SOFO Background Paper

The role of forest ecosystem services to support the green recovery: Evidence from the Ecosystem Services Valuation Database

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Executive Summary

Forests are an important component of natural capital and deliver a broad range of ecosystem services (ES) that underpin human well-being in a social, physical, mental and economic sense. The extent and condition of forests in many parts of the world, however, have declined dramatically during the preceding decades due to conversion to agriculture, unsustainable harvesting of timber, forest fires, and urbanisation. This has resulted in a decline in forest ecosystem services (FES) while at the same time the demand for FES and the recognition of its importance has increased. It is therefore critical to gain an understanding of the value of forests to humans and to bring this value into decision-making.

This paper provides a description of the available information on the economic value of FES contained in the Ecosystem Services Valuation Database (ESVD). After updating forest value data for the SOFO 2022 report, the ESVD now contains over 2,700 unique values for FES for 10 forest types in all parts of the world. Summarising these monetary estimates for each FES and forest type in a common set of units, namely International dollars per hectare per year, shows that there is now a large quantity 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); and that the economic value of some FES are extremely high, reaching annual values over US$ 100k per hectare. There is high variation in the values of FES across forest types, reflecting differences in functions, condition and socio-economic context. Gaps remain in terms of limited available information for some FES and some forest types, which can be filled through additional targeted investment in primary valuation studies

Information on the economic values of FES from the ESVD can be effectively used in several forest policy and management contexts to inform the Green Recovery, including impact assessment; appraisal of green investments; price setting and sustainable financing; and natural capital accounting. Such information on the true economic value of intact, sustainably used forests can help to convince governments, business and individuals to invest in forest restoration and afforestation projects.

Our results highlight the need to look beyond narrow market values and take the full value of ecosystems into account. This not only helps to make better informed decisions but potentially provides many opportunities for innovative financing instruments and business opportunities. The ESVD provides the basis for conducting value transfers to inform forest policy and management decisions in a relatively low-cost and timely way, and to take the full value of nature into account in decision-making.

1. Introduction

Forests are an important component of 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 % of the terrestrial environment and provide habitat for the vast majority of the 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 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 et al., 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 during the preceding decades due to conversion to agriculture, unsustainable harvesting of timber, forest fires, and urbanisation (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 ameliorating the impacts of droughts, floods and extreme temperatures (Canadell and Raupach, 2008; Grassi et al., 2017; Chow, 2018).

In light of current global environmental challenges, it is important evaluate what is important to our well-being and improve decision making regarding the use and management of natural capital. Investment in forests and trees could potentially provide solutions to several of the challenges that we face 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 paper provides a description of the available information on the economic value of FES 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 has been updated with a focus on forest ecosystem services as a contribution to the FAO assessment of forest potential to support a green recovery reported on the FAO State of the World's Forests 2022. The ESVD currently contains over 2,700 unique value records for FES for 10 forest types in all parts of the world. The structure of the paper is 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 (ES) approach (MA, 2005; TEEB, 2010) and the concept of Total Economic Value (TEV) (Pearce and Turner, 1990). This framework builds on the conceptualisation 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, not replacing the intrinsic value of nature.

2.1. Ecosystem Services

The concept of ES has been defined in numerous different ways but in general it is agreed that ES are the direct and indirect contributions of ecosystems to human well-being, and that ES 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).

Similar to the prevalence of definitions of ES, there are also many alternative classifications, including those of Costanza et al. (1997); Daily (1997); the Millennium Ecosystem Assessment (MA, 2005); The Economics of Ecosystems and Biodiversity (TEEB 2010); the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2012; 2018); Final Ecosystem Goods and Services Classification System (FEGS-CS) (Landers and Nahlik, 2013), National Ecosystem Services Classification System (NESCS) (US EPA, 2015); Nature's Contribution to People (NCP) from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Diaz et al., 2018); and most recently the System of Environmental Economic Accounting - Ecosystem Accounts (SEEA EA) reference list (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

[1] The Millennium Ecosystem Assessment (MA 2005) included a fourth category, Supporting Services, to highlight the importance to maintain basic ecological processes. Examples include photosynthesis, nutrient cycling, soil formation and primary production. Similarly, the classification developed by the TEEB study (2010) 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.

of each classification system is dependent on the specific bio-physical, socio-economic 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 or not there is a market and monetary transaction for the good or service. Economic valuation is one way to quantify and communicate the importance of something (e.g., environmental damage, changes in resource availability, ecosystem services etc.) to decision makers, and can be used in combination with other forms of information (e.g., bio-physical 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 Total Economic Value (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 SEEA EA (see Section 4.5), which is consistent with the SNA, it is therefore 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. In other words, 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 (ESVD)

Considerable research effort over the past 40 years has attempted to estimate the economic value of ES 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, ES, location, valuation method, and beneficiaries (ESVD, 2020).[2]

[2] The ESVD can be accessed at https://www.esvd.info/

For SOFO 2022, 916 additional forest values were included in the ESVD, which reached a total of 2,746 value estimates. The data update was targeted at forest biomes and ecosystems that had relatively few value estimates (i.e., forested wetlands, forested peatlands, plantations, orchards / agro-forestry, high mountain forest, woodland and shrubland, and urban parks and forests). 89% of the value estimates for forested peatlands and 81% for forested wetland were included through this update of the ESVD database.

3.1. The database

The ESVD now contains 2,746 unique value records from FES for 10 forest types in all parts of the world. Figure 1 represents the locations of forest valuation study sites; Figures 2-5 represent the number of FES estimates by continent, forest type, ES and valuation method.

