

## Article

# The Economic Value of Wetlands in Urban Areas: The Benefits in a Developing Country

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**Abstract:** Urban growth has impacted natural ecosystems such as wetlands. This situation destabilizes the beneficial contributions of nature, generating a socioeconomic effect. There is a need to quantify the benefits of wetlands in developing countries and urban areas, where the growth of cities is fastest. This is the first valuation study of urban and peri-urban wetlands in Colombia. The methodology includes a benefit transfer (BT) method with a geographical information system (GIS) and an exploratory governance analysis. Because there are few studies on the economic valuation of urban wetlands in Latin America, we present a methodology of interest, which can be easily replicated in other cities of this subcontinent. Based on an economic approach, our results find that 76% of the total value of wetlands is provided by ecosystem services (ES) of existence and legacy value, followed by maintenance of the life cycle of migratory species and water supply. Urban areas are identified where users benefit more than areas where the population exerts greater pressure on wetlands. Weak governance is due to the disarticulation between regulation, land-use planning, and the social-ecological system. This research contributes to urban wetland management policies, as well as to sustainable solutions in cities.

**Keywords:** wetlands; urban ecosystem services; valuation; benefit transfer



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## 1. Introduction

Wetland systems support human livelihoods and are critical to sustainable development [1]. Despite this, 50% of the total area of wetlands in the world has been lost because of agricultural activities, cattle ranching, mining, the growth of cities, and other human actions [1]. As a result of the degradation of wetlands in Colombia, the floods that occurred between 2010 and 2011 affected 31% of the country, generating considerable economic losses [2]. In the Cauca River Valley, 88% of the wetlands were lost, mainly because of drainage activities, land reclamation, river-channel regulation, and pollution [3]. The city of Cali has 61 wetlands within its urban area and 175 peri-urban wetlands, which have been affected by change of use and a deterioration of their ecosystems [4]. As in other regions and countries, the pursuit of short-run human wellbeing has been detrimental to biodiversity [5,6]. With the deterioration of the wetlands in Cali, some ecosystem services (ES) have been lost (e.g., carbon sequestration—thus increasing greenhouse gases). This situation must be quantified because it means that the loss or gain of values will ultimately be reflected in society. Therefore, if the value of the benefits provided by nature is understood, we can move closer to the development of sustainable cities [7].

Although there are some studies, reports, and inventories of wetlands [8] in South America, there are few studies on the economic valuation of wetlands in Colombia [9], none of which are conducted on urban ES valuation. A knowledge gap has therefore been identified regarding the valuation of urban wetlands in developing countries, since most of these have mainly been conducted in Europe, North America, and China [10].

ES valuation research, within the economic approach, recognizes that many of the services provided by nature are not found in the market and, therefore, their benefits have been underestimated, generating uncertainty with regard to their value [11]. In other words, it recognizes a market failure, which arises within the biodiversity field for several reasons: the market cannot make an efficient allocation of resources; there is no clear definition of property rights; and there are externalities that have not been included in economic models [12]. In this research, the benefits provided by wetlands (positive externalities) are determined to construct an estimated value to facilitate their understanding and their contribution to society.

From an institutional perspective, it has been suggested that natural resources should be understood as common-pool resources [13]. In other words, they are rivalrous in terms of consumption because natural resources become depleted. Nor can they be excluded because they are freely accessible to people. There is a need to develop institutional rules within social-ecological systems that allow the development of institutions that achieve optimum levels of cooperation from stakeholders [13].

This work performs a monetary valuation of urban and peri-urban wetlands of Cali from an economic approach with two specific objectives; to determine and value the ES of the wetlands in Cali, and to explore governance characteristics for the management of the wetlands. To carry out the first, we use a benefit transfer (BT) method with a geographical information system (GIS). To the second, we apply the principles of institutional design proposed by Anderies et al. [14].

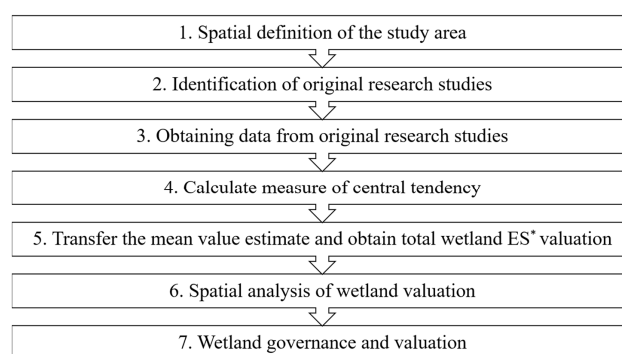
It should be clarified that primary research is the first-best strategy in project evaluation, but when there are difficulties in carrying this out, as in the case of Cali, the benefit transfer methodology is the second-best alternative to evaluate management and policy impacts [15].

Benefit transfer is understood as the estimation of a value from a study site to be applied to a policy site, where the former has similar characteristics to the latter [16]. GIS is a technique that integrates geographically referenced information [17]. Beyond using a constructive replication of the GIS-supported benefit transfer method to achieve an economic valuation of wetlands in Cali, this research proposes a starting point to apply this methodology in urban wetlands in Latin America.

The results of this study provide a basis for policy implementation in urban wetland management in developing countries. In addition, this research provides information for assessment of land-use change and the impact of climate change on the city, cost-benefit analysis, ecosystem services compensation assessments, and social appropriation of knowledge, among other applications.

## 2. Materials and Methods

We have based our methodological proposal on Champ et al. [16] and Dupras et al. [18] to create Figure 1. We merged the methodological steps and propose a new step (step 7) in our research:



**Figure 1.** Methodological steps for economic valuation of wetlands in Cali. Note: \* Ecosystem services. Source: Adapted from Champ et al. [16] and Dupras et al. [18].

Step 1: Spatial definition of the study area. First, we worked with the files of the wetland inventory maps provided by the Administrative Department of Environmental Management of Cali (DAGMA) and Spatial Data Infrastructure of Cali (IDESC). Next, the data were obtained in the R programming language with the assigned attributes in terms of wetland type (urban or peri-urban), name, location, and area. Then we proceeded to superimpose the maps of the urban perimeter, comunas (a group of neighborhoods within a city), corregimientos (a territorial area, the jurisdiction of which depends on the municipality), rivers, streams, and wetlands to define the study area set out in Section 2.1.

Step 2: Identification of original research studies. ES that benefit Cali were proposed by Tabares-Mosquera et al. [19]. This, therefore, was our point of reference as established in Section 2.2. ES-estimated values from the study site are taken from Ecosystem Services Valuation Database (ESVD) [20]. ESVD gives the values in USD/ha/year, which were standardized in 2020 in international dollars. This database includes ES from inland wetlands that fall within the Economics of Ecosystems and Biodiversity (TEEB) classification and Common International Classification of Ecosystem Services (CICES) V.5 [21,22]. Therefore, the ESVD is defined as a reliable source for benefit transfer applied to this research. In addition, we have taken into account the study of Dayathilake et al. [23] to refine our valuation of the carbon sequestration service. Last, we differentiate the value per hectare of urban and peri-urban (rural) wetlands, following the study of Chaikumbung et al. [24], who state that urban wetlands are more valuable than rural wetlands. The authors explain these findings both by income differences and by the willingness to pay to protect wetlands among urban and rural inhabitants.

