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The economic valuation of ecosystem services in Colombia. Challenges, gaps and future pathways

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ABSTRACT

This paper provides a comprehensive assessment of the economic values for ecosystem services (ESs) in Colombia. Were analyzed 154 studies that estimated economic values for 21 ESs in 18 general ecosystems. In total, 502 values were coded and classified according to the Common International Classification of Ecosystem Services – CICES. Despite being a technique that is not based on primary economic valuation information, Benefits transfer was the most common method used to estimate the value of ESs in Colombia, followed by market prices and contingent valuation. Opportunities for recreation and tourism, climate regulation, habitat conservation, and water have been the most valued ESs. Many important ESs remain unnoticed and are not adequately accounted (e.g. pollination). Additionally, 53% of the information available on the economic values of ESs is concentrated in only 5 of the 32 Colombian departments. Finally, this review highlights the multiple challenges of Colombian academics and practitioners to improve the economic valuation practice and complement and recognize the multiple social relationships and the multiple views in terms of the values nature has.

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Introduction

Ecosystem services (ESs) are the opportunities and benefits humans obtain from natural capital (MEA 2005; Braat and de Groot 2012; de Groot et al. 2012; Pandeya et al. 2016). As the ES approach to support decision-making gains momentum worldwide, ES valuation becomes more widely applied (Acharya, Maraseni, and Cockfield 2019; de Groot et al. 2010b; Liu et al. 2010). The purpose of ES valuation is to provide knowledge about the value of ecosystems and their services as a contribution to environmental decision-making (Kenter et al. 2015). A common approach for ES valuation relies on monetary valuation, which provides easily interpretable information as a reference for decision-making. In this line, the concept of ESs appeared as a means to improve communication and the conservation of the environment (Daily 1997; Mononen et al. 2016).

In the context of ES, Economic valuation (EV) is a procedure of expressing nature contributions in monetary value (Farber, Costanza, and Wilson 2002), appraises both use and non-use values, and

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helps decision and policymakers to identify, evaluate, and estimate trade-offs with other sustainable goals (Balmford et al. 2002; Christie and Rayment 2012). Therefore, understanding the knowledge (and practice) state of Ecosystem Services Economic Valuation (ESEV) is a fundamental task. However, despite substantial advances in methods and applications, economic valuation has also been subject to many critiques (Vatn and Bromley 1994; Spangerberg and Settele 2010; Pascual et al. 2017). Since the main reason for ES values is to support decision-making (Sukhdev 2008; Balmford et al. 2011; Laurans et al. 2013; Costanza et al. 2014), a growing concern has developed among researchers and practitioners regarding the implementation and impact of valuation in "real world" decision settings (Daily et al. 2009; de Groot et al. 2010; Liu et al. 2010; Balmford et al. 2011; Laurans et al. 2013; Rogers et al. 2013). However, despite criticism of this instrumental valuation approach (Wegner and Pascual 2011; Muradian and Pascual 2018), the detection and assessment of both use value and non-use value of ESs are essential for policy interventions and implementation of environmental programs. About this last aspect, it's fundamental to highlight the great push of accounting from UN SEEA EA is opening a new season for ES valuation (Turner, Badura, and Ferrini 2019).

Ecosystem services economic valuation in a megadiverse country

It is important to consider Colombia as an outstanding example for matching the implications of economic valuation initiatives in a megadiverse context. Colombia is located in the northwest section of the South American continent. Among the megadiverse countries, it ranks fourth in plant species richness, fifth place in mammals, first place in birds, third in reptiles, and second in amphibians, freshwater fish, and butterflies. More than 1000 species are threatened by anthropic actions (Andrade 2011; Ruiz-Agudelo and Cortes–Gómez 2021). Corresponding to the continental, coastal, and marine ecosystems map (IDEAM 2018), Colombia has 98 general ecosystems (74 and 24 of these systems correspond to natural and transformed ecosystems, respectively) and more than 8,000 specific ecosystems.

Despite this Colombian mega-diversity, multiple factors have interacted to shape the natural environment's transformation history (Ruiz–Agudelo and Bello 2014; Ruiz-Agudelo 2016; Ruiz-Agudelo et al. 2020; Ruiz-Agudelo and Cortes–Gómez 2021). According to Armenteras et al. (2017), ecosystem loss in Colombia has been driven by multiple changing forces in recent years. The main transformation drivers of natural ecosystems are the expansion of the agricultural frontier (Etter et al. 2006) and transformation of the natural forest into pastures for livestock to graze (Armenteras et al. 2013). Other causes of local transformation include road and human settlement constructions (Armenteras et al. 2011; 2013; 2017; Dávalos et al. 2014). Over the last several decades, illegal activities have also been part of the driving forces behind biodiversity loss, mainly through the expansion of illegal crops (Dávalos et al. 2011), mining (Chadid et al. 2015), and logging (Armenteras et al. 2013) and decades of armed conflict (Suarez, Árias-Arévalo, and Martínez-Mera 2018).

Therefore, it is important to consider the Colombian context and the relevant progress that has been made in recent years in the economic valuation of ecosystem services (e.g. de Groot et al. 2012; Hernández-Blanco et al. 2020; Kubiszewski et al. 2013; Costanza et al. 2014; Frélichová et al. 2014; Mastrangelo et al. 2015; Kubiszewski et al. 2017; Lara-Pulido, Guevara-Sanginés, and Arias-Martelo 2018). Literature reviews and databases have recently been developed to concentrate and systematize the economic values of ecosystem services estimated by thousands of authors. In this line, at the global level, de Groot, Brander, and Solomonides (2020) present an update of the Global Ecosystem Service Valuation Database (ESVD), with 4,809 economic values of ESs records. According to Lara-Pulido, Guevara-Sanginés, and Arias-Martelo (2018), this type of literature is usually concentrated in a few countries. For example, the ESDV (December 2020) has only 19 records of economic valuation Colombian studies, concentrated in the coastal ecosystems.