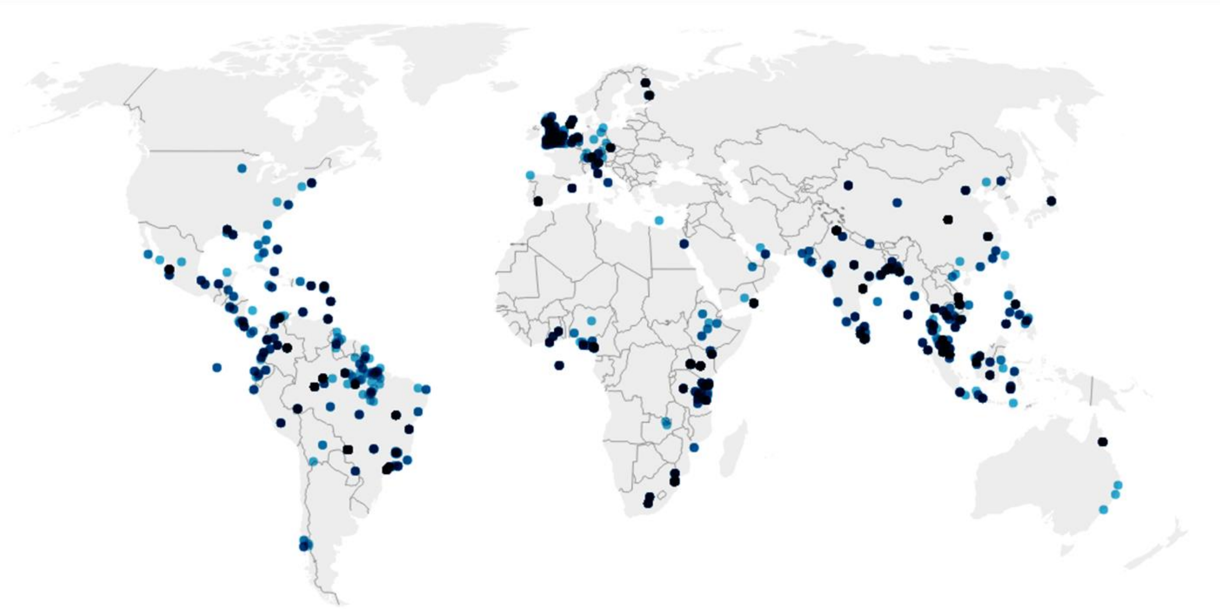

Figure 1. Location of forest valuation studies included in the ESVD

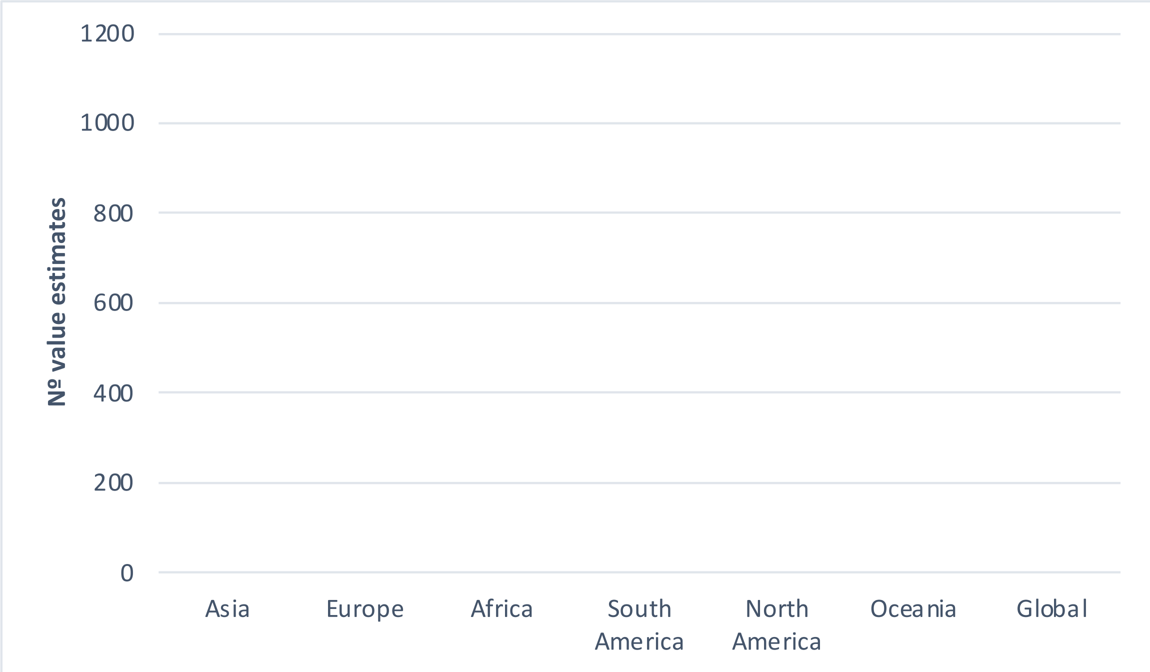

Figure 2. Number of value estimates by continent

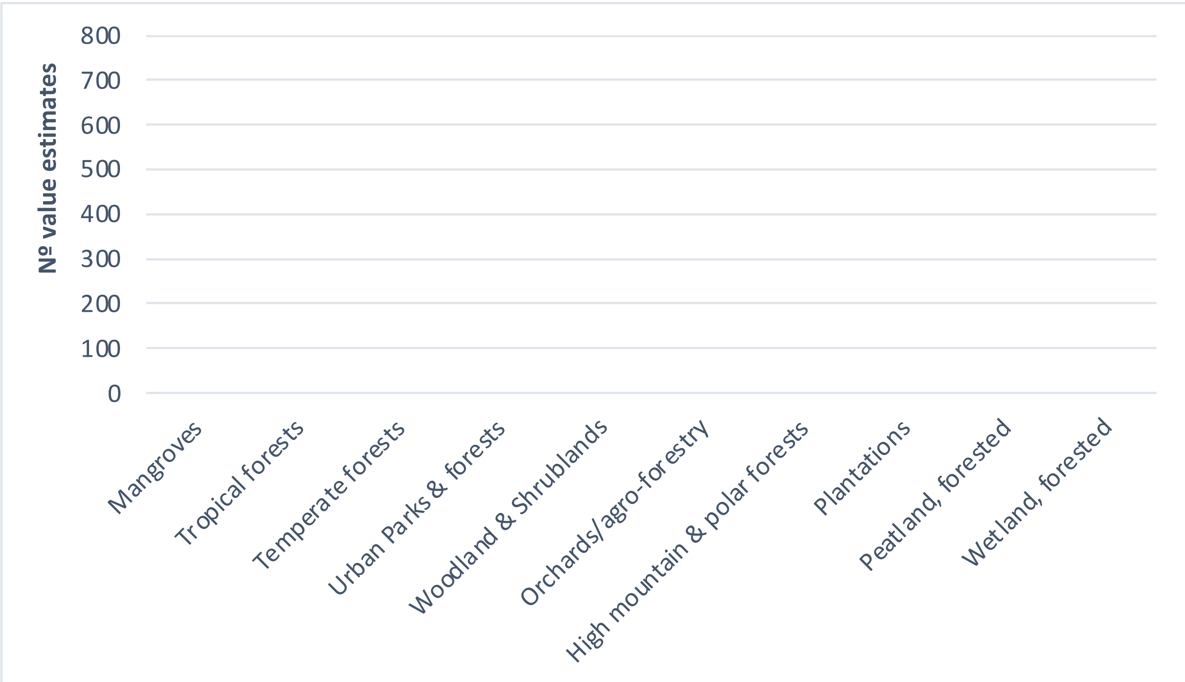

Figure 3. Number of value estimates by forest type

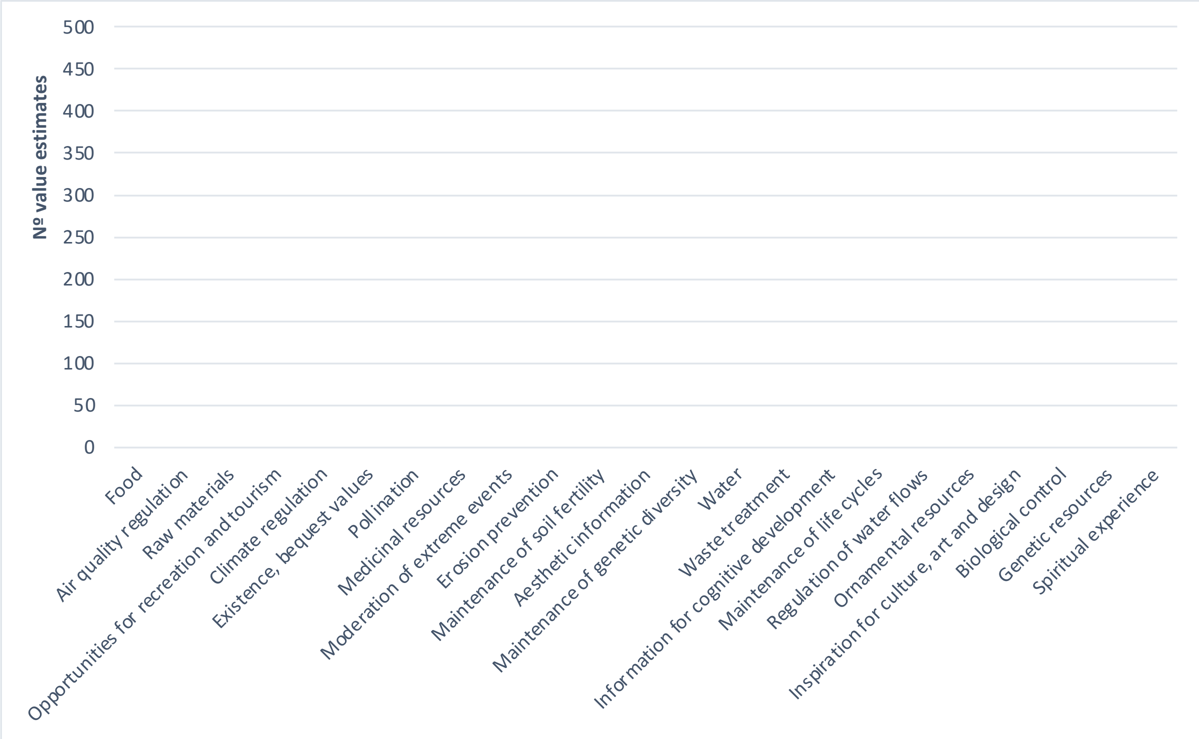

Figure 4. Number of value estimates by ecosystem service

Figure 5. Number of value estimates by valuation method

To enable comparisons and summaries of the forest value data, recorded values have been standardised to a common set of units: International dollars per hectare per year at 2020 prices levels. The standardization process involves five steps to address the following five dimensions: price level, currency, spatial unit, temporal unit, and beneficiary unit. Details on the standardisation methods can be found in Brander et al. (2021b). This standardization process is only to ensure that values are expressed in the same measurement unit and does not adjust for bio-physical 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 due primarily to missing data (e.g., on the total number of beneficiaries of a FES) or the incompatibility of spatial units (e.g., linear features such as avenues of trees cannot be meaningfully converted into hectares).

3.2. Forest valuation results

Table 1 provides an overview of the average monetary value per FES 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 Benefit Transfer values and manually excluded non-non-consistent/plausible values and applied some outlier rules. 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 insufficient value records were available to calculate an average value.

Table 1 shows that there is high variation in the values of FES across forest types and provides indicative information on the relative importance of different FES within each forest biome. For instance, provisioning and regulating ecosystem services provided by tropical forests are of approximately equal value, 47.3% and 49.3% of total value, respectively. In contrast, regulating and cultural services from temperate forests are of similar value, 42.6% and 44% respectively; and high mountain forests are overwhelmingly recognized for their regulating services, which respond for 86.9% of their attributed value.

A high variation is observed in the values of FES across forest types, with very high values for some FES. For example, mangroves have high mean values for the provision of food (by supporting adjacent fisheries) and moderation of extreme events (by mitigating coastal flooding); tropical forests have high mean values for climate regulation (by sequestering and storing carbon), medicinal resources and raw materials; and urban parks and forests have high mean values for air quality regulation and recreation.

The number of value estimates by forest type and by forest ecosystem service also merits discussion as they might be 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, the low number of value estimates for these forest types indicates an important research gap.