Step 3: Obtaining data from original research studies. The TEEB [21] classification is used as a reference to obtain the estimates of ES values of the study site. To obtain values from studies with similar characteristics to the policy site, the ESVD was filtered in terms of geographic coordinates, selecting those studies located within 23° north latitude and 23° south latitude (Tropical zone between the Tropic of Cancer triangle and Tropic of Capricorn triangle to which the Cali wetlands belong). Next, those values obtained through primary research were selected. Those corresponding to inland wetlands with local study scale located in developing countries were also selected. Moreover, aboveground and belowground carbon stock indicators from Dayathilake et al. [23] were taken and valued. Finally, considering that the coefficient on urban wetlands of meta-regression proposed by Chaikumbung et al. [24] is positive and statistically significant, we have taken into account this coefficient to differentiate the value of urban and peri-urban wetlands in Cali. See Section 2.4.

Steps 4, 5, and 6: Calculate measure of central tendency, transfer the mean value estimate, obtain total value, and spatial analysis of wetland valuation. Once the studies with the best fit for the conditions in Cali had been identified, the mean of the values obtained for each ES was calculated in USD/ha/year. Then we proceeded to calculate the total value of urban and peri-urban wetlands using Equation (3) in this paper. Next, the value of each wetland was calculated, and the maps of comunas and corregimientos were superimposed, obtaining the total valuation by zone. Last, the per capita value was obtained, considering the projected population in 2020. The results are presented in Section 3.

Step 7: Wetland valuation and governance. An exploratory review of the governance system in Cali was taken. The results are presented in Section 3.5, followed in Section 4.3 by the proposal of a link between economic valuation of wetlands in Cali and governance.

## 2.1. Study Area

This research is located in the Valle del Cauca region in southwestern Colombia, which is one of the most biodiverse countries on Earth (see <https://www.un.org/es/cr/C3%B3nica-onu/celebrando-y-salvaguardando-la-biodiversidad-para-evitar-la-siguiente-pandemia> (accessed on 12 May 2022) for more information). The River Cauca runs through the region from south to north, where swamps and marshes are common as a result of river flooding.

It has fertile land suitable for agriculture, natural pastures, and livestock [25]. Toward the flat region of the valley is Cali, which stands out for its richness in bird species, which include 487 breeding residents, 72 migratory species, and 2 introduced species [26].

The city of Cali extends into 56,168 hectares. This is located at latitude  $3^{\circ}27'26''$  N and longitude  $76^{\circ}31'42''$  W and lies 1079.5 m above sea level. The average temperature is  $24.3^{\circ}\text{C}$ , and the average annual relative humidity is 77.2%. By 2020 Cali had a projected population of 2,496,442 inhabitants with a gross density of 44.56 inhabit/ha [27,28]. In 2019, its GDP per capita was USD 6474 (this value is used as a proxy in the absence of municipal accounts, which is reported by the Administrative Department of Planning of the city) (current prices) with a 4.5% share of national GDP. In 2018, the access of the population to outdoor recreational areas was  $0.52\text{ m}^2/\text{inhabitant}$  [27]. This figure is below the recommendations of the World Health Organization ( $9\text{ m}^2/\text{inhabitant}$ ) [29].

The research area is located within the social-ecological structure of Cali, which was defined by Tabares-Mosquera et al. [19] taking into account land cover as a unit of analysis, as well as the urban-functional and ecological-biophysical factors of the region. Figure 2 shows the study area with 61 urban wetlands and 175 peri-urban wetlands with 33 ha and 217 ha respectively. The urban wetlands of Cali are similar in extension to the London Wetland Centre, UK (42 ha) and Kranji Marshes, Singapore (56.8 ha). The peri-urban wetlands of Cali are similar in extension to the wetlands in Sydney Olympic Park, Australia (175 ha) [30].

The proportion of inland waters in Colombia by thousands of hectares corresponds to 3225 ha (inland wetlands included) compared to 2043 ha in Mexico and 38,648 ha in Latin America and the Caribbean [31].

## 2.2. Ecosystem Services

Different ES taxonomies have been developed by the scientific community in conjunction with intergovernmental entities such as the Millennium Ecosystem Assessment (MEA), TEEB, European Environment Agency (EEA), and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). The economic valuation of ES of this study is based on TEEB classification with the categories: provisioning, regulatory, cultural, and habitat services [21].

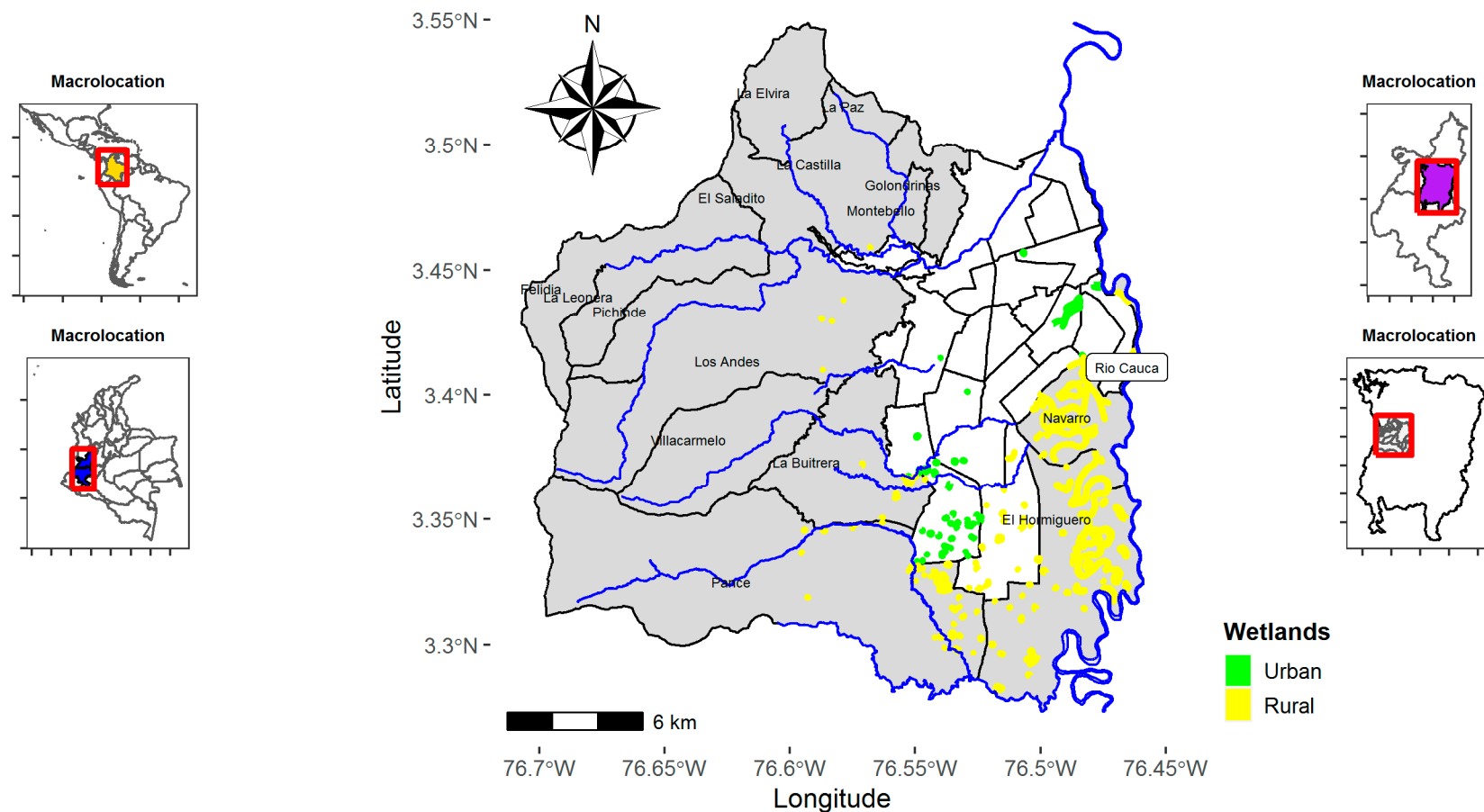
The characterization of ES of the wetlands in Cali is taken from the study by Tabares-Mosquera et al. [19]. This performs a nonmonetary valuation of ES based on a consulting panel of experts regarding the capacity to provide and demand ES within the social-ecological system of the city. The authors propose ES of the CICES V.4.3 classification [32] that are applicable to the land within the area of the city.

