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On the investigation of an economic value for forest ecosystem services in the past 30 years: Lessons learnt and future insights from a North–South perspective

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Since the publication of the Millennium Ecosystem Assessment, the research of ecosystem services valuation has seen an exponential growth with a consequent development, improvement, and spread of different qualitative and quantitative methods. The interest is due to the benefits that ecosystem services provide for human wellbeing. A large part of ecosystem services is provided by the so-called forest ecosystem services (FES) in both protected and non-protected areas. The aim of the present study is to investigate key variables driving the FES value at the global level. These include, other than socio-economic information, the ecosystem services' quality condition and the location of the study. The research uses a meta-regression of 478 observations from 57 studies in the time span 1992–2021 retrieved from the online Ecosystem Service Valuation Database (ESVD). The main results show that both the ES quality condition and spatial aspect are relevant factors in determining the estimated value of FES, suggesting the existence of a difference in the forest value from a North-South perspective. The investigation of an economic assessment of FES is advised as a key research trend in the immediate future. This allows to close the gap between the global North and South and favors the implementation of adequate socio-economic and environmental governance for an efficient forest management.

KEYWORDS

economic value, forest ecosystem services, systematic review, North–South, monetary estimation method, meta regression

Introduction

Ecosystem services (ES) provide different benefits to the human being (Costanza et al., 1997, 2014; Daily, 1997; Faith et al., 2010; Pascual et al., 2010). ES are defined by the Millennium Ecosystem Assessment (MA, 2005) as "the direct and indirect contributions of ecosystems to human wellbeing." Based on the type of benefits provided, ES can be split into groups. At the international level, three different classifications are generally investigated: the Millennium Ecosystem Assessment (MA, 2005); the Economics of Ecosystems and Biodiversity (Kumar, 2010) and the Common International Classification of Ecosystem Services (CICES, 2021). According to the MA classification, ES are considered according to four categories: provisioning, regulating, cultural, and supporting. Provisioning services represent the benefits obtained from the natural environment (e.g., drinking water, timber, wood fuel, and natural gas), while regulating services refer to ecological processes that mitigate natural phenomena (e.g., erosion and flood control regulation, climate regulation, and pollination). Cultural services are considered as non-material benefits, contributing to the cultural, intellectual, and creative development of people and communities (e.g., cultural, spiritual, and recreation). Supporting services identify natural process services (e.g., nutrient and water cycling, primary production), which provide life on Earth. Without supporting services, ES would be unable to provide provisioning, regulating, and cultural services.

Based on its biophysical characteristics, each ecosystem provides part or all of the above-mentioned services. Three ecosystem categories are considered worthy of investigation by the international debate such as terrestrial, fresh water, and marine ecosystems (Maes et al., 2016). Among terrestrial ecosystems, forests cover about 31% of the global surface (FAO and UNEP., 2020). Approximately 20% of this amount is currently under some form of legal protection (World Resources Institute, 2021)[1] such as protected natural areas (PA) (IUCN, 2008), such as natural reserves, wilderness areas, or national parks. Nowadays, PA fulfill the aim to reduce habitat loss and fragmentation (Rylands and Brandon, 2005; Lindenmayer et al., 2006; Ortiz-Lozano et al., 2009), other than ensuring the correct functioning and efficient use of resources for biodiversity protection (Costa et al., 2003; Lindenmayer et al., 2006; Galpern et al., 2011; Panday et al., 2015). Since 2015, while PA have increased at the global level (FAO., 2010), this trend has not been observed in areas with particularly high ecological values. The latter appears often under- or inadequately preserved (Joppa and Pfaff, 2009; Watson et al., 2014). In addition, although it is widely recognized the general importance of forests on human beings, not all forests share the same significance in terms of provision of ecological functions (Foley et al., 2007; Gibson et al., 2011). Primary forests are defined by the Global Forest Resource Assessment (FRA) (FAO., 2015) as: "*naturally regenerated forest of native species where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. Key characteristics include: they show natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure, and natural regeneration processes; the area is large enough to maintain its natural characteristics; there has been no known significant human intervention or the last significant human intervention was long enough ago to have allowed the natural species composition and processes to have become re-established.*" Primary forests cover 26% of the global forest area (FAO., 2015), although in the last 30 years this latter suffered a decrease by 2.5% (Keenan et al., 2015).