In the Colombian case, the sources that consolidate initiatives of ES have been insufficient. There exist only two important sources of information-oriented to synthesize the information about the economic valuation of ESs. The first one is presented by Ruiz-Agudelo and Bello in 2014, concentrated on mountain ecosystems. Using various sources of information, the literature about the economic valuation of ESs in Colombia was revised. Ruiz–Agudelo and Bello's (2014) research, analyze the diversity and trends of value estimations, identify research gaps, and suggest directions for future research, and its use in socioenvironmental decision-making. The second is the national assessment of ecosystem services launched in 2021 (Gómez-S et al. 2021) which identify some economic valuations of ES. However, there is still a gap regarding the consolidation of the pros and cons of ES economic valuation in the context of Colombia.

Therefore, considering that ES valuation could produce information for decision-makers, the aim of this paper is to consolidate the approaches of economic valuation generated in Colombia in the last years, in order to highlight the challenges, the gaps, and the future directions that ES valuation proves should follow to promote ecosystem conservation.

Methods

In order to identify the body of literature regarding Economic Values of Ecosystem Services (EVES), a systematic literature review was conducted. In this review, were followed fours steps. First, literature searching, second, the definition of criteria for selecting study cases, third, a standardization of the EVES and finally, the generation and classification of a database.

Literature search

(1) **National and international peer-reviewed journals.** A systematic literature search was conducted using journal papers that contained the following search terms (in English and Spanish): Ecosystem services, economic valuation, valuation, Colombian ecosystems, biodiversity, ecosystem services valuation, ecosystem valuation, human well-being valuation, Amazon region, the Caribbean region, Pacific region, Chocó region, Andes region, Orinoquia region, coastal areas, insular areas. Papers were sourced from the following science databases: Science Direct, SCOPUS, SCIELO, ISI Web of Knowledge, web of science, DIALNET, EBSCO, REDALYC, and Google Scholar.
(2) **Technical reports of Government environmental institutions.** Document bases of the following Colombian Government institutions were reviewed: Ministry of Environment and Sustainable Development (MADS), Regional Environmental Authorities, National natural parks of Colombia, Biological Resources Research, Institute Alexander von Humboldt (IAvH Institute), Amazon Institute of Scientific Research (SINCHI Institute), Pacific Environmental Research Institute (IIAP Institute) and Institute of environmental studies (IDEAM).
(3) **University Collections**. The web and several university (national or international) collections of books, theses, and working papers, in both Spanish and English. We checked if documents availability was relatively easy and open to the public.

Case studies selection criteria

We defined a series of selection criteria based on Ruiz–Agudelo and Bello (2014): (a) they must have been conducted in Colombia; (b) be a practical case study (theoretical approach documents were not included in this research); (c) provide information about the valuation method used; (d) provide a monetary value of a given ecosystem service and (e) provide the location of the case study.

It is important to highlight that of the 154 case studies identified in this review, 19 correspond to the benefit transfer method (203 of 506 EVES – Economic Values of Ecosystem Services). Additionally, it is not superfluous to emphasize that the benefits transfer method is not a primary valuation method. However, according to D'Alberto et al. (2021), Benefit Transfer (BT) allows transferring the EVES from existing studies (study sites) to the policy site of interest. The two most applied BT approaches are value and function transfer. The former uses a measure of central tendency distribution such as the mean or the median, transferring it by eventually adjusting for the policy site characteristics. Function transfer is based on the estimation of the EVES function at the study site and on the subsequent transfer of the estimated coefficients at the policy site where the EVES is predicted using independent variables from secondary data. For the Colombian case 18 of the 19 case studies apply for values or functions transfer. Only the contribution by Ruiz–Agudelo and Bello (2014) considered transfer through Meta regressions.

One of the relevant concerns with the application of the BT method is the relative validity of value or function transfer that depends on several aspects with respect to which the literature on the topic is not conclusive (Czajkowski et al. 2017; Artell, Ahtiainen, and Pouta 2019). First, the transfer validity depends on the consistency and accuracy of the original estimates (Lloyd-Smith, Zawojska, and Adamowicz 2018). Second, the relative validity of the transfer depends on how much the utility function is adapted to the policy site characteristics. Then, function transfer should be better equipped to represent the heterogeneity of the individuals' preferences than value transfer (Rosenberger 2015). Finally, how to properly reproduce the preferences heterogeneity at the policy site is still an unsolved BT challenge: choosing a functional form often leads to misrepresenting the EVES distribution.

Aware of these controversies and complexities, we evaluated in detail the 19 BT case studies identified in this review, finding that 17 of them (199 EVES) present a clear methodology and are based on global databases (p.e., de Groot et al. 2012; Costanza et al. 2014), or in original studies from Central and South America with a consistent methodology. For this reason, they are included in this review. The two remaining studies (Ruiz–Agudelo and Bello 2014; Piraquive-Quesada and Velasquez-Loaiza 2018) that correspond to four EVES, are based on other original studies carried out in Colombia, in fact also identified in this review. For this reason, and to avoid potential double accounting, these two studies and their four EVES were excluded from the analyses of this research.

Value standardization

For this research, the standard unit is Int.$2020 (USD adjusted for differences in purchasing power across countries), per hectare, and per year. The standardization process consists of five steps to address each of these five components: price level, currency, spatial unit, temporal unit, and beneficiary unit.

Price level standardization

The selected base year for price levels in this research is 2020. This standardization was performed using available domestic price indices or GDP deflators that measure the annual rate of price change in an economy. Colombian GDP deflators were obtained from the World Bank´s World Development Indicators (https://datatopics.worldbank.org/world-development-indicators/).

The formula for this adjustment is (de Groot, Brander, and Solomonides 2020a):

$$V_{2020} = V_t(D_{2020} \;/\; D_t) \tag{1}$$

Where:

$V_{2020} =$ Value observation at 2020 price level.
$V_t =$ Value observation at study year price level.
$D_{2020} =$ Colombian GDP deflator index for the base year 2020.
$D_t =$ Colombian GDP deflator index for the study year.

Currency standardization

The selected common currency for this research was the international Dollar (Int$), which represents the value of the US dollar in the United States in terms of purchasing power. Converting Colombian pesos (COP$) to Int$ involved using purchasing power parity adjusted exchange rates, which are available from the World Bank´s World Development Indicators.

The formula for this adjustment is (de Groot, Brander, and Solomonides 2020a):

$$V_{Int\$} = V_{Lc} \text{ x } FX_{ppp} \tag{2}$$

Where:

$V_{Int\$} =$ Value observation in Int$.

