CAPITAL NATURAL DE COLOMBIA

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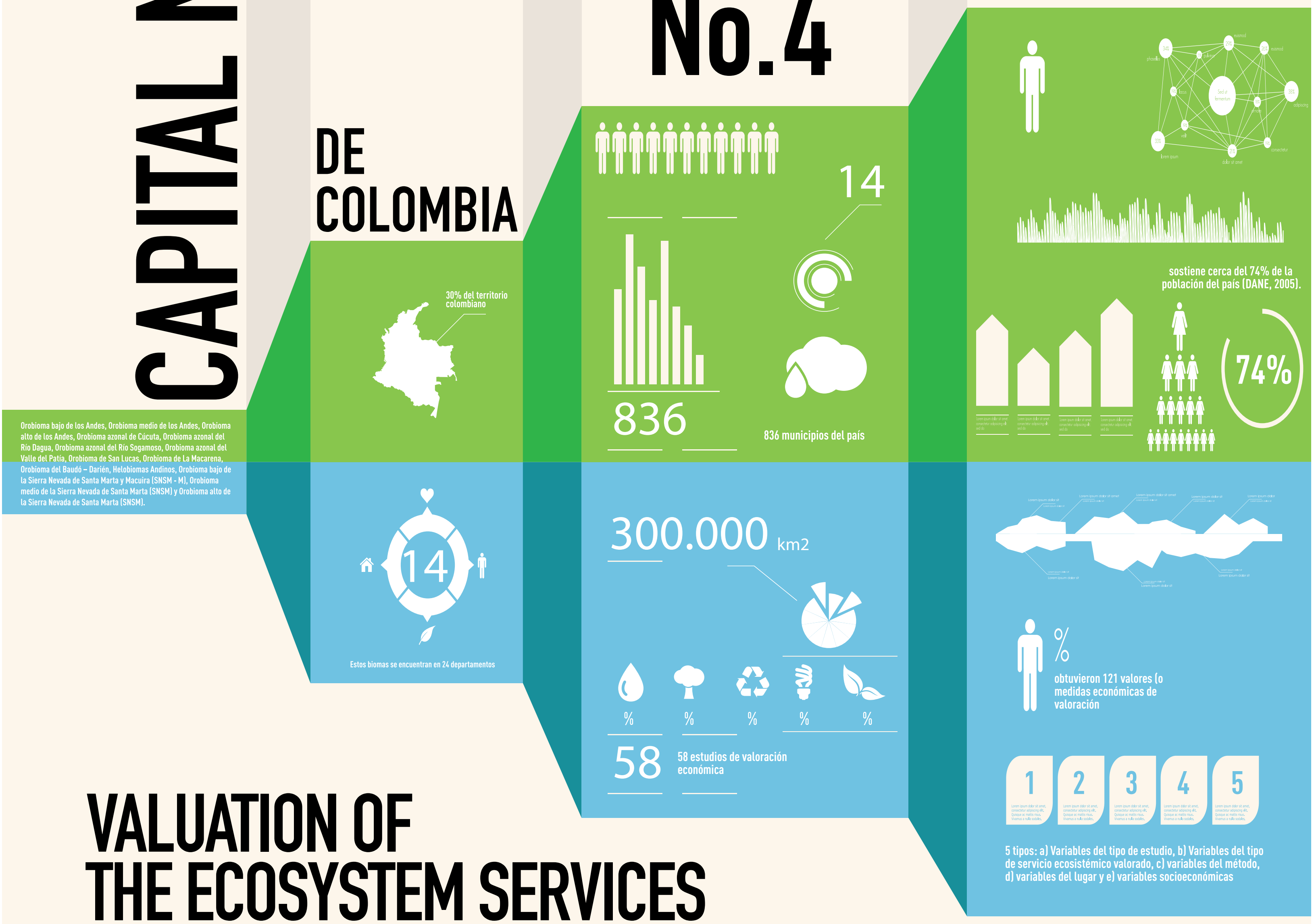

