curve in the conventional sense that it represents the quantity of the service that producers are willing to supply at each price. The quantity of the service that is supplied is not determined through a market at all but by other decisions regarding protection status, land use, management, access, etc. The quantity of the service supplied is, therefore, independent of its value. This is represented in Figure A1.1 Panel 2 as a vertical line. The demand curve for non-marketed services is still represented as a downward sloping line since marginal benefits are expected to decline with quantity (the more a service is available, the lower the additional welfare of consuming more of it). In this case, consumers do not pay a price for the quantity (Q) that is available to them, but they do receive a benefit or value (V) and the entire area under the demand curve (D + E) represents their consumer surplus.

Note that the demand for goods and services that are used as inputs into the production of marketed goods and services (e.g. the habitat and nursery service provided to fisheries by mangroves are generally uncompensated inputs into fisheries production) is derived from the demand for the good or service that is finally consumed (e.g. fish).

The *marginal value* of a good or service is the contribution to well-being of one additional unit. It is equivalent to the price of the service in a perfectly functioning market (P in Figure A1.1). Small changes in ecosystem service provision should be valued using marginal values. The *average value* of a good or service can be calculated as its total value divided by the total quantity of the service provided and consumed. From Figure A1.1 Panel 2, average value can be calculated as (D + E) / Q. Average values may be useful for comparing the aggregate value of a good or service relative to the scale of provision (defined in terms of units of provision, area of ecosystem or number of beneficiaries).

The concept of the total economic value (TEV) of an ecosystem is used to describe the comprehensive set of utilitarian values derived from that ecosystem. This concept is useful for identifying the different types of value that may be derived from an ecosystem. TEV comprises *use values* and *non-use values*. Use values are the benefits that are derived from some physical use of the resource. *Direct use values* may derive from on-site extraction of resources (e.g. fisheries) or non-consumptive activities (e.g. recreation). *Indirect use values* are derived from off-site services that are related to the resource (e.g. climate regulation, coastal protection). *Option value* is the value that people place on maintaining the option to use an ecosystem resource in the future. Non-use values are derived from the knowledge that an ecosystem is maintained without regard to any current or future personal use. *Non-use values* may be related to altruism (maintaining an ecosystem for others), bequest (for future generations) and existence (preservation unrelated to any use) motivations. The constituent values of TEV are represented in Figure 13. It is important to understand that the *total* in total economic value refers to the identification of all components of value rather than the sum of all value derived from a resource. TEV is a comprehensive measure, as opposed to a partial measure, of value. Accordingly, many estimates of TEV are for marginal changes in the provision of ecosystem services but are total in the sense that they take a comprehensive view of sources of value.

Figure A1.2 Components of total economic value (TEV)



Source: Adapted from Pearce, D.W. & Turner, R.K. 1990. Economics of natural resources and the environment. Johns Hopkins University Press.

The classification of different types of economic value within the concept of TEV is complementary to the classification of ecosystem services. Table A1.1 sets out the correspondence between categories of ecosystem services and components of TEV.

TABLE A1.1
Correspondence between ecosystem services and components of total economic value

Ecosystem services	Total economic value			
	Direct use examples	Indirect use examples	Option value	Non-use examples
Provisioning	Timber		Option to use provisioning service	
Regulating		Climate regulation	Option to use regulating service	
Cultural	Recreation		Option to use cultural service	Bequest value

Source: Adapted from Pearce, D.W. & Turner, R.K. 1990. Economics of natural resources and the environment. Johns Hopkins University Press.

The concept of welfare value is used in most assessments of ecosystem services, but it is not used in the System of National Accounts (SNA) that is used to calculate GDP and other economic statistics. The SNA uses the concept *exchange value*, which is a measure of producer surplus plus the costs of production. In Figure A1.1 Panel 1, this is represented by areas B and C, or equivalent to P × Q. Under the concept of exchange value, the total outlays by consumers and the total revenue of producers are equal. For national accounting purposes, this approach to valuation enables a consistent and convenient recording of transactions between economic units since the values for supply and use of products are the same. In the context of natural capital accounting under the SEEA–EA, which is consistent with the SNA, it is therefore necessary to value the total quantity of ecosystem services at the market prices that would have occurred if the services had been freely traded and exchanged. In other words, it is necessary to measure exchange value and not welfare value.

The differences between the concepts of welfare value and exchange value are the inclusion of consumer surplus (A) in the former and the inclusion of production costs in the latter (C). The concept of welfare value corresponds to a theoretically valid measure of welfare in the sense that a change in value represents a change in welfare for the producers of the goods and services under consideration, for the consumers, or both. The concept of exchange value does not correspond to a theoretically valid measure of welfare and a change in exchange value does not necessarily represent a change in welfare for either producers or consumers.[4]

Value transfer methods

The alternative methods of conducting value transfer are briefly described here:

1. Unit value transfer uses values for ecosystem services at a study site, expressed as a value per unit (usually per unit of area or per beneficiary), combined with information on the quantity of units at the policy site to estimate policy site values. Unit values from the study site are multiplied by the number of units at the policy site. Unit values can be adjusted to reflect differences between the study and policy sites (e.g. income and price levels).
2. Value function transfer uses a value function estimated for an individual study site in conjunction with information on parameter values for the policy site to calculate the value of an ecosystem service at the policy site. A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service. Value functions can be estimated from numerous primary valuation methods including hedonic pricing, travel cost, production function, contingent valuation and choice experiments.
3. Meta-analytic function transfer uses a value function estimated from the results of multiple primary studies representing multiple study sites in conjunction with information on parameter values for the policy site to calculate the value of an ecosystem service at the policy site. A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service. Since the value function is estimated from the results of multiple studies, it can represent and control for greater variation in the characteristics of ecosystems, beneficiaries and other contextual characteristics.

[4] See Day (2013) for a more detailed explanation of welfare and exchange values.

The choice of which value transfer method to use to generate information for a specific policy context is largely dependent on the availability of primary valuation estimates and the degree of similarity between the study and policy sites. In cases where value information is available for a highly similar study site, unit value transfer may provide the most straightforward and reliable means of conducting value transfer. On the other hand, when study sites and policy sites are different, value function or meta-analytic function transfer offers a means to systematically adjust transferred values to reflect those differences. Similarly, in the case that value information is required for multiple different policy sites, value function or meta-analytic function transfer may be a more accurate and practical means for transferring values. Using meta-analytic functions that include a parameter for ecosystem scarcity provides a means to account for simultaneous changes in the stock of ecosystems on the value of all ecosystem services (i.e. more accurately *scale-up* ecosystem service values) (Brander *et al*., 2012b).

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