$V_{Lc} =$ Value observation in local currency (COP$).

$FX_{ppp} =$ Purchasing power parity adjusted exchange rate between the local currency and the USD.

Spatial unit standardization

According to our review, the value observations are being reported for different spatial dimensions of the ecosystem that provides the service, primarily either per unit area of the ecosystem (value/hectare of forest or ecosystem, 85% of our data for Colombia), per unit length of the ecosystem (value/km of river or shoreline, 10% of our data for Colombia), and for the total spatial extent of the ecosystem (5% of our data for Colombia).

In order to compare and synthesize value observations, it was necessary to standardize values to the same spatial units. The selected common unit of area was one hectare since this is widely used in other value databases and publications (de Groot, Brander, and Solomonides 2020a). Converting values reported in other areal units involved multiplying them by an appropriate conversion factor, following the methodological recommendations of de Groot, Brander, and Solomonides (2020a). The conversion factors for areal units to hectares were: 1) – Square feet (Factor = 107,640). 2) – Square meters (Factor = 10,000). 3) – Acres (Factor = 2.471). 4) – Square kilometres (Factor = 0.01). 5) – Square miles (Factor = 0.003861). Values that are reported per unit of length of the ecosystem can use multiple different units (e.g. feet, meters, kilometers, miles, etc.). The selected common unit of length is one kilometer since this is used widely used in other value databases and publications. Converting values reported in other units of length involves multiplying them by an appropriate conversion factor.

Temporal unit standardization

The selected unit of time is one year (de Groot, Brander, and Solomonides 2020a). Values reported as present values over a specified period of time were converted to annual values by using the discount rates quoted in the study. When the discount rate is not quoted, we applied 3% in accordance with Mejia et al. (2012) and Maldonado et al. (2013).

Beneficiary standardization

For the Colombian case, it was necessary to standardize values to the same specification of the beneficiary. The selected specification was the total population of beneficiaries. This can also be described as the ‘market size’ or ‘economic constituency’ for the ecosystem service in question (de Groot, Brander, and Solomonides 2020a). For value observations reported per visitor, it was necessary to multiply the economic value reported in the study by the total number of visitors. Similarly, for value observations reported per person or per household, it was necessary to multiply the economic value reported by the total number of people or households that benefit from the ecosystem service. 75% of the cases included in this review reported the relevant number of beneficiaries over which to aggregate. For 25% of the remaining studies, secondary information sources were used, especially DANE (National Department of Statistics) (2021).

Database and classification

Key information was recorded for each study, including descriptors for the publication and geographic information (**Supplementary material 1**). For each selected case study, the ecosystem/biome was identified, following the typology of the Colombian continental, coastal, and marine ecosystems map (IDEAM 2018). The ecosystemś names were homologated, according to the IUCN Global Ecosystem Typology 2.0 (Keith et al. 2020). This research applied the CICES V5.1 classification (Young and Potschin 2018) (**Supplementary material 2).** For each value observation in the database, it was necessary to record the specific economic valuation method that had been applied. **Supplementary material 3** detail the categorization of economic valuation methods, based on Brander et al. (2018) and de Groot, Brander, and Solomonides (2020a).

Results

Publication trends. An overview

The number of studies about Colombian ESs economic valuation has increased since 1996. The 154 studies we evaluated included 62 papers (40.3%) in national and international peer-reviewed journals, 48 university theses (31.2%), 37 technical reports of Government environmental organizations (24%), and seven peer-reviewed books (4.5%). Most of the studies were very recent. Seventy-six percent were published in the period between 2013 and 2020, and another 24%, between 1996 and 2009 (Figure 1).

On the basis of the 154 studies (**Supplementary material 1**), we gathered 502 EVES for Colombia (four EVES were excluded to avoid double accounting, as they are based on Benefit Transfer from other Colombian case studies). The Colombian departments with the highest number of EVES were Antioquia (98), Cundinamarca (67), Meta (46), Valle del Cauca (29), and Bolivar (28). These departments contributed with 53% of our current knowledge on ESs economic valuation (Figure 2). Additionally, the collected studies included EVES for 115 municipalities and 191 specific localities.

According to this review, the 502 EVES are represented in 18 general ecosystems. Tropical montane rainforests (34%), tropical lowland rainforests (12%), tropical dry forests (11%), and mangrove

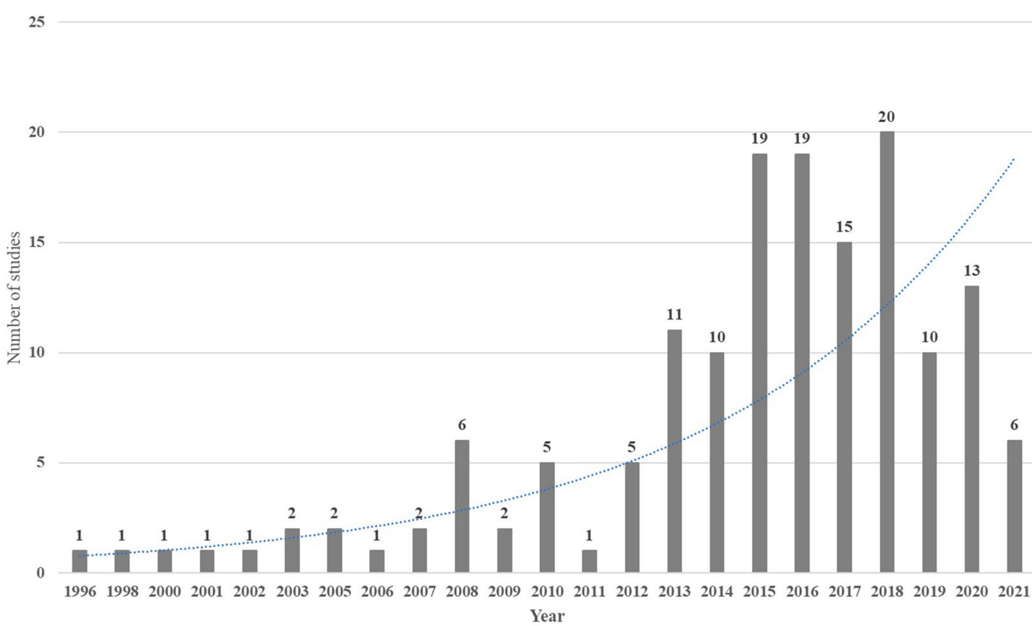

Figure 1. Studies number by publication year.