Forest ecosystem services (FES) can be defined as the benefits provided by forests to the society such as: carbon sequestration, water purification, timber production, soil conservation, flood regulation (Gibson et al., 2011; Molina et al., 2012; Brown et al., 2013; Yamazaki et al., 2013; Sorribas et al., 2016; Ellison et al., 2017). While it is acknowledged the importance of ecosystems for the global society, their economic value is central to the scientific debate since most benefits lack of a market price (Lant et al., 2008; Turner et al., 2010; Johnson et al., 2012; Ninan and Inoue, 2013a; Froger et al., 2015). A consequent mis-match between demand and supply of ES arises, thus supporting the case for an ES valuation. As for FES, these provide society with a multitude of values in the form of both private and public goods. As a result, their management should be optimized (i.e., assessed) to consider all positive and negative side effects and increase the overall contribution of forests to the collective wellbeing (Schroder et al., 2016). The ES assessment, which proceeds with the identification of externalities and the consequent computation of monetary costs and benefits, leads the policy maker to choose between relevant alternatives (i.e., ES valuation) for an efficient management of ecosystems. Pisani et al. (2021) argue that improving and spreading the monetary valuation of forest and protected areas may be a viable solution to guarantee an efficient management of ecosystems, ES, and biodiversity.

Over time, different valuation techniques have attracted the attention of scholars and scientists. These techniques consider *price and value estimation methods*. The former is also known as *market price methods;* the latter as *non-market valuation methods* (Bateman et al., 2002, 2010; Pearce et al., 2006; Nelson and Kennedy, 2009; Christie et al., 2012; Baker and Ruting, 2014; Freeman et al., 2014). In price estimation methods, the economic value is an expression of the market price of the goods under study or similar goods (e.g., *market price*, *restoration cost*, *damage cost avoided*, *shadow price,* or *mitigation cost*) (Wilson and Carpenter, 1999; Hussain and Badola, 2010; Bellver-Domingo et al., 2018; Chen and Wu, 2018; Markandya et al., 2018). In contrast, *value estimation methods* refer to consumer preferences and the theory of value of Lancaster (1966). This theoretical approach, based on the principle that all goods have their own features or attributes, takes into account the utility (i.e., the level of satisfaction) provided by each attribute associated with the consumption of given quantities of the goods (Monica et al., 2008; Baker and Ruting, 2014). Generally, value estimation models make use of direct or *stated*

1 https://www.wri.org/

preferences such as *contingent valuation* (Champ et al., 2005; Tao et al., 2012; Cook et al., 2020) and *choice experiment approaches* (Scarpa et al., 2007; Shen et al., 2015; Alcon et al., 2020; Andrews et al., 2021; Ureta et al., 2021) and indirect or *revelated preferences* such as *hedonic price* (Lansford and Jones, 1995; Sander and Haight, 2012; Catma, 2020; Moore et al., 2020), *travel cost* (Alberini and Longo, 2006; Bertram and Larondelle, 2017; Cetin et al., 2021; Mäntymaa et al., 2021), and *defensive expenditure models* (Costanza et al., 2008; Zhang and Mu, 2018; Akmal and Jamil, 2021).

In addition, the *benefit transfer method*, which does not belong to the above classification, considers the economic value as a proxy from the assessment result of similar studies (Robinson, 2002; Liu and Costanza, 2010; Johnston et al., 2015; Xu et al., 2020; Zhou et al., 2020).