Table 1 shows the ES valued. Note that the value estimates used correspond to 11 ES. We did not value other ES proposed by Tabares-Mosquera et al. [19] because of a lack of data. This situation impacts the economic valuation of wetlands in Cali because there are unvalued ES.

## 2.3. Benefit Transfer Method

Benefit transfer is the application of values and/or data from one  $V_{Sj}$  study site to another that has little or no information, known as the  $V_{pj}$  policy site [15]. Among the categories of benefit transfer are value transfer, including measure of central tendency, point estimate and administratively approved estimate, and function transfer, including benefit function and meta-regression analysis function [16].

Benefit transfer has been widely applied in the ES valuation literature as a tool to inform policy makers [33,34]. This methodology complemented with GIS is applied in this study to perform a cross-sectional valuation. Benefit transfer with GIS includes biogeophysical and sociodemographic elements applicable to the policy site; therefore, it is a viable alternative in the valuation of environmental goods and services [35].



**Figure 2.** Study Area. The geographic coordinates were provided by the Spatial Data Infrastructure of Cali and the resolution 055 of 2018 by the Administrative Department of Environmental Management of Cali. The red frame corresponds to the study site at national, regional and local level. The purple color on the red frame corresponds to the social-ecological structure of Cali proposed by Tabares-Mosquera et al. [19]. Both comunas of Cali (urban zone) and the urban expansion zone are shown in white. Corregimientos (peri-urban zone) are shown in gray. Rivers are shown in blue. Sixty-one urban wetlands are located in comunas and shown in green; 175 peri-urban wetlands are located in corregimientos and the urban expansion zone. These are shown in yellow. Note that most of these are small in their extension. The inventory of urban and peri-urban (rural) wetlands in Cali is available upon request.

**Table 1.** Ecosystem services valued in wetlands of Cali.

Group	Description *
Provisioning	Food
	Water
	Raw material
Regulation and maintenance	Climate regulation **
	Regulation of extreme events
	Water flow regulation
	Waste treatment
Habitat	Maintenance of life cycle of migratory species
Cultural	Aesthetic information
	Recreation and tourism
	Existence and legacy value

Note: \* Based on the description of TEEB [21] ecosystem services classification; \*\* this ecosystem service relates to carbon sequestration.

To value urban and peri-urban wetlands in Cali, a central tendency is used following the methodology of Champ et al. [16]. This is based on taking the average value from studies of the literature, which can be defined as shown in Equation (1):

$$V_{Pj}|Q_{Pj} = \bar{V}_S|\bar{Q}_S \quad (1)$$

where  $V_{Pj}$  is the measure needed for the policy site  $j$ , given the characteristics of policy site  $Q_{Pj}$ .  $\bar{V}_S$  is the measure of central tendency of the studies of study site, given the characteristics of the study site  $\bar{Q}_S$ . The unit of measurement of the studies is in this case USD/ha/yr.

If the measure of the central tendency being worked on is the mean as shown in Equation (2), then:

$$\bar{V}_S|\bar{Q}_S = VC_{kj} \quad (2)$$

where  $VC_{kj}$  is the mean value of each ES for the policy site  $j$  and category  $k$ .

The total ES value of wetlands is calculated following the methodology of Dupras and Alam [36]. This is done by multiplying the total hectares by the mean value of each ES, as shown in Equation (3):

$$ESV_k = \sum_j A_k \times VC_{kj} \quad (3)$$

where  $ESV_k$  corresponds to ES value of wetlands for category  $k$  (urban or peri-urban),  $A_k$  hectares of wetlands for category  $k$ , and  $VC_{kj}$  is the average value of each ES  $j$  in the category  $k$ .

#### 2.4. Data

The ESVD and Dayathilake et al. [23] provided the original studies presented in Table 2, which served as the basis for the benefit transfer in Cali. There are 29 studies located in 18 developing countries.

Notice that the study site valuations differ widely. Despite their location in developing countries, only two have been performed in Latin America (Mexico and Guatemala). This situation confirms the need to carry out valuations of urban wetlands in South America. Furthermore, these studies are evaluating different kinds of ES. For this reason, the methodology of BT adopted by this research takes into account the mean value of each ES (94 value estimates in our case), as was explained in Section 2.3.

As we have mentioned before, the literature indicates that the economic value of urban wetlands is different from rural wetlands, being that urban wetlands more valuable [24]. This is why we carried out our urban wetland valuation taking into account the estimated coefficient of urban wetlands from meta-regression economic valuation by Chaikumbung et al. [24]. That is 2.531 (statistical significance at the 5% level of subgroup



without marine); this coefficient shows that if there are urban wetlands, wetland values increase by approximately 2.531 times. See results in Section 3.1.