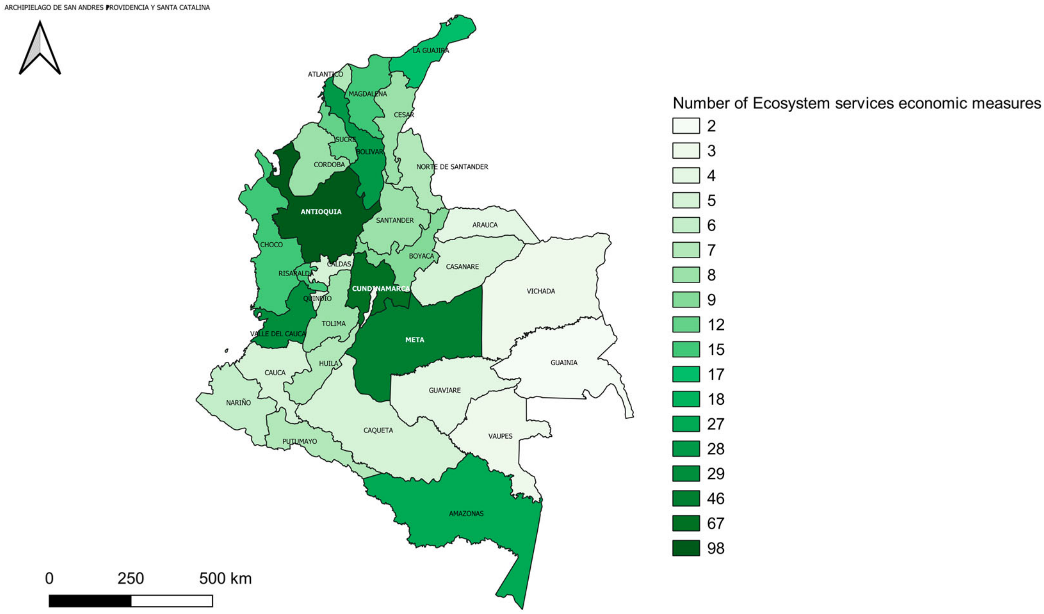

Figure 2. Economic values of ecosystem services (EVESs) by Colombian departments.

swamps (10%) contain 68% of the ESs economic measures (Table 1). On the other hand, general ecosystems such as coral reefs, mountain wetlands, sown pastures and fields, sandy shores, rivers, seagrass meadows, seasonal savanna, plantations, coastal river deltas, open ocean, urban and industrial ecosystems, flooded savanna, and insular areas that represent the 50% (approx.) of the Colombia total extent, represent less than 24% of the ESs economic measures identified in this research (Figure 3).

Valuation methods typology

This review identified eleven economic valuation methods. Value transfer (benefits transfer – 203 EVES – 16 ESs) was the most common method used to estimate the value of ESs in Colombia,

Table 1. Number EVES by Colombian ecosystems.

General Ecosystems	Number of economic values of environmental goods or services (EVESs)	Percentage
Tropical montane rainforests	170	33.9
Tropical lowland rainforests	61	12.25
Tropical dry forests	57	11.46
Mangrove swamp	51	10.08
Páramo	40	7.91
Mountain wetlands	23	4.55
Coral Reefs	19	3.75
Sown pastures and fields	19	3.75
Sandy shores	14	2.77
Rivers	11	2.17
Seagrass meadows	9	1.78
Seasonal savanna	8	1.58
Plantations	4	0.79
Coastal river deltas	4	0.79
Open Ocean	4	0.79
Urban and industrial ecosystems	3	0.59
Flooded savanna	3	0.59
Insular	2	0.40
Total	**502**	**100.00**

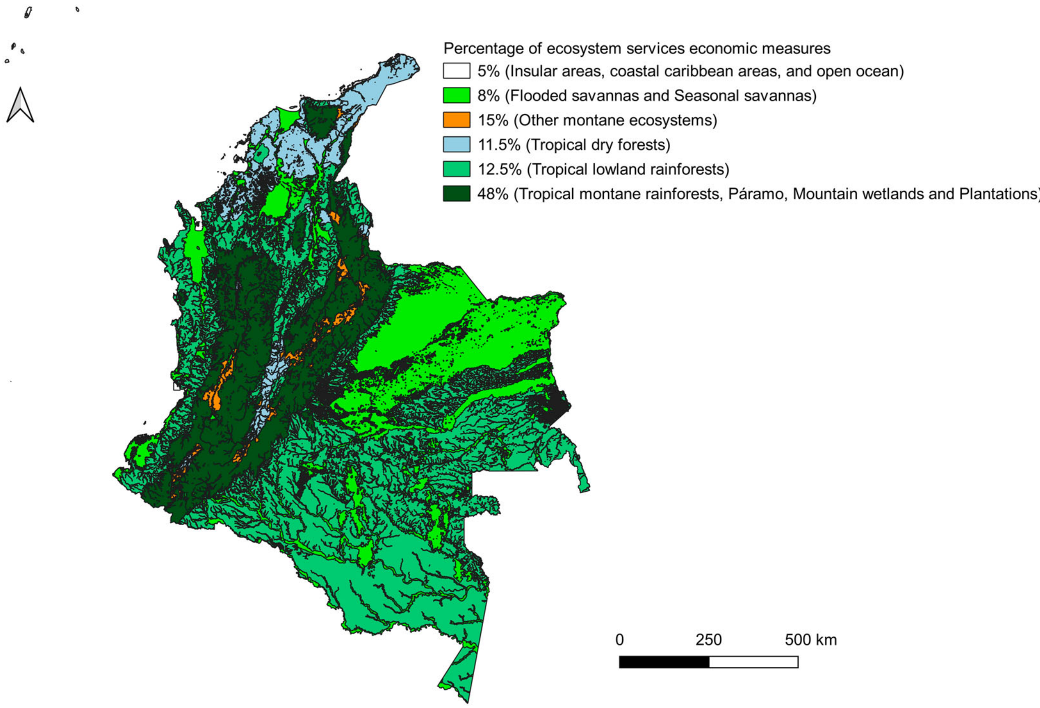

Figure 3. Distribution (%) of EVES by Colombian ecosystems.

followed by market prices (Gross Revenue – 178 EVES – 15 ESs) and contingent valuation (82 EVES – 8 ESs). Other methods, such as group valuation (participatory valuation), input-output modeling, defensive expenditure, and restoration cost, were not commonly used in Colombian economic valuation studies (Figure 4).