Given the above, forests contribute to human health (Foley et al., 2005; Díaz et al., 2019), satisfaction of materials (e.g., food, water and timber) and psychological needs (Frumkin, 2001; Wilson, 2001). However, the increase of anthropological pressures threatens the ecosystem health and, consequently, the ecosystems' capacity to provide quality benefits to the society (Maller et al., 2008; Dakubo, 2011; Lemieux et al., 2012). Several studies have investigated the drivers that influence the economic value of ES (Costanza et al., 1997, 2014; Zhongxin and Xinshi, 2000; Sutton and Costanza, 2002; de Groot et al., 2012). Focusing on FES, different studies both at global (Ninan and Inoue, 2013a; Acharya et al., 2019) and national levels (Ninan and Inoue, 2013b; Grammatikopoulou and Vačkárová, 2021; Taye et al., 2021; Kang et al., 2022) suggest that bioma, ES type, and GDP have a significant influence on their economic value. But none of these studies consider an ES quality condition and the spatial factor (i.e., being in the North or South of the world) as key explanatory variables of the FES value.

The present paper aims to investigate potential drivers of the FES value at global level through a meta-regression analysis. It employs a panel of 57 studies and analyses a sample of 478 observations retrieved by the Ecosystem Service Valuation Database (Ecosystem Service Valuation Database, 2021)[2] (de Groot et al., 2012). The latter is one of the most widely used database on ecosystem service valuation (ESV) and comprises data from 1992 to 2021[3].

The remainder of the work is structured as follows: straightforward, we describe the methodology; next, we offer a description of the obtained results; and finally, the last section discusses and concludes.

2 https://www.esvd.net/login/esvd

3 The use of the ESVD database facilitated the building of the final dataset. This is because it provides the economic value of ES normalized to the same value unit such as the US$ per hectare per year in 2020 price ($/ha/year).

Methodology

The construction of the dataset and the consequent inferential analysis follows three steps: (i) creation of a database identifying relevant FES articles provided by the ESVD; (ii) addition of variables useful for the meta-regression analysis which are not present in primary studies; and (iii) estimation of the regression model.

Data collection

From the ESVD, all studies are selected according to the following categories: "*Tropical Forest*", "*Temperate Forest*," or "*Woodland and Shrubland*." The initial dataset comprises 1,654 observations from 140 studies. After a screening process[4], a sample of 569 observations from 58 articles is obtained.

Dataset compilation

While the ESVD provides adequate information about ES valuation, it does not contain socio-economic details of the country where the studies were conducted. To overcome this lack, data such as population density and GDP from the World Bank online resources[5] are added. Also, to harmonize the latter information with the ESVD data, a dataset normalization process to the base year 2020 is performed. Finally, to include the spatial dimension, the sample follows the North–South division proposed by the International Monetary Fund (IMF, 2021) and the United Nations (UN)[6] This is based on GDP and current prices and considers three types of economies: advanced, emerging and developing economies[7] and emerging and developing economies[8]. Therefore, in the present study, the North is represented by advanced economies and the South consists of emerging and developing economies, respectively.

Meta-regression model

To identify and handle potential outliers the interquartile range criterion is useful for the purpose of the analysis (Schwertman et al., 2004). According to this criterion,

4 Double counting ($n = 24$); publication year before 2000 ($n = 26$); global economic valuation ($n = 5$); lack of any economic valuation ($n = 473$); lack of protection status ($n = 132$); and lack of ES quality ($n = 425$).

5 https://data.worldbank.org/

6 https://www.imf.org/external/datamapper/NGDPD@WEO/WEOWORLD/ADVEC

7 Not present in the list of least developed countries (LDC) of the UN.

8 Present in the list of LDC of the UN.

exceptionally small outliers by Q1–1.5*IQR and exceptionally large outliers by Q3 + 1.5*IQR are identified, where $IQR =$ Q3–Q1 and Q1 and Q3 are the first and third quartiles of the value distribution, respectively. This process drops further 91 observations. The final sample for the meta-regression analysis comprises 478 observations from 57 studies.

Table 1 shows the dependent (y) and explanatory (x) variables included in the meta-regression model. The dependent variable (y) is a vector of US$ per hectare per year expressed at the 2020 baseline price year. In terms of explanatory variables, the model considers socio-economic characteristics (x_{sec}), study characteristics (x_{sc}), and ES or bioma characteristics (x_{bc}).