**Table 2.** Studies selected for the benefit transfer in Cali.

Authors	Country	Name of Wetland	USD/ha/yr *
Hanafi et al. Year 2014 °	Indonesia	Tapin District	72,967.5
Midora y Anggraeni. Year 2006 °	Indonesia	Batang Gadis National Park	38,360.0
Mukherjee. Year 2008 °	India	Kalobaur beel (oxbow lake)	32,955.7
Eaton y Sarch. Year 1997 °	Nigeria	Hadejia-Nguru wetlands	16,077.4
Ibarra et al. Year 2013 °	Mexico	Xochimilco	13,796.4 **
Emerton et al. Year 1998 °	Uganda	Nakivubo	10,019.8
Kadigi et al. Year 2005 °	Tanzania	Usangu wetland and floodplain	6531.9
Nalukenge et al. Year 2009 °	Uganda	Pallisa District wetlands	5754.9
Nuva. Year 2009 °	Indonesia	Gunung Gede Pangrango National Park	4580.4
Karanja et al. Year 2001 °	Uganda	Namatala	3475.0
		Pallisa District wetlands	318.8
Kakuru et al. Year 2013 °	Uganda	Kyoga plains	2818.3
		Southwestern farmlands	2208.0
		Lake Victoria crescent	2205.5
Gerrard. Year 2004 °	Laos	That Luang Marsh	2662.4
Dayathilake et al. [23] °°	Sri Lanka	Kolonnawa wetland and Thalawatugoda wetland park	1522.8 ***
Hap et al. Year 2000 °	Cambodia	Muk Kompul and Ponheur Leu Districts	320.5
Barbier et al. Year 1991 °	Nigeria	Hadejia-Nguru	311.2
Sención [37] °	Guatemala	Petexbatu'n	244.3
Munasinghe. Year 1993 °	Madagascar	Mantadia National Park	228.9
Le et al. Year 2016 °	Vietnam	Tam Dao National Park	137.7
Siima et al. Year 2012 °	Tanzania	Kilombero	77.9
Turpie et al. Year 1999 °	Mozambique	Barotse floodplain	75.9
		Lower Shire wetlands	21.2
Angella et al. Year 2014 °	Uganda	Dohu Rice Irrigation system	52.3
Abila y Othina Year 2006 °	Kenya	Yala Wetland	51.2
Loth. Year 2004 °	Cameroon	Waza Logone	42.6
Kasthala et al. Year 2008 °	Tanzania	Mtanza-Msona village wetlands	15.2
Mireri et al. Year 2008 °	Kenya	Tana River Delta	7.5
Geta et al. Year 2015 °	Ethiopia	Dechatu drainage basin	3.9
Roy et al. Year 2012 °	India	Bhomra Beel	0.6
Setlhogile et al. Year 2010 °	Botswana	Makgadikgadi wetland	0.6
Manlosa et al. Year 2013 °	Philippines	Layawan Watershed	0.1

Note: \* International dollars. Year 2020; \*\* This value includes carbon sequestration valuation = 421.34 USD/ha/yr; \*\*\* Aboveground carbon stock = 46.63 tC/ha, belowground carbon stock = 7.24 tC/ha and price EU allowances (EUA) = 28.27 USD/t; ° These studies and data are taken from the Ecosystem Services Valuation Database by De Groot et al. [20]; °° We have taken into account this study to refine our valuation of the carbon sequestration service.

### 3. Results

#### 3.1. Valuation

The benefit transfer method allowed us to obtain the mean for 11 ES and 94 value estimates, whose description was taken from TEEB [21]. Tables 3 and 4 present the results of the Cali urban and peri-urban wetland valuation, which is USD 8,643,583. On one hand, the total value of urban wetlands is USD 2,388,942 (72,825 USD/ha/year). On the other hand, the total value of peri-urban wetlands is USD 6,254,641 (28,773 USD/ha/year). Urban and peri-urban wetland valuations represent 28% and 72% of total value, respectively. The lower proportion of the value of the former is a consequence of their smaller quantity and extension.

**Table 3.** Total value of urban wetlands in Cali.

ES *	N **	Minimum USD/ha/yr °	Maximum USD/ha/yr °	St. Deviation USD/ha/yr °	Mean USD/ha/yr °	Total ° Urban (33 ha)
Provisioning						
Food	24	0.52	65,000	13,904	5003	164,102
Water	23	0.10	81,073	22,955	9261	303,807
Raw material	25	1.03	40,692	8518	3342	109,636
Regulation and maintenance						
Climate regulation	2	1066	3854	1971	2460	80,709
Regulation of extreme events	1	0.37	0.37	NA ***	0.37	12
Water flow regulation	3	4.87	449	253	156	5128
Waste treatment	7	11	24,509	9210	3627	118,973
Habitat						
Maintenance of life cycle of migratory species	2	348	33,379	23,356	16,864	553,195
Cultural						
Aesthetic information	1	1.02	1.02	NA ***	1.02	33
Recreation and tourism	4	5.14	11,593	5725	3008	98,684
Existence and legacy value	2	29,019	29,185	118	29,102	954,662
	94	30,457	289,736		72,825	2,388,942

Note: \* Ecosystem services; \*\* number of value estimates; \*\*\* does not apply; ° international dollars. Year 2020.

**Table 4.** Total value of peri-urban wetlands in Cali.

ES *	N **	Minimum USD/ha/yr °	Maximum USD/ha/yr °	St. Deviation USD/ha/yr °	Mean USD/ha/yr °	Total ° Peri-Urban (217 ha)
Provisioning						
Food	24	0.20	25,682	5494	1977	429,647
Water	23	0.04	32,032	9069	3659	795,416
Raw material	25	0.41	16,077	3366	1320	287,044
Regulation and maintenance						
Climate regulation	2	421	1523	779	972	211,309
Regulation of extreme events	1	0.15	0.15	NA ***	0.15	32
Water flow regulation	3	2	177	100	62	13,425
Waste treatment	7	4	9684	3639	1433	311,492
Habitat						
Maintenance of life cycle of migratory species	2	138	13,188	9228	6663	1,448,356
Cultural						
Aesthetic information	1	0.40	0.40	NA ***	0.40	87
Recreation and tourism	4	2	4580	2262	1189	258,371
Existence and legacy value	2	11,465	11,531	47	11,498	2,499,462
	94	12,034	114,475		28,773	6,254,641

Note: \* Ecosystem services; \*\* number of value estimates; \*\*\* does not apply; ° international dollars. Year 2020.

The highest valuations obtained are those of existence and legacy value (40%), maintenance of the life cycle of migratory species (23%), and water supply (13%). The first results can be understood as the heritage of future generations. In line with this, the land-use plan of Cali [38] includes wetlands as conservation and environmental protection areas. The second findings can be interpreted as the evidence of having shelter for animals. This is why bird watching is a common activity in Valle del Cauca (see <https://ebird.org/region/CO-VAC?yr=all> (accessed on 10 May 2022) for more information). The latter results suggest that wetlands in Cali have the potential to provide water for the inhabitants.