Characteristics of ecosystem services

This research identified EVES for 21 ESs in Colombia. Opportunities for recreation and tourism (109 EVES), climate regulation (95 EVES), habitat conservation (90 EVES), and water (74 EVES) have been the most valued ESs in Colombia. Regulating services (9 ESs and 172 EVES) and provisioning services (6 ESs and 130 EVES) are the more commonly valued categories in the Colombian context (Figure 5).

The Colombian departments with the highest number of ecosystem services valued (Figure 6) are Antioquia (with 12 out of 21 ESs identified), Valle del Cauca (12), Bolivar (11), and Cundinamarca (11). Our results show that 50% (16 out of 32) of Colombian departments present less than four economically valued ecosystem services.

Mean standardized values per ES and ecosystem (Int.$2020/hectare/year)

Table 2A shows a summary of the monetary values for each service per Colombian ecosystem (including the 199 EVES from cases that apply Benefits Transfer), which are presented as averages in this table. The ESs with the highest standardized means value were pollination ($231,946 – Int $2020/hectare/year – tropical dry forest) followed by information for cognitive development (Science / Research) ($165,000), habitat conservation ($156,881 – mangrove swamp), biological control ($134,064 – tropical dry forests) and genetic resources ($117,300 – tropical lowland forests). Medicinal resources ($34.28 – mangrove swamp) and maintenance of genetic diversity ($7.32 – tropical montane rainforests) are ESs with the lowest means value.

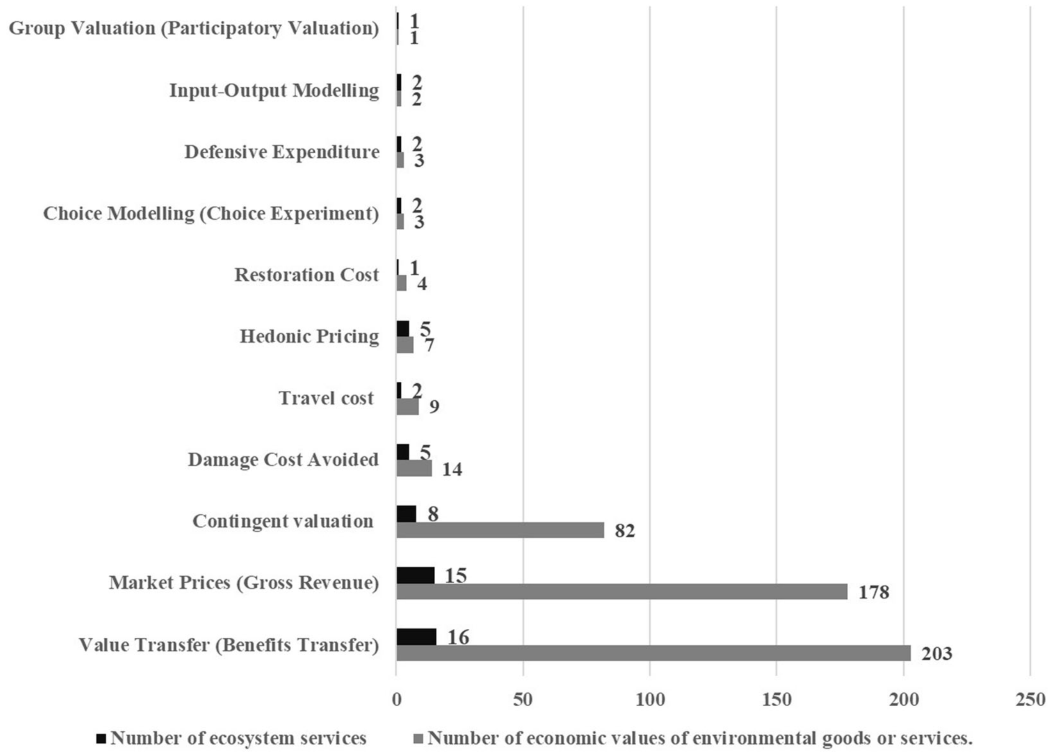

Figure 4. Economic valuation methods applied in Colombia.

Table 2B shows these same values excluding the 199 EVES coming from Benefit Transfer studies. In synthesis, the pattern is the same, only finding some differences in the aggregates for the ecosystems Flooded savanna (38,445.32 Int.$2020/hectare/year), Mangrove swamp (124,824.26 Int.$2020/hectare/year), and Tropical dry forests (417,642.80 Int.$2020/hectare/year).

Table 3 shows a summary of the monetary values of the ESs found for the 18 Colombian ecosystems. This provides a first estimate of the mean value for the bundle of services provided by each Colombian ecosystem. Table 3 shows that the total value ranges between 1.75 int.$2020/year for an average hectare of rivers to almost 422,101.70 int.$2020/year for an average hectare of tropical dry forests.

Discussion

The economic valuation of ESs in Colombia: current status

The results of this review show that the number of studies about the economic valuation of Colombian ecosystem services has increased significantly since 2013. One reason for this growth could be explained by the launching of the national policy of Biodiversity and Ecosystem services management in 2012, which promoted valuation exercises to support decision-making in all the departments of Colombia. An interesting aspect is that 60% of studies are working papers, government/non-government reports, and university theses. This situation is like the one reported by Lara-Pulido, Guevara-Sanginés, and Arias-Martelo (2018) for Mexico. Although the knowledge increase in the economic valuation of Colombian ESs is significant, more efforts are still needed to disseminate (with greater academic rigor) and systematize this information for its use in decision-making. Recently, internationally funded projects are providing this support. For example, the GROW Colombia initiative (https://www.growcolombia.org), focuses on carrying out research