Since the ES classification offered by the ESVD follows the TEEB classification, the ES or bioma characteristics (x_{bc}) are grouped into six classes: provisioning services such as provisioning timber biomass (raw materials) and other provisioning (*food, water, genetic resources, medicinal resources, and ornamental resources*); regulation services such as atmospheric regulation (*air quality regulation, climate regulation, and moderation of extreme events*) and other regulation (*regulation of water flows, waste treatment, erosion prevention, maintenance of soil fertility, pollination, and biological control*); maintenance services (*maintenance of life cycles and maintenance of genetic diversity*); and cultural services (*aesthetic information, opportunities for recreation and tourism, inspiration for culture, art and design, information for cognitive development, existence, and bequest values*).

The study characteristics (x_{sc}) consider the following valuation methods: benefit transfer (value transfer); cost-based (*damage cost avoided, defensive expenditure, opportunity cost, replacement cost, and restoration cost*); price-based (*market price*); production-based (*net factor income, production function, and public pricing*); stated preference (*choice experiment, contingent valuation, and group valuation*); and revealed preference (*hedonic price and travel cost*) and other (*other*)[9].

The functional form to estimate the meta-regression model is a semi-log function as specified in Equation 1:

$$\log\left(\mathbf{y_i}\right) = \alpha + \beta_{\text{sec}}\mathbf{x_{seci}} + \beta_{\mathbf{sc}}\mathbf{x_{sci}} + \beta_{\mathbf{bc}}\mathbf{x_{bci}} + \varepsilon_{\mathbf{i}} \quad (1)$$

where α represents the constant term, β vectors are the coefficients of the independent variables to be estimated, ε is a vector of independently and identically distributed residuals, and i is the considered study.

Results

Table 2 shows the estimated results of the inferential model. Since the Breusch–Pagan test (109.52 p-value = 0.000) is statistically significant and rejects the null of a homoskedastic model[10], the re-estimated model in Table 2 uses robust standard errors.

In terms of socio-economic characteristics, different estimated coefficients show a statistically significant effect. First, the value of FES was between the North (−) and South (+) of the world. This increases if studies are carried out in the South and vice versa. Second, the *scale* (i.e., when studies are conducted at the national level) positively affects the economic value of FES. Opposite results appear for *population density*, as it negatively affects the FES value.

As for the study characteristics, the variable *year* presents an estimated negative impact on the economic value as suggested by the international literature (Chaikumbung et al., 2016; Taye et al., 2021). As a result, more recent studies value FES less than older studies. This may be due to some refinement of statistical software employed in the analyses. In addition, the use of *production-based methods*, *cost-based methods*, and *the benefit transfer* tends to have a positive impact on the estimated economic value of FES compared to reference methodologies (*revelated methods* and *other* methodologies).

In terms of biome, *Temperate* FES shows a positive effect on the estimated economic value compared to *Woodland and Shrubland* FES. A similar result is obtained by *atmospheric regulation*. Finally, the main results suggest that compared to a *high* (quality) *condition*, the magnitude of a *low* ES quality *condition* is higher than that provided by a *medium* (quality) *condition* on FES values.

Discussion and conclusion

The present study offers a meta-regression analysis of scientific articles published during the time period 1992–2021 dealing with the economic valuation of FES. Given the importance of ES for the sustainable growth of the actual society, the main aim of the present work provides an overview of the existing difference between the global North and South in terms of the economic value of FES.

Main findings show the existence of this difference in favor of Southern countries. Hence, emerging and developing economies as countries belonging to the South of the World

9 This label is provided by default by the ESVD database.

10 We checked for multicollinearity by examining the coefficients of the variance inflation factor (VIF) as follows: *North: 4.142; Temp: 4.274; Trop: 4.138; Provisioning_other: 2.701; Regulation_atmospheric: 2.449; Regulation_other: 4.063; Mantainence: 1.198; Cultural 2.718; Scale national: 2.612; Partially protected 2.772; Protected: 3.272; ES condition low: 1.972; ES condition medium: 3.253; Price Based: 6.442; Production Based: 2.124; Cost Based: 5.117; State Preference based: 3.060; Benefit Transfer: 1.979; Year: 2.110;Population density: 2.025; GDP: 2.146. In a subsequent step, we removed the variables with a VIF>5.0* (Menard, 2001; James et al., 2013).