The following services are in lower proportions (24%). These values are understood as the potential to provide natural resources (11%), regulation services (9%), and cultural

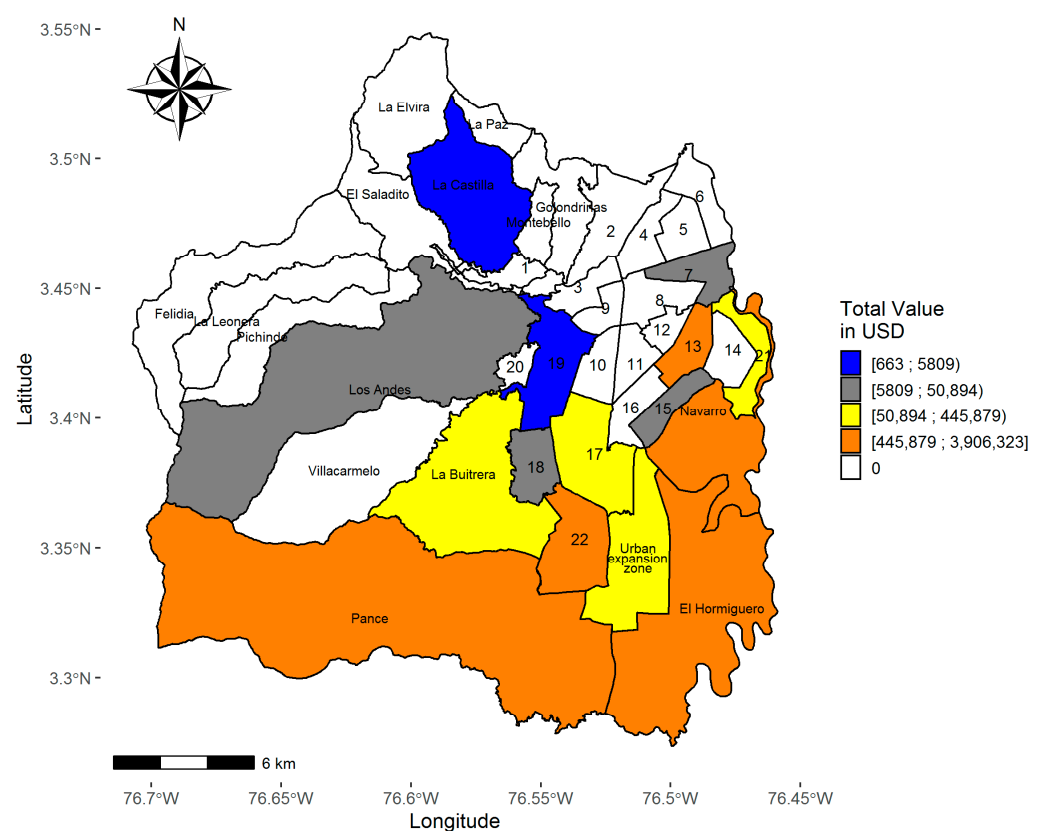


(4%) services to the city. Addressing regulation services, it should be clarified that carbon sequestration (climate regulation service) represents 3% of total valuation. This finding shows that the more wetlands are lost, the more greenhouse gas emissions increase. Moreover, in 2018, Latin America and the Caribbean reported 32% of greenhouse gas emissions by agriculture [31]. Thus, loss of wetlands and agricultural activities in the Valle del Cauca region are probably responsible for a greater impact of climate change at the local level.

The differential between the value of urban and rural wetlands can be explained by ecosystems found in peri-urban areas, which are subject to greater pressures caused by the occupation of territories by new housing developments, different types of governance, and different preferences between rural and urban inhabitants [39–41]. Additionally, perceptions of ES change from being perceived as livelihoods and local cultural amenities, in the case of rural wetlands, to aesthetic and recreational activities in urban areas [42,43].

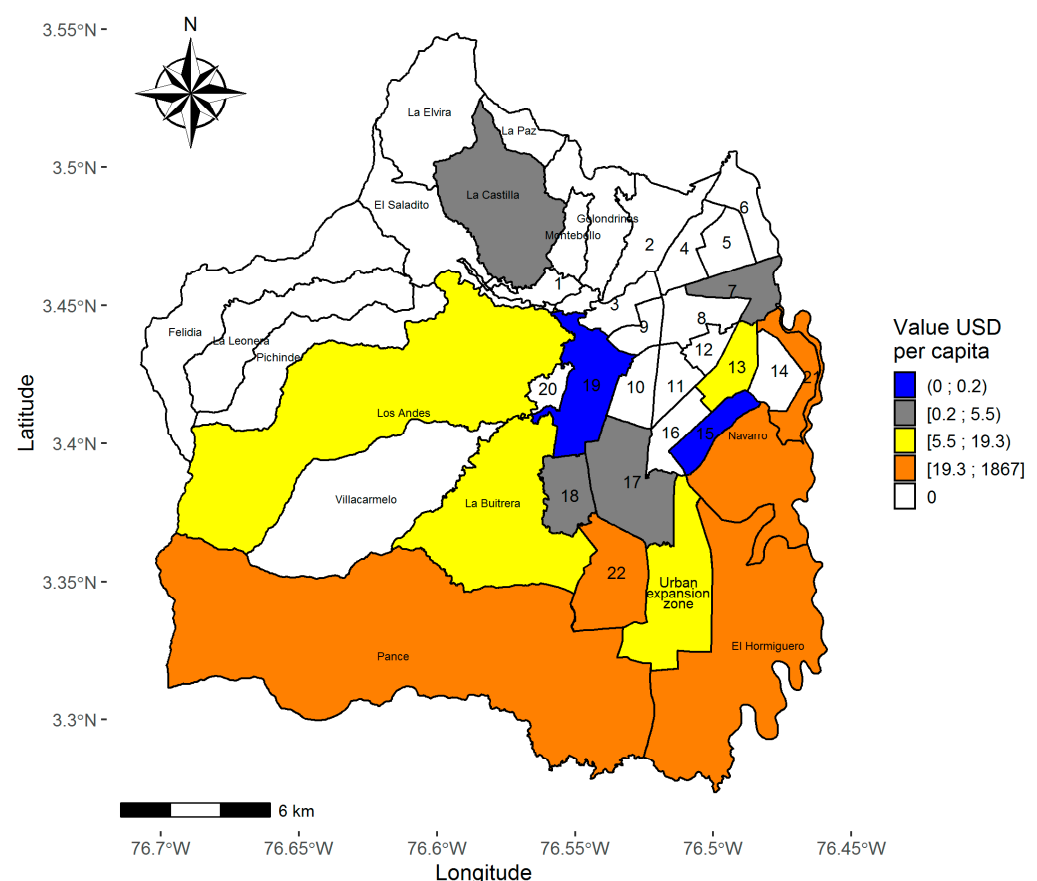
### 3.2. Spatial Analysis

The valuation of wetlands in Cali is analyzed by taking into account their distribution by comunas and corregimientos. Figure 3 shows that the highest total value areas are between 445,879 and 3,906,323 USD/year. The lowest total value areas are between 663 and 5809 USD/year. These findings can be interpreted as the more wetlands there are, the more ES are available to Cali. Furthermore, the findings show from which places ES are supplied—in other words, which are the critical ecological zones. For instance, Comuna 22 has 50 urban wetlands and Comuna 13 has the biggest urban wetland in the city; thus, those wetlands have the highest ES valuation. Moreover, those wetlands have a potential to improve the quality life of people and biodiversity by promoting cultural services and shelter for species.