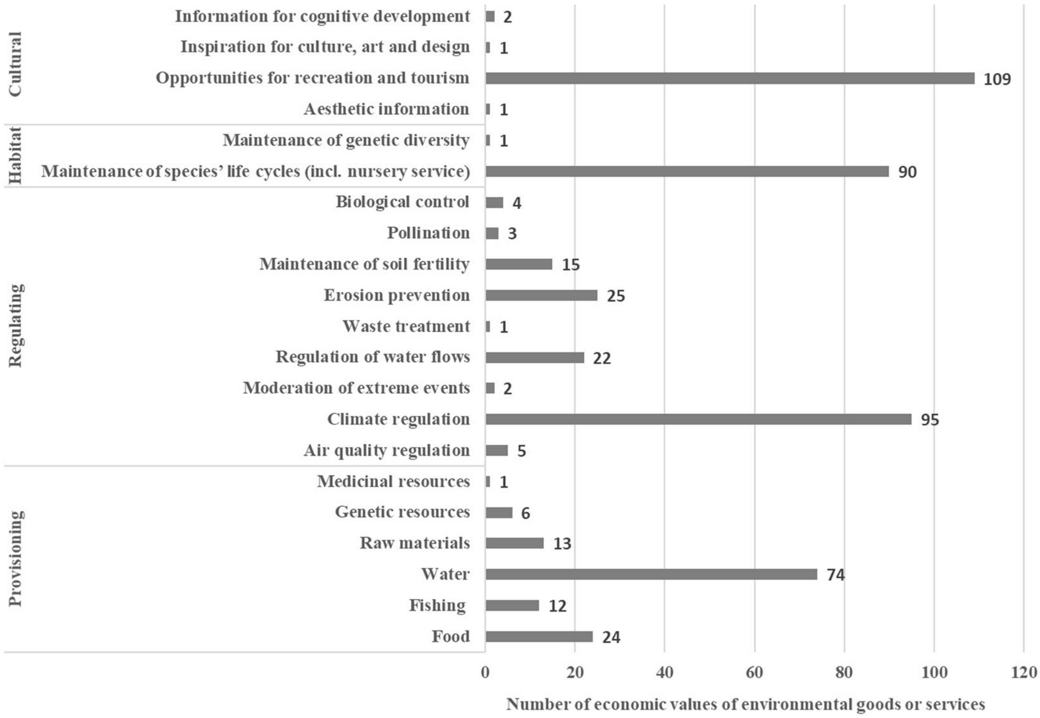

Figure 5. Ecosystem services with economic values in Colombia.

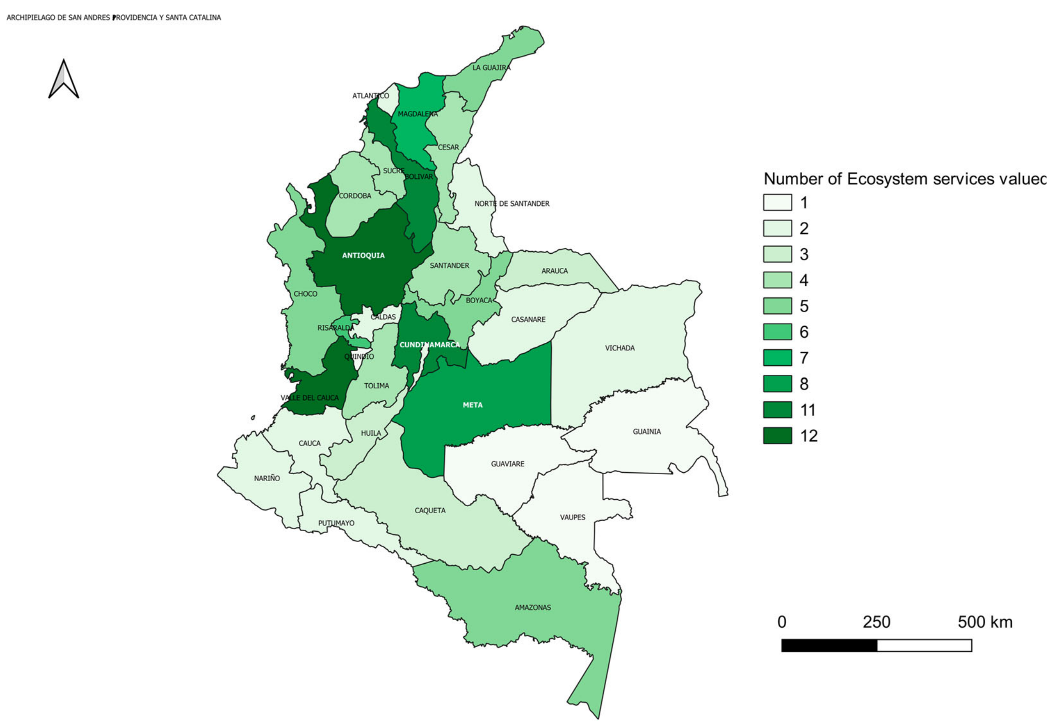

Figure 6. Number of ecosystem services valued by Colombian departments.

Table 2. A. Summary of monetary values for each service per Colombian ecosystem (Int.$2020/hectare/year). Numbers in the cells are averages of the values found for a particular service and Colombian ecosystem. Calculations are based on a total of 502 EVES.

Ecosystem services	Coastal river deltas	Coral Reefs	Flooded savanna	Insular	Mangrove swamp	Mountain wetlands	Open Ocean	Páramo	Plantations	Rivers
Aesthetic information										
Air quality regulation						1,119.27				
Biological control										
Climate regulation					4,420.13	6,161.10		1,262.93	178.85	
Erosion prevention					29,038.74	38.19		4,600.92		
Fishing		8.84			1,761.97					
Food										
Genetic resources					4,339.85			11,260.48		
Habitat Conservation (Maintenance of species' life cycles (incl. nursery service))	63,504.31	127,415.22	6,675.33		156,881.43	118,694.76	1,856.45	53,062.06		
Information for cognitive development							165,000.00			
Inspiration for culture, art and design						130.15				
Maintenance of genetic diversity										
Maintenance of soil fertility										
Medicinal resources					34.28					
Moderation of extreme events										
Opportunities for recreation and tourism		22,458.42		3.87	45.57	3,593.40		164.27		
Pollination										
Raw materials					893.79			13,073.40		
Regulation of water flows					11,952.36	69,634.41		612.06		
Waste treatment										
Water			27,037.39			3,278.19		3,542.20		1.75
Total economic value	**63,504.31**	**149,882.47**	**33,712.73**	**3.87**	**209,368.13**	**202,649.48**	**166,856.45**	**87,578.34**	**178.85**	**1.75**

Sandy shores	Seagrass meadows	Seasonal savanna	Sown pastures and fields	Tropical dry forests	Tropical lowland rainforests	Tropical montane rainforests	Urban and industrial ecosystems
1,195.11							
						8,500.00	6.48
				134,064.80	8.82	38.77	
	2,179.86	141.62	1,023.02	359.63	6,209.68	2,330.08	
46,423.48			2,657.99	4,824.78		1,392.40	
					2,862.95		
			496.33		915.34	1,365.73	
					117,300.75	6,186.29	

(*Continued*)

Table 2. Continued.