The ESVD also provides some important indications of the potential to monetize FES. The high mean value of the estimates for recreation and tourism provided by urban parks and forests indicates a potential revenue source and economic argument for urban municipalities to protect such green infrastructure. In temperate forests, FES with high values, such as regulation of water flows and recreation/tourism, might also be used as an argument in favor of the preservation and restoration of such forests.. The results illustrate the relevance of valuing and protecting forests for the large array of benefits they generate, and the potential of creating finance instruments to generate streams of funds to support forest holders and managers (e.g. via PES schemes).

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 IQR 1.5 of log transformed values)

Ecosystem services / biomes	High Mountain - forest	Mangroves	Orchards/ agro-forestry	Peatland, Forested	Plantations	Temperate forests	Tropical forests	Urban Parks & Forests	Wetlands, Forested (on alluvial soils)	Woodland & 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)

Ecosystem services / biomes	High Mountain - forest	Mangroves	Orchards/ agro-forestry	Peatland, Forested	Plantations	Temperate forests	Tropical forests	Urban Parks & Forests	Wetlands, Forested (on alluvial soils)	Woodland & Shrubland
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)
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)

Ecosystem services / biomes	High Mountain - forest	Mangroves	Orchards/ agro-forestry	Peatland, Forested	Plantations	Temperate forests	Tropical forests	Urban Parks & Forests	Wetlands, Forested (on alluvial soils)	Woodland & Shrubland
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)
Sum	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)

[1] The summary values reported in this table are intended for illustration and to identify data gaps. These summary statistics reflect the underlying ecological and socio-economic 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.

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

3.3. Limitations

The data included in the ESVD and in the selected data underlying the summary table are carefully screened, coded and reviewed to ensure the information is as robust as possible. 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 over 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 none value estimates available. Mean values (in Table 1) for a given combination of forest type and ES that are based on few value estimates may be less robust than mean values that can rely on much broader empirical basis of values. Furthermore, due to missing values for FES, the total values computed for each forest type in Table 1 are likely to be underestimates and will increase as more data become available and the gaps can be filled.

2) Representativeness

The ESVD is a global database containing value observations for all biomes and all ecosystem services. In the most recent update for the SOFO 2022 report 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 should not be treated as representative of each biome-FES combination. Indeed, it is not possible for a single unit value to be representative of an entire biome given the natural variation in supply and demand for ecosystem services across locations.

3) Not all records have been externally reviewed yet

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

4) Trade-offs between ecosystem services

In computing total values from each forest type (Table 1) we make the assumption 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 the harvesting of timber and use for recreational activities. Such trade-offs introduce further complexity to any analysis, since it becomes necessary to consider how one use of one FES affects other potential uses and values. This has not been possible in the computation of the summary values presented here.

5) Average and marginal values

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

6) Need for meta-regression analysis.

Accounting for location specific differences in bio-physical, socio-economic and cultural conditions 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 a number of policy and decision-making contexts to support the green recovery. The purpose of this section is to firstly explain in general terms how information from the ESVD can be transferred to inform decision making, and then provide specific example applications on: impact assessment; appraisal of green investments; price setting and sustainable financing; and natural capital accounting.

4.1 Value transfer

Decision-making often requires information quickly and at low cost. New 'primary' valuation research, however, is generally time consuming and expensive. For this reason there is interest in using information from existing primary valuation studies to inform decisions regarding impacts on ecosystems that are of current interest. This transfer of value information from one context to another is called value or benefit transfer.

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 is also known as benefit transfer but since the values that are transferred may be costs as well as benefits, the term value transfer is more generally applicable.

In addition to the need for expeditious and inexpensive information, there is often a need for information on the value of ecosystem services at a different geographic scale from that at which primary valuation studies have been conducted. So 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 ES 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.

The number of primary studies on the value of ecosystem services is substantial and is growing rapidly. This means that there is a growing body of evidence to draw on for the purposes of transferring values to inform decision-making. With an expanding information base, the potential for using value transfer is improved.

Value transfer can potentially be used 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). 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 a number of 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 is able to represent and control for greater variation in the characteristics of ecosystems, beneficiaries and other contextual characteristics.

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 ecosystem on the value of all ecosystem services (i.e., more accurately “scale-up” ecosystem service values) (Brander et al., 2012b). Box 1 provides an example application of meta-analytic value transfer to estimate the economic value of mangrove ecosystem services in Southeast Asia.

Box 1: Value of mangroves in Southeast Asia (Brander et al., 2012a)

Data contained in the ESVD has been used to estimate the value of ecosystem services provided by mangroves in Southeast Asia for the period 2000–2050 (Brander et al., 2012a).

This study 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 bio-physical characteristics (size, fragmentation, scarcity) and socio-economic context (population and income). This function is then combined with spatial data on individual mangrove ecosystems in Southeast Asia to produce site specific values, which are aggregated to the country level.

The study uses this approach to estimate the annual value of declining mangrove area and lost ecosystem services in Southeast Asia for the period 2000-2050. The study estimates the lost annual value to be approximately US$ 2.16 billion in 2050 (2007 prices), with a 95% prediction interval of US$ 1.58 – 2.76 billion. Figure 1.1 shows the values of foregone mangrove ecosystem services aggregated to the country level.