**Figure 3.** Total valuation of wetlands by comunas and corregimientos. The high-value areas are highlighted in orange. The low-value areas are highlighted in blue. Note that comunas are numbered between 1 and 22. The corregimientos are indicated by their proper name. The expansion zone of the city is shown in yellow. There are no wetlands in zones that are shown in white.

In addition, in Figure 4, we analyze and show the distribution of the value of the wetlands among the population of the comunas, corregimientos, and urban expansion zone. Note that Figures 3 and 4 show a change in the incidence of the value that is due to the number of inhabitants in each zone. For instance, in Figure 4, the incidence of the value of wetlands is higher in Corregimientos La Castilla and Los Andes, owing to its low population density. Moreover, in Comunas 13, 15, and 17, which have the highest population concentrations in the city, the incidence of the value of wetlands is lower. This can be interpreted as the existence of areas where users enjoy greater benefits compared to others, where the population exerts greater pressure on the wetlands. Last, the per capita value of the urban expansion zone is likely to decline if housing projects threaten wetlands.



**Figure 4.** Valuation of wetlands per capita. The high-value and low population density areas are highlighted in orange. The low-value areas and high population density are highlighted in blue. Note that comunas are numbered between 1 and 22. The corregimientos are indicated by their proper names. The expansion zone of the city is shown in yellow. There are no wetlands in zones that are shown in white.

### 3.3. Robustness

Based on findings in the literature, which show a negative relationship between wetland value and wetland area [24,44], an additional filter is applied to the data selected. In this way, the wetland area of the source studies is restricted by selecting those smaller than 6000 ha, a dimension that includes two valuations in Latin America [37,45]. Twenty-seven value estimates were obtained, in seven ES, for wetlands located in eight developing countries. We proceeded to carry out benefit transfer as shown in Tables 5 and 6 and obtained a value of 76,827 USD/ha/year and 30,354 USD/ha/year for urban and peri-urban wetlands, respectively. The results coincide with Chaikumbung et al. [24] and Woodward and Wui [44], where having smaller wetland areas has an increase in valuation.

Additionally, the values obtained are similar to the benefit transfer of this research presented in Tables 3 and 4.

**Table 5.** Total value of urban wetlands in Cali with area constraint.

ES *	N **	Minimum USD/ha/yr °	Maximum USD/ha/yr °	St. Deviation USD/ha/yr °	Mean USD/ha/yr °	Total ° Urban (33 ha)
Provisioning						
Food	8	6	5218	2101	2071	67,932
Water	3	79	78,842	45,459	26,351	864,422
Raw material	8	10	40,692	14,115	5806	190,451
Regulation and maintenance						
Climate regulation	2	1066	3854	1971	2460	80,709
Water flow regulation	1	449	449	NA ***	449	14,713
Waste treatment	4	37	24,509	12,133	6311	207,022
Habitat						
Maintenance of life cycle of migratory species	1	33,379	33,379	NA ***	33,379	1,094,962
	27	35,026	186,943		76,827	2,520,211

Note: \* Ecosystem services; \*\* number of value estimates; \*\*\* does not apply; ° international dollars. Year 2020.

**Table 6.** Total value of peri-urban wetlands in Cali with area constraint.

ES *	N **	Minimum USD/ha/yr °	Maximum USD/ha/yr °	St. Deviation USD/ha/yr °	Mean USD/ha/yr °	Total ° Peri-Urban (217 ha)
Provisioning						
Food	8	2	2062	830	818	177,856
Water	3	31	31,151	17,961	10,411	2,263,199
Raw material	8	4	16,077	5577	2294	498,633
Regulation and maintenance						
Climate regulation	2	421	1523	779	972	211,309
Water flow regulation	1	177	177	NA ***	177	38,521
Waste treatment	4	15	9684	4794	2493	542,018
Habitat						
Maintenance of life cycle of migratory species	1	13,188	13,188	NA ***	13,188	2,866,789
	27	13,839	73,861		30,354	6,598,324

Note: \* Ecosystem services; \*\* number of value estimates; \*\*\* does not apply; ° international dollars. Year 2020.

### 3.4. Legal Framework

There are guidelines that contain the regulations that address the management of wetlands in Cali. First, there is the Convention on Wetlands of International Importance (Ramsar Convention). Colombia committed to the Ramsar Convention through Law 357 in 1997. Nationally, the Political Constitution of Colombia protects natural resources, regulates their exploitation, and creates control agencies. There are policies related to the integrated management of water resources such as the 2002 National Policy for Inland Wetlands. There is also the 2012 National Policy for the Integrated Management of Biodiversity and its Ecosystem Services (PNGIBSE). Regionally, the 2007 Agreement No. 038 of the Regional Autonomous Corporation of Valle del Cauca (CVC) declares the natural wetlands of the Valle del Cauca as a renewable natural resource reserve. Locally, the land-use plan of Cali [38], defines the conservation and environmental protection areas of the city that include water sources, surface streams, and wetlands.

This legal and regulatory framework provides the formal rules governing the management of urban and peri-urban wetlands in a centralized manner. This situation poses challenges to the collective actions that could contribute to wetland management, as well

as enhancing the capacity of cities to promote environmental culture, which is the case studied by Nagendra and Ostrom [39] in peri-urban wetlands in Bangalore, India.

### 3.5. Governance

By reviewing the environmental management plans of wetlands available in Cali, an exploratory review of principles of institutional design proposed by Anderies et al. [14] was undertaken. The analysis shows that governance is weak in Cali; for example, there are issues to be solved in property rights, proportional equivalence in costs and benefits, efficient collective choice agreements, integrated monitoring indicators, and institutions adapted to the needs of users. The existence of regulations covering graduated sanctions, conflict resolution mechanisms, and recognition of organizational rights is highlighted.

Clearly defined boundaries: Twenty-two percent of the city's urban wetlands are located on private land and 78% on public land. This means that there are users who do not have the right to enjoy the benefits of some wetland ES located on private properties. We are faced here with an unresolved problem of property rights and social justice.

Proportional equivalence between benefits and costs: Thirty-one percent of the urban wetland area is located in Comuna 22 where the socioeconomic level corresponds to the highest in the city. The wetlands in other areas are in poor condition and have a higher incidence of hostile actors such as gangs or criminality [46–48]. Despite that the wetlands of the city are protected, 27 are located in the urban expansion zone where housing activity is permitted. That is, these wetlands are in danger of being lost.