Sandy shores	Seagrass meadows	Seasonal savanna	Sown pastures and fields	Tropical dry forests	Tropical lowland rainforests	Tropical montane rainforests	Urban and industrial ecosystems
2,563.94	98,291.99	258.93		5,031.17	1,704.63	160,022.13	
					102.83		
						7.32	
			8,836.72	23,053.46		14.67	
						189.04	
123,775.01	8,990.58	68.27	1.00	4,484.39	223.94	13,776.50	
				231,946.01		70.71	
				15,095.82	2,758.53	488.01	
				30.69	3,310.23	4,086.49	
						489.36	
		39.74	99.39	3,210.94	1,075.28	1,222.43	
173,957.55	**109,462.43**	**508.56**	**13,114.46**	**422,101.70**	**136,472.98**	**200,179.93**	**6.48**

B. Summary of monetary values for each service per Colombian ecosystem (Int.$2020/hectare/year). Numbers in the cells are averages of the values found for a particular service and Colombian ecosystem. Calculations are based on a total of 303 EVES (excluding the 199 EVES coming from Benefit Transfer studies)

Ecosystem services	Coastal river deltas	Coral Reefs	Flooded savanna	Insular	Mangrove swamp	Mountain wetlands	Open Ocean	Páramo	Plantations
Aesthetic information									
Air quality regulation						1,119.27			
Biological control									
Climate regulation					4,420.13	6,161.10		1,262.93	178.85
Erosion prevention					29,038.74	38.20		4,600.92	
Fishing		8.84			1,761.97				
Food									
Genetic resources					4,339.85			11,260.48	
Habitat Conservation (Maintenance of species' life cycles (incl. nursery service))	63,504.31	127,415.22	11,407.93		72,337.55	118,694.76	1,856.45	53,062.06	
Information for cognitive development							165,000.00		
Inspiration for culture, art and design						130.15			
Maintenance of genetic diversity									
Maintenance of soil fertility									
Medicinal resources					34.28				
Moderation of extreme events									
Opportunities for recreation and tourism		22,458.42		3.87	45.58	3,593.40		164.27	

Pollination									
Raw materials					893.80			13,073.41	
Regulation of water flows					11,952.36	69,634.41		612.07	
Waste treatment									
Water			27,037.39			3,278.19		3,542.20	
Total economic value	**63,504.31**	**149,882.47**	**38,445.32**	**3.87**	**124,824.26**	**202,649.48**	**166,856.45**	**87,578.34**	**178.85**
Rivers	Sandy shores	Seagrass meadows	Seasonal savanna	Sown pastures and fields	Tropical dry forests	Tropical lowland rainforests	Tropical montane rainforests	Urban and industrial ecosystems	
	1,195.11								
							8,500.00	6.48	
					134,064.80	8.82	38.77		
		2,179.86	141.62	1,023.02	359.63	6,209.68	2,330.08		
	46,423.48			2,657.99	4,824.78		1,392.40		
						2,862.95			
				496.33		915.34	1,365.73		
						117,300.75	6,186.29		
	2,563.94	98,291.99	258.93		5,031.17	1,704.63	160,022.13		
						102.83			
							7.32		
				8,836.72	23,053.46		14.67		
							189.04		
	123,775.01	8,990.58	68.27	1.00	25.49	223.94	13,776.50		
					231,946.01		70.71		
					15,095.82	2,758.53	488.01		
					30.69	3,310.23	4,086.49		
							489.36		
1.75			39.74	99.39	3,210.94	1,075.28	1,222.43		
1.75	**173,957.55**	**109,462.43**	**508.56**	**13,114.46**	**417,642.80**	**136,472.99**	**200,179.93**	**6.48**	

Table 3. First approach to total monetary value of the bundle of ESs per Colombian ecosystems (Int.$2020/hectare/year).

Ecosystem	No. of estimates	Total of service mean values (Int.$2020/ hectare/year)	Total of St. Dev. Of means	Total of median values	Total of minimum values	Total of maximum values
Tropical dry forests	58	422,101.70	36,025.05	11,466.97	25.49	231,946.01
Mangrove swamp	51	209,368.13	94,807.21	31,667.13	0.95	446,707.33
Mountain wetlands	23	202,649.48	154,120.99	65,658.00	38.20	645,539.86
Tropical montane rainforests	172	200,179.93	195,086.25	20,535.16	1.60	2,528,147.78
Sandy shores	14	173,957.55	257,453.61	74,862.46	2.15	968,350.46
Open Ocean	4	166,856.45	81,571.77	42,642.34	1,849.22	165,000.00
Coral Reefs	19	149,882.47	108,346.99	59,945.15	2.85	350,000.00
Tropical lowland rainforests	62	136,472.99	45,083.69	8,040.33	0.98	350,222.53
Seagrass meadows	9	109,462.43	51,642.32	37,049.30	4.92	124,656.05
Páramo	40	87,578.34	39,943.95	10,008.56	0.98	250,603.39
Coastal river deltas	4	63,504.31	51,728.37	63,504.31	21,658.68	133,213.92
Flooded savanna	3	33,712.73	10,655.92	15,040.22	6,675.33	27,037.39
Sown pastures and fields	19	13,114.46	6,275.92	2,281.75	0.97	26,508.23
Seasonal savanna	8	508.56	127.13	125.21	0.65	311.61
Plantations	4	178.85	72.07	178.85	86.07	239.11
Urban and industrial ecosystems	3	6.48	5.82	6.48	2.93	13.20
Insular	2	3.87	4.42	3.87	0.74	7.00
Rivers	11	1.75	1.64	1.75	1.26	6.70

programs about natural diversity, agrobiodiversity, socioeconomic studies, and capacity-building activities implementation on different levels.