TABLE 1 Variables included in the model.

Variable	Description of variable	Mean	SD	No. obs
Socio-economic characteristics				
GDP per capita	Log of GDP per capita	4.310	4.142	478
Population density	Log of population density	5.211	2.446	478
North	Dummy: 1 = if the study was conducted in norther country; 0 = otherwise	0.127	0.334	61
Scale_local (R1)	Dummy: 1 = if the study has a local scale; 0 = otherwise	0.941	0.235	450
Scale_national	Dummy: 1 = if the study has a national scale; 0 = otherwise	0.058	0.235	28
Study characteristics				
Year	Year of valuation	2010	7.121	478
Benefit transfer	Dummy:1 = Service valued by benefit transfer method; 0 = otherwise	0.050	0.218	24
Cost based	Dummy:1 = Service valued by cost-based methods; 0 = otherwise	0.301	0.459	144
Price based	Dummy:1 = Service valued by price-based methods; 0 = otherwise	0.338	0.473	162
Production based	Dummy:1 = Service valued by Production based methods; 0 = otherwise	0.050	0.218	24
State preference based	Dummy:1 = Service valued by stated preference methods; 0 = otherwise	0.154	0.362	74
Revelated preference based Other (R2)	Dummy:1 = Service valued by revelated methods or other methods; 0 = otherwise	0.104	0.306	50
Bioma/ES characteristics				
Tropical Forest	Dummy:1 = Tropical forests; 0 = otherwise	0.780	0.414	373
Temperate Forest	Dummy:1 = Temperate forests; 0 = otherwise	0.161	0.367	77
Woodland and Shrubland (R3)	Dummy:1 = Woodland and Shrubland; 0 = otherwise	0.058	0.235	28
ES condition low	Dummy:1 = ES condition low; 0 = otherwise	0.142	0.349	68
ES condition medium	Dummy:1 = ES condition medium; 0 = otherwise	0.556	0.497	266
ES condition high (R4)	Dummy:1 = ES condition high; 0 = otherwise	0.301	0.459	144
No protection (R5)	Dummy:1 = no protection; 0 = otherwise	0.196	0.397	94
Partially protected	Dummy:1 = Partially protected; 0 = otherwise	0.232	0.422	111
Protected	Dummy:1 = Protected; 0 = otherwise	0.571	0.495	273
Provisioning_timber (R6)	Dummy:1 = Timber provision; 0 = otherwise	0.136	0.343	65
Provisioning_other	Dummy:1 = Other provisioning services 0 = otherwise	0.326	0.469	156
Regulation_atmospheric	Dummy:1 = Atmospheric regulation services; 0 = otherwise	0.117	0.321	56
Regulation_other	Dummy:1 = Other regulation services; 0 = otherwise	0.259	0.438	124
Mantainence	Dummy:1 = Maintenance services; 0 = otherwise	0.014	0.120	7
Cultural	Dummy:1 = Cultural services; 0 = otherwise	0.146	0.353	70

R1: is locale scale studies; R2: is valuation by revelated based methods or other methods; R3: is Woodland and Shrubland forests; R4: is ES condition high; R5: is forest under no protection; R6: is timber provisioning services.

TABLE 2 Estimated results of the model with robust standard errors.

	Coefficient	Std. err	Prob.
GDP per capita	0.446	0.288	0.122
Population density	−0.0225	0.122	0.067
North	−2.556	0.679	0.000
Scale_national	3.585	0.769	0.000
Year	−0.125	0.022	0.000
Benefit Transfer	1.348	0.735	0.067
Cost based	2.061	0.565	0.000
Price based	−0.452	0.653	0.488
Production based	2.359	0.723	0.001
State preference based	−0.377	0.600	0.530
Tropical Forest	0.223	0.553	0.686
Temperate Forest	2.258	0.591	0.000
ES condition low	1.140	0.478	0.017
ES condition medium	−1.895	0.448	0.000
Partially protected	0.384	0.424	0.364
Protected	0.299	0.412	0.467
Provisioning_other	−0.298	0.351	0.396
Regulation_atmospheric	1.042	0.555	0.060
Regulation_other	0.328	0.468	0.483
Maintenance	−0.425	0.748	0.569
Cultural	0.406	0.519	0.434
Constant	250.598	44.864	0.000
No of observations	478		