Collective choice agreements: There is representation of the population for wetland management. This is the case of the community action boards, local action boards, and committees that represent the community and environmental organizations. On the other hand, a lack of organization among communities occurs in wetland areas where there is limited supply of institutional services, as well as irregular settlements, and marginalization of these ecosystems in urban planning, among others [46,47].

Monitoring: The legal framework corresponds to political-administrative limits that go against the areas of environmental influence [19]. This encompasses areas that go beyond the boundaries of the department of Valle del Cauca. Connections and shared ecological monitoring with other local authorities are needed to carry out actions in regions that share ecological structures.

Gradual sanctions: The legal framework defines the uses of wetlands and water bodies, as well as the consequences of noncompliance [49].

Conflict resolution mechanisms: The legal framework includes instruments for conflict resolution [49].

Minimum recognition of organizational rights: Users have access to existing community action boards, local action boards, and on local and civic organizations. In Comuna 22, an outstanding case is that of water-user associations recognized as social stakeholders of the wetlands [50,51].

Nested enterprises: The institutions are perceived as rigid and often slow to respond, leading to inappropriate policy decisions [46].

In line with this, because of the weak governance that has been found, policy and decision makers in Cali are not well-informed. Insufficient attention is given to the economic valuation of wetlands in Cali as an input in project assessment. Therefore, if the benefits of wetlands are unknown, the cost-benefit analysis would not sufficiently take into account the benefits of biodiversity. For instance, a decision maker who is unaware of the economic value of maintenance of the life cycle of migratory species will not realize that birds will be impacted if a housing project is approved where a wetland exists. Consequently, the economic cost of damage could be higher than the benefits of the construction project.

## 4. Discussion

### 4.1. Comparison with Other Research

Table 7 shows the average value per ES of wetlands: developing countries, 236–6620 USD/ha/year/ES; developed countries, 2942–7403 USD/ha/year/ES; and global 2279 USD/ha/year/ES. On one hand, the meta-regressions by He et al. [52] and Chaikumbung et al. [24] show that the value of wetlands in developing countries is lower than in developed countries. This can reflect findings that explain that the value of wetlands is influenced by the level of development of the country, showing a higher value in those countries with higher GDP [24]. On the other hand, in developing countries, the valuation of peri-urban wetlands in Cali presents values lower than those obtained by Ibarra et al. [45] in Mexico City for the urban wetland of Xochimilco. This can be explained by the fact that evidence has been found where urban wetlands have a higher value than rural wetlands. This is due to urban residents having higher incomes than rural inhabitants, in addition to having different preferences. Citizens with higher incomes are also more willing to pay to protect wetlands [40,41]. Furthermore, the valuation of urban wetlands in Cali presents values that are higher than Ibarra et al. [45]. This can be understood by the findings in the literature that show a negative relationship between wetland value per hectare and wetland area [24,44]. Notice that the wetland of Xochimilco in Mexico is larger than the urban wetlands of Cali. At the same time, the value of urban wetlands obtained by Liu et al. [17] is lower than our value of urban wetlands. This can be due to urban wetlands in New Jersey being larger than urban wetlands in Cali.

**Table 7.** Valuation compared to other research.

Authors	Country	Wetland	ha *	Method **	Year +	USD/ha/yr ++	ES °	USD/ha/yr/ES ++
Costanza et al. [11]	Global	Generic	330,000,000	BT	1997	22,790	10	2279
Liu et al. [17]	New Jersey, NJ, USA	Urban	329,608	BT, GIS	2004	11,769	4	2942
He et al. [52]	Quebec, Canada: Africa, North America Asia, Europe Australia	Rural and urban: Man-made, isolated, complex	NA ***	MRA, GIS	2014	22,208 °°	3	7403
Chaikumbung et al. [24]	Developing countries: Asia, Africa, Latin America, Pacific Islands	Rural and urban: Estuarine, riverine, marine, artificial, lacustrine, marshy among others	NA***	MRA	2002	2829 °°	12	236
Ibarra et al. [45]	Mexico	Urban	2614	RC, MP	2020	13,796	3	4599
This study	Cali, Colombia	Urban	33	BT, GIS	2020	72,825	11	6620
This study	Cali Colombia	Peri-Urban	217	BT, GIS	2020	28,773	11	2616

Note: \* Hectares; \*\* BT: benefit transfer, GIS: geographical information system, MRA: meta-regression analysis, RC: replacement cost, MP: market prices; \*\*\* does not apply; + year of reported value; ++ international dollars. Year 2020; ° assessed ecosystem services; °° average per hectare value calculated from the meta-analysis database.

However, the average value per ES in Cali is higher than Costanza et al. [11]. This can be attributed to the fact that this study performed worldwide valuations that do not report urban wetlands. Finally, the mean value of the studies analyzed by Chaikumbung et al. [24] includes rural and urban wetlands that mostly reflect valuations performed in Southeast Asian countries. They provide values that are very different from those obtained by Ibarra et al. [45] and the benefit transfer performed in Cali.

Regarding our methodological approach, one of the applications of the GIS-supported benefit transfer method in scientific literature consists of the combination of a land cover layer with another that represents the geography, which can be connected with ES facilitating their assessment [17]. In the context of our economic valuation, this methodology permits the analysis of physical and sociodemographic variables, such as the wetlands area and inhabitants around wetlands. As a result, we obtained the value of wetlands by zone, as well as per inhabitant. The first encourages policy makers to achieve policies for peri-urban wetlands (e.g., ecotourism), urban wetlands (e.g., appropriation of knowledge), and comunas of Cali (e.g., improvement of environmental culture). The second can be used

as a starting point for payments of ecosystem services in the protection and conservation programs of wetlands.

#### 4.2. Convergent Validity and Transfer Error

The concept of convergent validity has been discussed in the literature in the context of the benefit transfer applied to ES assessment. Thus, validity refers to the degree to which a construct is adequately measured. In this case, the construct refers to the estimate derived from the original study site, which is a proxy for the true value [17]. There are two ways to determine whether the measurements are valid: compare the value transferred with the value of an original study site conducted in the study area and compare two transferred values to determine the variability of the valuations [15]. Since there is no primary valuation study for wetlands in Cali, the second alternative is chosen to identify the convergence between the valuation performed and the benefit transfer calculated from another study with similar characteristics to the research area.

Validity is linked to the error generated during the process of benefit transfer in ES valuations. Plummer [53] identifies generalization error as the main source of errors in this methodology; there are uniformity error, sampling error, and regionalization error. The first occurs when it is assumed that the value of an ES is constant regardless of the land cover being analyzed. The second occurs with the bias in the selection of source studies (since the availability of these studies is sometimes very limited and there are few measurements). The third occurs when small study areas are taken as a reference, which may not be representative for extrapolation to a wider region [54]. Additionally, error measurement involves errors associated with the estimation of values of the source studies, which is linked to the methodology and quality of the study, and those inherent in the transfer process [17,55].