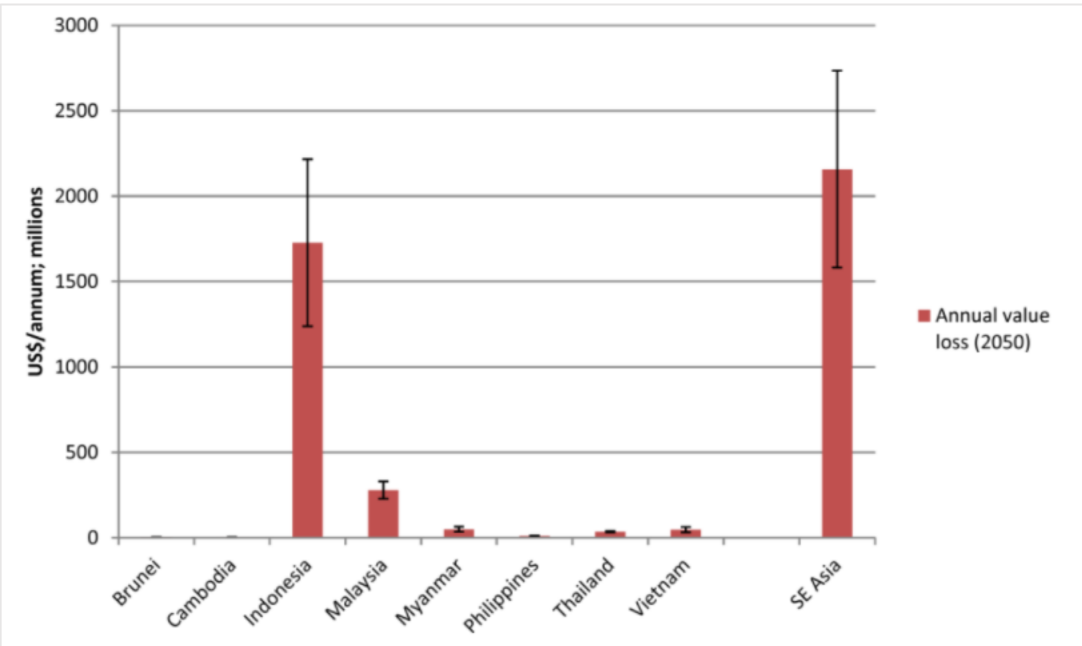

Figure 1.1 Value of foregone mangrove ecosystem services in 2050.

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, land use change in the form conversion of forest 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 how successful investment implementation will be. For example, it is often the case with the establishment of protected areas that attempting to exclude local stakeholders from accessing an environmental resource will not be successful without sharing the benefits of conservation with them. Understanding who gains and who loses from each policy/investment option can provide important insights into the incentives that different groups have to support or oppose each project. This approach can thus provide useful information in the design of appropriate responses and increase success in implementing projects/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 disproportionate or undesirable allocation of impacts, compensation mechanisms, or payment schemes between gainers and losers. 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 Satelligence and using the ESVD to value the loss of services and the value of the maintained forest areas (FSD, 2021)

This case study 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 intact 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 US$10 billion per year (see figure 2.1). 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 of land uses, with a negative monetary value ranging from $48 million to almost $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 considering provisioning ecosystem services only.

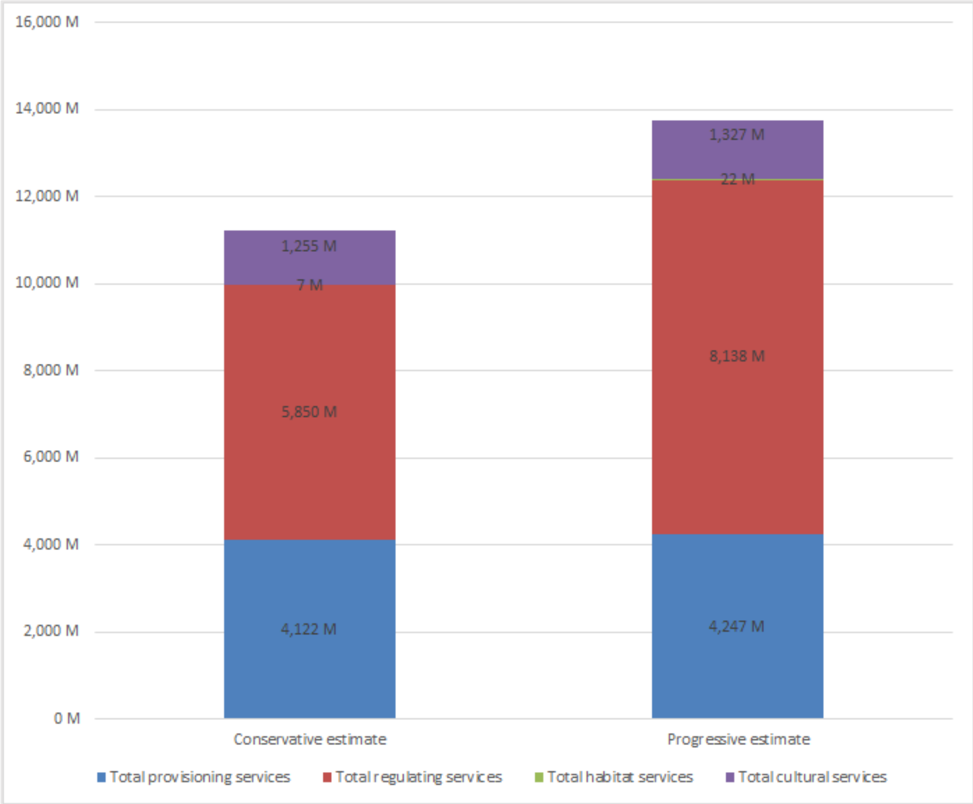

Figure 2.1 The total economic value (TEV) in Million $/year for entire remaining area (3,211,319 ha), including Mangroves (3,928 ha), Tropical forests (3,079,883 ha) and peat forests (127,507 ha).

4.3 Appraisal of green investments

Making decisions between alternative investments, projects or policies that affect the provision of ecosystem services often involves weighing up and comparing multiple costs and benefits that are measured in different metrics and are incurred at different locations and points in time. For example, the establishment of a new protected area might involve costs in terms of the purchase of land, compensation of local communities, and on-going maintenance and enforcement costs; and 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. Organising, comparing and aggregating information on such a complexity 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 a number of economic assessment methods available to help decision makers to structure the information and factors that are relevant to a decision and to select between 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 focusse don market values and therefore 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.

Box 3: Overview of an integrated Cost-Benefit Analysis of Landscape Restoration (Wainaina et al., 2020).

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/strategies carried out by Wainaina et al. (2020). This study was conducted to understand the extent and coverage of existing studies, as well as gaps, with the aim to help prioritize investment of the scarce resources.

The systematic review included 31 publications that were either entirely focused on Cost-Benefit Analysis of landscape restoration, or included a component on it. The publications included in the review were conducted in about 20 countries distributed across five regions. This study uses the value estimates provided in the ESVD as a source of information to assess the benefits of landscape restoration. Figure 3.1 presents reported NPV (positive or negative) by various iCBA studies for different landscape restoration options.