Finally, this research shows that regulating and provisioning services are the most recurrent categories in the Colombian context. These results are like those reported by Lara-Pulido, Guevara-Sanginés, and Arias-Martelo (2018) for Mexico. Although opportunities for recreation and tourism was the most common ES studied in Colombia, other cultural ESs are little considered in the Colombian literature, thus, pointing to a relevant research gap for a multiethnic and multicultural country (Angarita-Baéz et al. 2017; Ruiz-Agudelo et al. 2020) where the tourist potential is important, but ethnic diversity indicates a variety of values relevant for the Colombian territorieś sustainable management.

The use of economic valuation methods in Colombia

This review identified eleven economic valuation methods. Value transfer (benefits transfer) was the most common method used to estimate the value of ESs in Colombia, followed by market prices and contingent valuation. Benefit transfer is a practical way to consider values, using functions and estimates acquired through primary valuation methods from other sites (Rosenberger and Loomis 2003; Andreopoulos and Damigos 2017). According to Richardson et al. (2015), benefits transfer is increasingly being used to meet the demand for increased information on nonmarket ecosystem service values.

In the Colombian context, the benefits transfer method has been applied by direct values or functions transfer. There is only one study where functions transfers with meta regressions are applied (Ruiz–Agudelo and Bello 2014). Despite being one of the most popular economic valuation methods globally, it has been receiving significant criticism about its validity, relevance, and appropriate application form (Bateman et al. 2011; Kaul et al. 2013; Baumgärtner et al. 2017; Johnston, Rolfe, and Zawojska 2018; Kling and Phaneuf 2018; Moeltner 2019). For these reasons, it is important to mention that it is very likely that many of the EVES collected in this review are values that contain significant levels of uncertainty and transfer error. This highlights the relevance of implementing other valuation methods in Colombia, which generate primary information with less uncertainty for decision-making.

This review shows a critical gap; it is essential to produce more and better primary (original) information on economic valuation and not only taking into account the technical weaknesses of the methods, but also the ethnic, ecosystems, and cultural diversity of a country like Colombia. The direct transfer of values (from international studies or databases) is not the best way to economically value the country's ESs. In addition to the above and following what was initially suggested by Ruiz–Agudelo and Bello (2014), building a better capacity in Colombia is still necessary to advance in terms of ESs valuation.

Mean standardized values per ES and ecosystem (Int.$2020/hectare/year). Limitations, caveats and potential uses of this study

This review focuses on the Colombian literature to compile and standardize economic values. Several recommendations and caveats are necessary for the interpretation and potential uses of these results:

(1) Economic valuation of Colombian ecosystem services can provide powerful insight for decision-makers (MEA 2005; Kubiszewski et al. 2013). Furthermore, it can provide support to monitoring changes, providing crucial information for natural resource planning and management (Barbier, Acreman, and Knowler 1997; Xu et al. 2018), and offers a policy insight for sustainable management and wise use of ESs. It is important to note that for some Colombian ecosystems, less than half of the total number of ESs are represented in the data shown in Table 3. This result calls attention to the need to undertake additional efforts to value the ES in these ecosystems.
(2) This review shows that the number of ESs and the estimates per ecosystem varies significantly; for this reason, these results should be interpreted as a first approximation that can be complemented with future studies. Additionally, they are necessary more research on specific ESs, for example, in waste treatment, pollination, moderation of extreme events, medicinal resources, maintenance of soil fertility, and maintenance of genetic diversity, which are poorly studied in the Colombian literature.
(3) The number of ESs estimates per ecosystem differs greatly (e.g.172 tropical montane rainforests but only three for flooded savanna). This is a consequence of the data scarcity in the Colombian literature, and the exclusion of some studies due to technical deficiencies or double accounting. Furthermore, many of these studies focus on ecosystems close to large cities, universities, and research centers. Ecosystems in the country periphery and far from large cities are the least studied. It is recommended that future research focus on those ecosystems that, currently, have little information.

How adequate is the ESs economic valuation in the Colombian context?

Colombia is a multiethnic and multicultural country, and this fact constitutes an important challenge in the ESs valuation exercises, given the multiple conceptions of the natural world and its multiple notions of value for ethnic and non-ethnic groups. In this line, Suarez et al. (2021) conclude that ES valuation, expressed in monetary units, does not necessarily reflect the social importance attributed to ES. In addition, decision-making often takes place at the local or regional level, and the valuation process needs to involve many stakeholders and their multiple visions of value. According to Kenter et al. (2016), mixes of monetary and non-monetary deliberative valuation processes are needed to provide sustainable outcomes. Colombia has an important challenge since, currently, the economic valuation of ESs needs to be technically strengthened and expanded to generate better quality primary valuation information for many of the country's strategic ecosystems. This review shows a relevant advance, but given the country's socio-ecological complexity, it is essential to complement and recognize the multiple social relationships and multiple values of nature. Strengthening (technically) the economic valuation studies, and complementing them with plural or integral views, is a recommendation for future research (Pérez-Sánchez et al. 2021).

Conclusion

The results of this review show that the number of studies about the economic valuation of ESs has increased significantly since 2013. However, more efforts are still needed to disseminate and systematize this information for its use in decision-making. Additionally, they are necessary more research on specific ESs, such as waste treatment, pollination, moderation of extreme events, medicinal resources, maintenance of soil fertility, and maintenance of genetic diversity, which are poorly studied in the Colombian literature. Finally, it is essential to produce more and better primary (original) information on economic valuation and the ethnic, ecosystems, and cultural diversity of a country like Colombia. The direct transfer of values is not the best way to economically value the country's ESs.

Colombia is one of the megadiverse countries on the planet, with an important Natural Capital that could be the basis of new paths of sustainable socio-environmental development. In 2022 a progressive government (2022-2026) was elected (for the first time in the country's history), whose government agenda includes the conservation and sustainable management of biodiversity and its ES. This new political scenario could encourage the ecosystem valuation to move up front in the political agenda, invest in valuing ecosystem services, and strengthen the assessment of ES in decision-making.

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