It is therefore necessary to ensure that the information is accurate and valid. Equation (4), proposed by Champ et al. [16], shows one way of measuring the accuracy of benefit transfer in which the error associated with benefit transfer is:

$$V_{Ti} = V_{Pj} + \sigma_{ij} \quad (4)$$

where  $V_{Ti}$  corresponds to the transferred value from study site  $i$ ,  $V_{Pj}$  is the required value for policy site  $j$ , and  $\sigma_{ij}$  is the transfer error. The error is calculated as the difference between the known value and the transferred value, measured in absolute percentage. In Equation (5), established by the same authors, the absolute error is:

$$\% \sigma_{ij} = |((V_{Ti} - V_{Pj}) / V_{Pj})| \times 100 \quad (5)$$

As mentioned above, to identify the convergent validity of the benefit transfer of this research, two transferred values are compared to determine the variability of the valuations and the equations described are used to measure the transfer error. First, we selected the study by Ibarra et al. [45] conducted in Mexico City. They performed a monetary valuation of the Xochimilco urban wetland for three ES: waste treatment, climate regulation, and maintenance of the life cycles of migratory species. Second, we proceeded to perform benefit transfer based on the value of 13,796 USD/ha/year from Ibarra et al. [45]. Third, benefit transfer was carried out based on the estimates of ES values selected from our database for the three ES mentioned. Fourth, the variation between the two valuations was identified, finding an absolute error of 34% for peri-urban wetlands and 66% for urban wetlands. This is within the range of 4% to 191% found for wetlands by Morrison and Bennett [56].

Finally, it should be clarified that the uniformity error for this study is limited by taking value estimates from studies originating only from wetlands, so that ES values from other land cover are not involved. With regard to the sampling error, study selection bias has been declared because benefit transfer methodology requires obtaining studies with context characteristics similar to those in the policy site, which in this study are wetlands



located in tropical zones in developing countries and continental areas. The regionalization error is dealt with by taking into account that the source studies include inland wetlands at a local level, but with a larger extension than the Cali wetlands. Therefore, it is expected that characteristics of small contexts will not be reflected in the value of the wetlands of the city. On the other hand, the error of the source studies is reduced because we worked with an ESVD database that has a peer review process, as well as published papers.

#### 4.3. Economic Valuation and Governance

The economic valuation and governance system in Cali can be interpreted through the frameworks for integrated assessment and valuation of ecosystem services [57] and social-ecological systems [58]. The first framework takes into account ES that provide benefits to society (e.g., wetlands offer ES to Cali), as well as actors who assign economic, sociocultural, and ecological values to the ES. The second considers unit resources (e.g., a wetland), system resources (e.g., urban wetlands), governance systems, and actors. All of these interact with action situations that produce social and ecological outcomes (e.g., sustainable development and conservation policies of wetlands).

The above indicates that in the case of Cali, economic valuation is an input that interacts with actors and the governance system. As a result of these interactions, decision making is carried out to produce outcomes such as policies. To illustrate, because of the highest valuation of existence and legacy value and maintenance of the life cycles of migratory species, decision makers could enhance conservation policies, ecotourism, and the environmental culture in the city. Tabares-Mosquera et al. [19] confirms that these ES are relevant to the city. Therefore, there is a need for policies that are focused on these issues.

Kabil et al. [59] propose policies to enhance ecotourism and environmental education in protected areas through economic valuation, as a policy to support local, regional, and national economies. The wetlands of Cali are also considered as areas of conservation and environmental protection. These policies could thus stimulate economic activities in the city.

Addressing the subject of weak governance in Cali, the centralized government has to move toward governance that is more inclusive and well-informed. On one hand, decision makers must encourage collective actions where inhabitants' points of view are taken in wetland management policies. On the other hand, policy makers should pay special attention to the provisions of the land-use planning, since approving changes in land use with misinformation could be detrimental to wetlands.

For the abovementioned reasons, findings of this research can be applied to urban wetlands from developing countries (e.g., Latin America). By encouraging wetland protection and restoration programs, local authorities could develop green infrastructure projects to compensate for areas where wetlands are absent or scarce. Likewise, by promoting greater community participation, social appropriation of the benefits of wetlands could be encouraged. As a result, these policies would foster environmental culture among city residents.

#### 5. Conclusions

Using benefit transfer and supported by data provided by GIS, this study carried out a total valuation of 61 urban wetlands and 175 peri-urban wetlands in Cali, covering an area of 250 ha. The wetlands are part of the environmental influence area that provides ES to the city, benefiting the population, businesses, and institutions. The total annual value of wetlands in Cali is estimated as USD 8,643,583. Seventy-six percent of the total value of the wetlands is provided by the ES for existence and legacy value, maintenance of the life cycles of migratory species, and water supply. The per capita value of wetlands depends on the distribution of the population in the *comunas* and *corregimientos* of the city. The economic valuation is an approximate estimate that provides information on the benefits of wetlands, thus being a better alternative to not recognizing any value of these ecosystems. An exploratory analysis of governance suggests the need for a regulatory framework that

aims at wetland protection, and which includes noncompliance with regulations, dispute settlement, and legal recognition of users.

The results of this research have theoretical, methodological, and public policy implications. The theoretical implications have to do with the identification and valuation of positive externalities provided by wetlands, which benefit society without users paying for them. The methodological implications refer to the constructive replication of the GIS-supported benefit transfer method to perform an economic valuation of wetlands. This is not an end in itself, since it requires developing and applying integral valuation methodologies that make it possible to understand their monetary and nonmonetary dimensions. The implications in terms of public policies are directed at the need to design dynamic institutions that allow for better coordination between environmental regulations, the land-use plan, and the social-ecological system of the city. This requires governance built on an understanding of the benefits provided by wetlands that places the needs of all users before particular short-run interests. For example, despite the national and regional legal framework that has guidelines related to the sustainable management of wetlands in the urban expansion zone, 27 wetlands are being pressured by housing projects. That is because the land-use plan has allowed construction projects in this area.

Regarding the limitations of this work, the economic valuation should be interpreted with caution, owing to the small number of studies found with similar characteristics to those of Cali (of which there are only two in Latin America). Selection bias is declared because the sample of source studies is not chosen randomly. Additionally, the assessment of the wetland area does not include the hydrological complex of rivers and streams that feed them, which is due to data limitations. Last, it should be clarified that governance analysis is exploratory, and it requires confirmatory empirical studies that could emerge as lines of research derived from this work.

This research is positioned as a starting point for urban wetland valuation studies in Colombia, as well as in Latin America. Research into valuations of the loss of ES is needed. An empirical analysis of the differences between urban and rural wetlands, in terms of user preferences and benefits is also necessary. Finally, it is necessary to continue research on the valuations of urban wetlands in developing countries to generate contributions to the development of their governance systems.

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