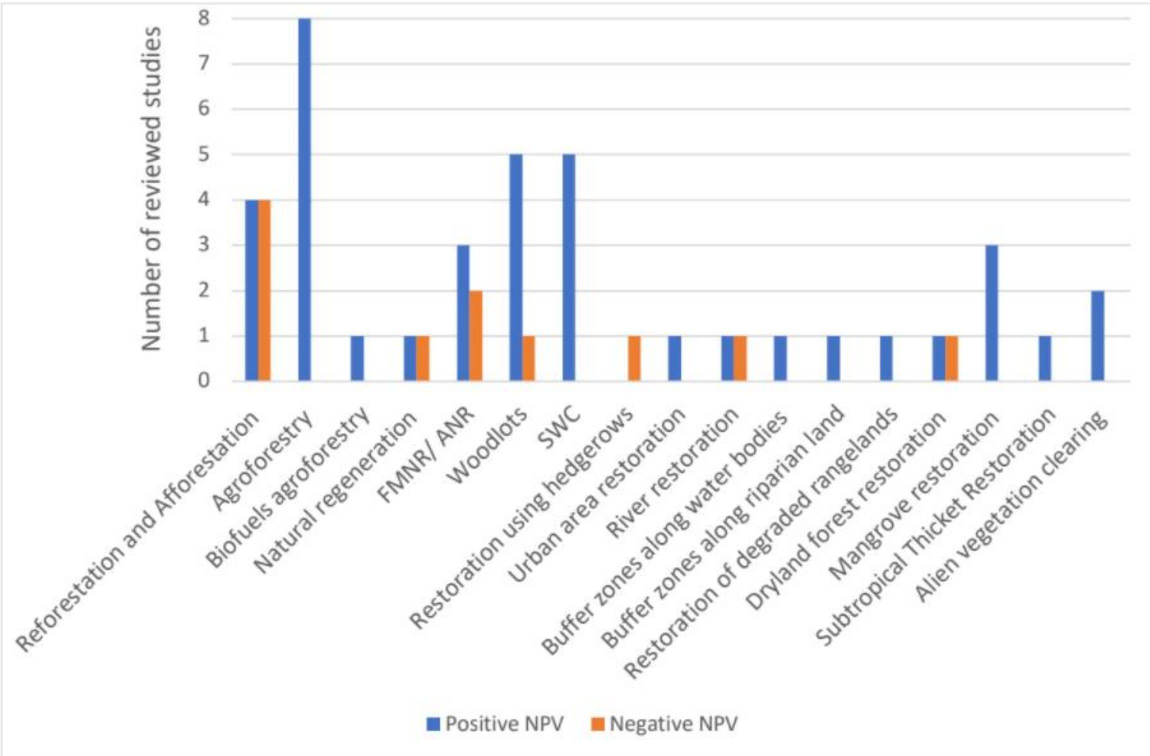

Figure 3.1 Reported NPV for the various landscape restoration type by the various assessed studies

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 (CTF), debt for nature swaps (DNS), green bonds, and payments for ecosystem services. The term “payments for ecosystem services” (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 incentivized to provide that service through some form of payment or compensation, which may be paid by the beneficiaries of the service (e.g., downstream farmers that benefit from lower exposure to flooding). PES schemes attempt to provide incentives for the continued or enhanced provision of services and address the commonly observed problem that markets do not exist for ecosystem services (Wunder, 2014 Pagiola et al., 2005; Engel et al., 2008). It is the creation of incentives that 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 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` (ES 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.

Box 4: Payments for forest ecosystem services generate double dividends (Phan et al., 2018).

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

In order to quantify the environmental and socio-economic impacts for the analysis, this study 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 this study show that farmers or people with experience in forestry activities contribute significantly to forest conservation, the improvement of local livelihoods, and the reduction of income inequality. The environmental impacts of PFES show a significant 4.9% increase in the average percentage of tree-cover after the introduction of PES. Figure 4.1 shows the comparison of mean tree-cover during the pre-PES and PES periods. The study also reveals that the absolute and relative changes in income proved to be significantly higher for participating households than non-participating households (see Figure 4.2). Moreover, the average income level of participating households has increased by 45% since the introduction of PES in Vietnam.

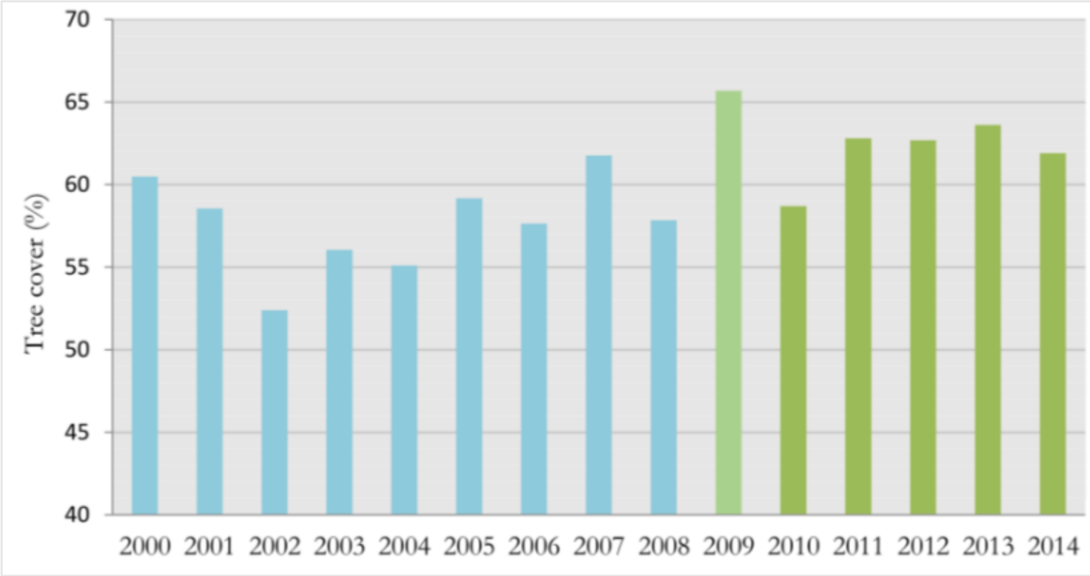

Figure 4.1 Comparison of mean VCF tree-cover in the study area between the pre-PES period (blue) and during the PES period (green).