R1: is local scale studies; R2: is revealed methods and other method; R3: is Woodland and Shrubland forests; R4: is ES condition high; R5: is forest under no protection; R6: is timber provisioning services.

seem to have a larger FES economic value than advanced economies. This may be due to a number of reasons mainly cultural or structural, but this goes beyond the scope of the present research.

The second novelty factor with respect to the existing literature, is to consider the quality condition of ES. Estimated results show as this aspect presents contrasting effects on the FES value. Generally, the presence of a high-quality condition, for example, provides a positive effect compared to a medium one. Several studies on marine ES (Andreopoulos et al., 2015; Dias and Belcher, 2015; Remoundou et al., 2015) or FES (Owuor et al., 2019), associate a high economic value to these ES when their quality is good/high. In contrast, estimated results show how the magnitude of *low* ES quality condition is higher than that provided by a *high* (quality) *condition* on FES values. An argument in support of this result is that people perceive FES as a valuable resource when it is scarce or when its quality is low. Also, a positive effect on the FES value is provided by the valuation of atmospheric regulation. This result may be due to the rising interest of the international community for climate change issues since the publication of the first report of the Intergovernmental Panel on Climate Change (IPCC) (Acharya et al., 2019; Taye et al., 2021). An exception to the above analysis is the GDP per capita which is not statistically significant (Taye et al., 2021; Kang et al., 2022). From a North–South perspective, the present study asserts the existence of a difference in the economic value between southern and northern FES. From an ecological point of view, this outcome is supported by the presence of primary forests (almost 80%) (FAO., 2015) which are predominant in the global South. Nonetheless, the global South performs the highest deforestation rate (Hansen et al., 2013; FAO., 2015). A viable solution to reduce deforestation rates in primary forests of the global South may be to increase PA, both in size and number, as these forests often appear under- or inadequately preserved (Joppa and Pfaff, 2009; Watson et al., 2014). It is worth noting that although the estimated coefficient of PA is not statistically significant, this explanatory variable has contrasting results also in the international literature (Getzner and Islam, 2020; Grammatikopoulou and Vačkárová, 2021; Taye et al., 2021). As a consequence, an increase in total forest areas is also desirable to allow the creation of PA which are worthy of ecological importance (Morales-Hidalgo et al., 2015). To achieve this, not only adequate economic incentives should be provided in support of an efficient management of FES, but also the recognition of multiple and plural values offered by PA to local communities through continuous learning and participatory practices (Martin et al., 2014). These activities would reconcile PA with equity and conservation goals by letting the members of local communities to create an authentic participatory decision-making approach through the assessment of their views, reduce ecological and economic vulnerabilities and increase distributional effects from biodiversity and conservation strategies. Governing PA as a socio-ecological system as a whole creates opportunities to overcome the traditional dichotomy between humans and nature, and promotes environmentally friendly justice prospects to help in creating a resilient framework in the global South (Loos, 2021).

Finally, this research is not without limitations. First, the choice to use certain variables could have limited the number of studies to consider in the dataset. For example, the quality of ES is retrieved as a normalized value from the ESVD database. The addition of other information about this variable would have been impossible to perform and/or adapt to the database. Second, the forest size (even if present in other studies) was omitted due to a high number of missing observations.

Nonetheless the above limitations, the present study suggests that the spatial dimension and ES quality are important drivers contributing to the current debate on the economic valuation of FES. This would help the policy maker to develop *ad hoc* policies (e.g., financial incentives such as payment for ecosystem services schemes) and tools based on the geographic location of the area under study and its territorial characteristics. As a result, further investigations of economic assessments of FES are advised as a key research trend in the immediate future.

Author contributions

CD and PP supervised this work. DP provided the writing, methodology, data handling, investigation, and visualization of the present work. All authors approved the submitted version.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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