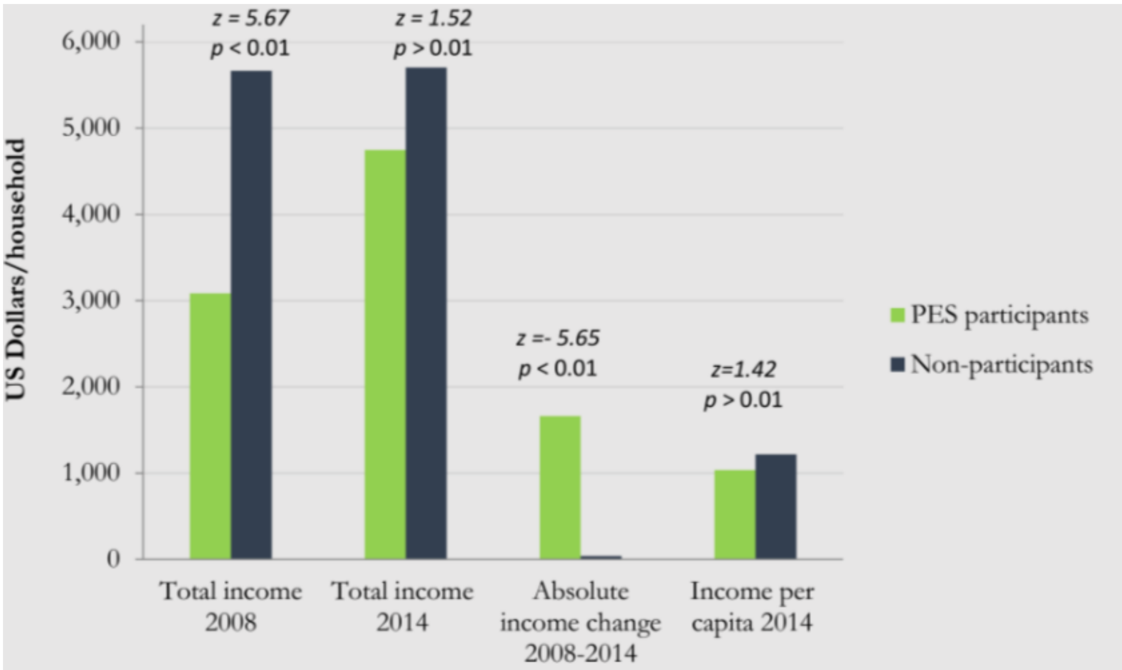

Figure 4.2 Comparison of changes in gross income of PES participants and non-participants.

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) 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 macro-economic 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 System of Environmental-Economic Accounting (SEEA) provides detailed methodological guidance on how to prepare environmental-economic accounts.[3] 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 and provides an accounting framework that is consistent and can be integrated with the structure, classifications, definitions and accounting rules of the System of National Accounts (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 The System of Environmental-Economic Accounting—Ecosystem Accounting (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).

SEEA EA offers a synthesis of the current knowledge of ecosystem accounting and serves as a platform for its development at national and sub-national levels. It provides a common set of terms, concepts, accounting principles and classifications, and 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. For example, they do not include the value of the wider social benefits of ecosystems, including their non-use values. Box 5 provides an example application of forest accounts for Guatemala.

Box 5: Forest accounts in Guatemala (Waves Partnership, 2016)

Studies that make use of forest accounts can potentially make use of valuable information from the ESVD. A case study of forest accounts in Guatemala shows how the country has rapidly lost a valuable asset and how that loss has substantially affected the monetary value of the forest (see Figure 5.1).

This research follows the System of Environmental-Economic Accounting (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 from which to transfer monetary values to account for the ecosystem services benefits that forests provide.

The results of this study show that forestry activities contribute 2.5% of GDP, which is higher than the 1% currently recorded by the (conventional) national accounts. However, the massive disparity between reported activities and actual forest change shows that as much as 96% of forest use is illegal (see Figure 5.2). As a result of these accounts, policy makers were able to better understand the flows through the entire timber sector. In response, Guatemala is designing a new strategy to prevent illegal logging.

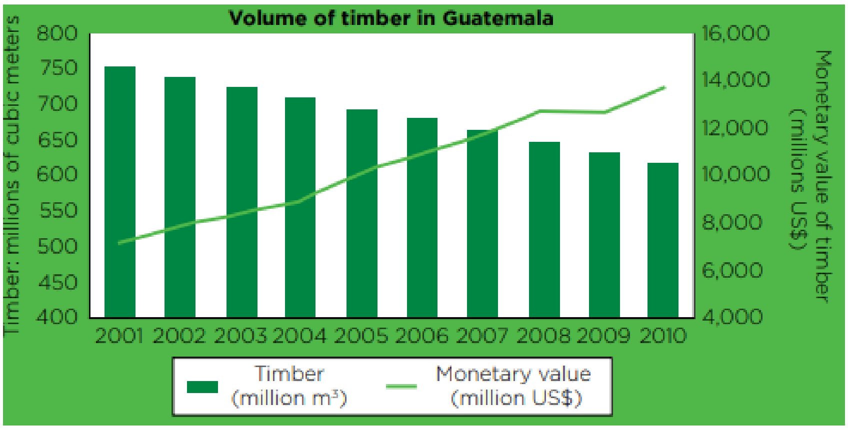

Figure 5.1 Volume of timber in Guatemala and its monetary value.

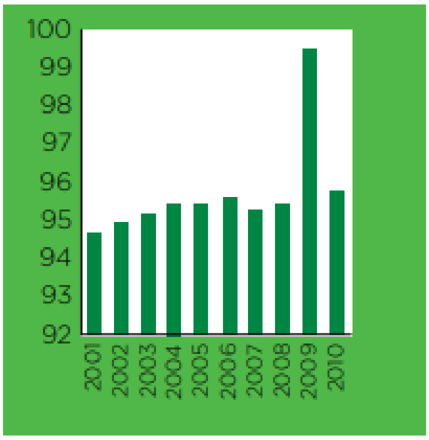

Figure 5.2 Proportion of use not registered in the economy.

5. Discussion and conclusions

Forests deliver a broad range of ecosystem services that are crucial to human wellbeing. This paper provides an overview of the available empirical data on the economic value of forest ecosystem services, with which to 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 the results of economic valuation studies and, as a result of the update conducted for the SOFO 2022 report, it now contains over 2,700 unique value records from FES for 10 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 key observations for this overview of FES values compiled in the ESVD are:

1. There is now a large quantity 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);

2. The economic value of some FES are extremely high, reaching annual values over US$ 100k per hectare;

3. There is high variation in the values of FES across forest types, reflective of differences in functions, condition and socio-economic context. In consequence of high spatial heterogeneity of values, simple summary unit values should not be used to inform decision making and it is necessary to more fully account for the specific characteristics of different policy contexts. Meta-regression-analysis in combination with GIS may allow to account for such differences (e.g., bio-physical, sociocultural and economic) and offers opportunities for more robust value transfer;

4. Gaps remain in terms of limited available information for some FES (e.g., regulation of water flows, biological control) and some forest types (e.g., forested peatlands and wetlands), which can be filled through additional targeted investment in primary valuation studies;

5. 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.

To further support the use of FES economic values to inform the green recovery requires closer collaboration with the business community and local, national and international governments to communicate the importance of FES valuation and the development of best practice user cases on the integration of FES values in decision-making to provide guiding examples of how value information can be used.

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Annex 1. Economic value

This Annex provides the definitions of the various concepts of economic value that are relevant to the assessment of forest ecosystem services.

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 etc.) to decision makers, and can be used in combination with other forms of information (e.g. bio-physical 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.

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 A1 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'.

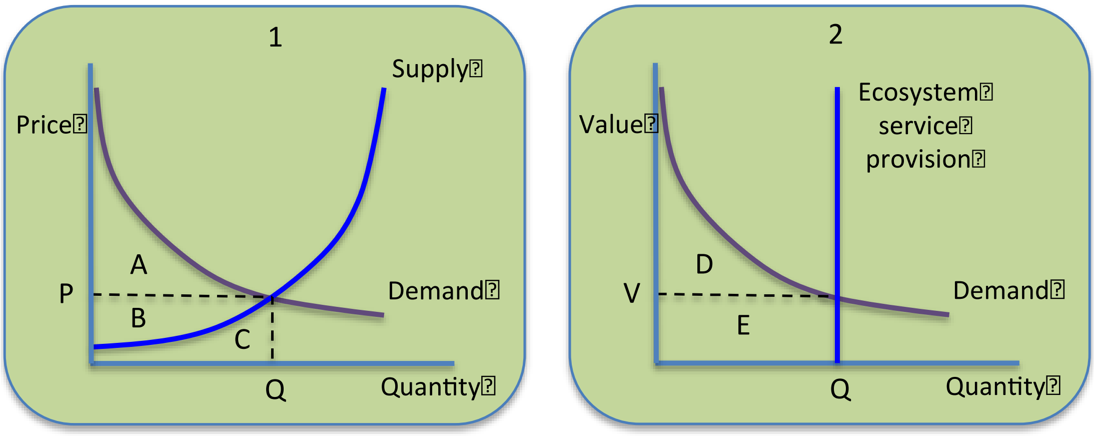

Figure A1. Demand and supply curves for marketed goods and services (Panel 1) and non-marketed goods and services (Panel 2) (see text for explanations of symbols). Source: Brander et al., 2018b.

In Figure A1 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 that 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 differ among producers and/or 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 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 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). In this case, consumers don't 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). 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 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 **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 A2. 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 “total” in the sense that they take a comprehensive view of sources of value.

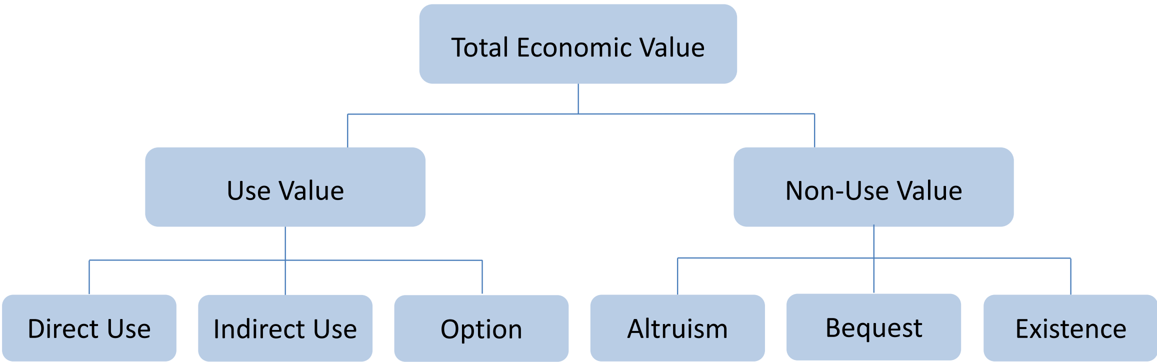

Figure A2. The components of Total Economic Value. Adapted from Pearce and Turner (1990).

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

Table A1. Correspondence between ecosystem services and components of Total Economic Value.

	Total Economic Value			
Ecosystem service	Direct use examples	Indirect use examples	Option value	Non-use examples
Provisioning	E.g. timber		Option to use Provisioning service	
Regulation and maintenance		E.g. climate regulation	Option to use Regulating service	
Cultural	E.g. recreation		Option to use Cultural service	E.g. bequest value

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 Gross Domestic Product (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 Panel 1 this is represented by areas B and C, or equivalent to P x 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 and/or consumers of the goods and services under consideration. 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]

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