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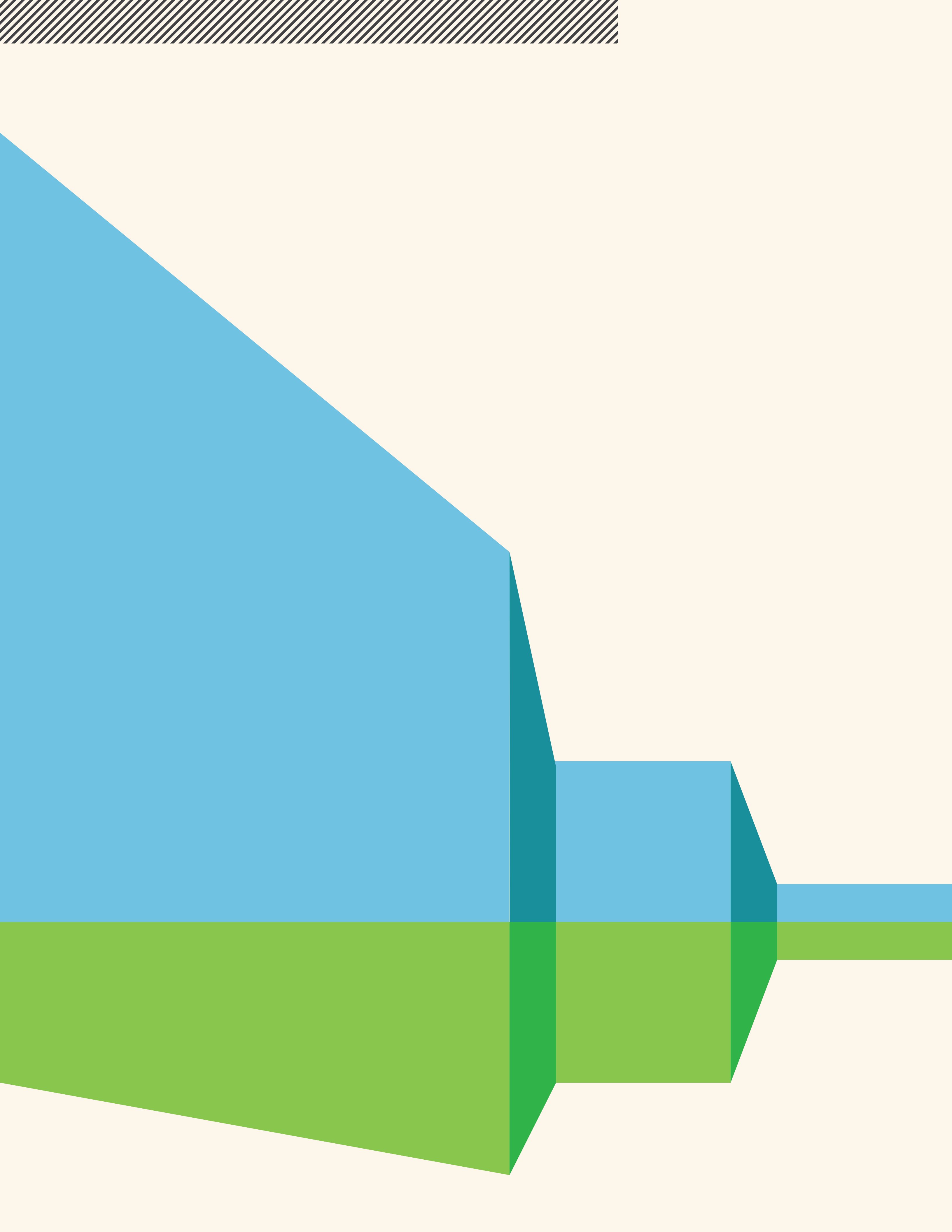
VALUATION OF THE ECOSYSTEM SERVICES IN THE COLOMBIAN ANDES. THE BENEFIT TRANSFER METHOD: A META-ANALYSIS.

CONSERVACIÓN INTERNACIONAL Colombia



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VALUATION OF THE ECOSYSTEM SERVICES IN THE COLOMBIAN ANDES. THE BENEFIT TRANSFER METHOD: A META-ANALYSIS.

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2. https://docs.google.com/file/d/0B5we0mcGmul5TjlRMVZMRFl0TTg/edit

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CONTENT TABLE

1. ABSTRACT

The economic valuation of biodiversity and ecosystem services plays an important role in Colombia's conservation planning and economic development, but gathering data to conduct an original study can be expensive. To this end, there is an alternative yet controversial method called "benefits transfer". Here, we present a meta-analysis of available literature on the economic valuation of the Colombian Andes using two approaches: transfer of mean values and transfer functions. The economic value of ecosystem services, which included water availability, recreation and conservation for the Colombian Andes, yielded values between 106 and 339 trillion 2011 USD. However, determining the overall value of ecosystems presents a complex challenge due to the difficulty in the synthesis of the studies, their variability, and the nonexistence of documented experiences. Economic valuation in Colombia is faced with issues in the presentation, collection and variability of data. We concluded that the existing information is insufficient; there are few well-designed studies to procure consistent ecosystem values to support the creation of development policies in Colombia.

Keywords: Meta-analysis; Meta-regressions; Benefit transfer; Valuation; Ecosystem Services; Colombian Andes.

2. PRESENTATION

In 2010, the Colombian Natural Capital Strategy was initiated to augment awareness of the Natural Capital of the country, and to ensure its proper incorporation into the implementation of policies and the advancement of socio-economic projects.

Despite being recognized for its natural diversity, Colombia faces the challenge of achieving economic development based on the sustainable management of its natural resources and the services provided by its ecosystems. The current National Development Plan (NDP – "Prosperidad para todos") 2010-2014, projects national economic growth based on the endorsement of five engines or forces behind development (agriculture, mining and energy, infrastructure, housing and innovation) that affect, to a greater or lesser extent, the perpetuity and integrity of the Colombian natural capital creating a dichotomy between environmental and economic growth.

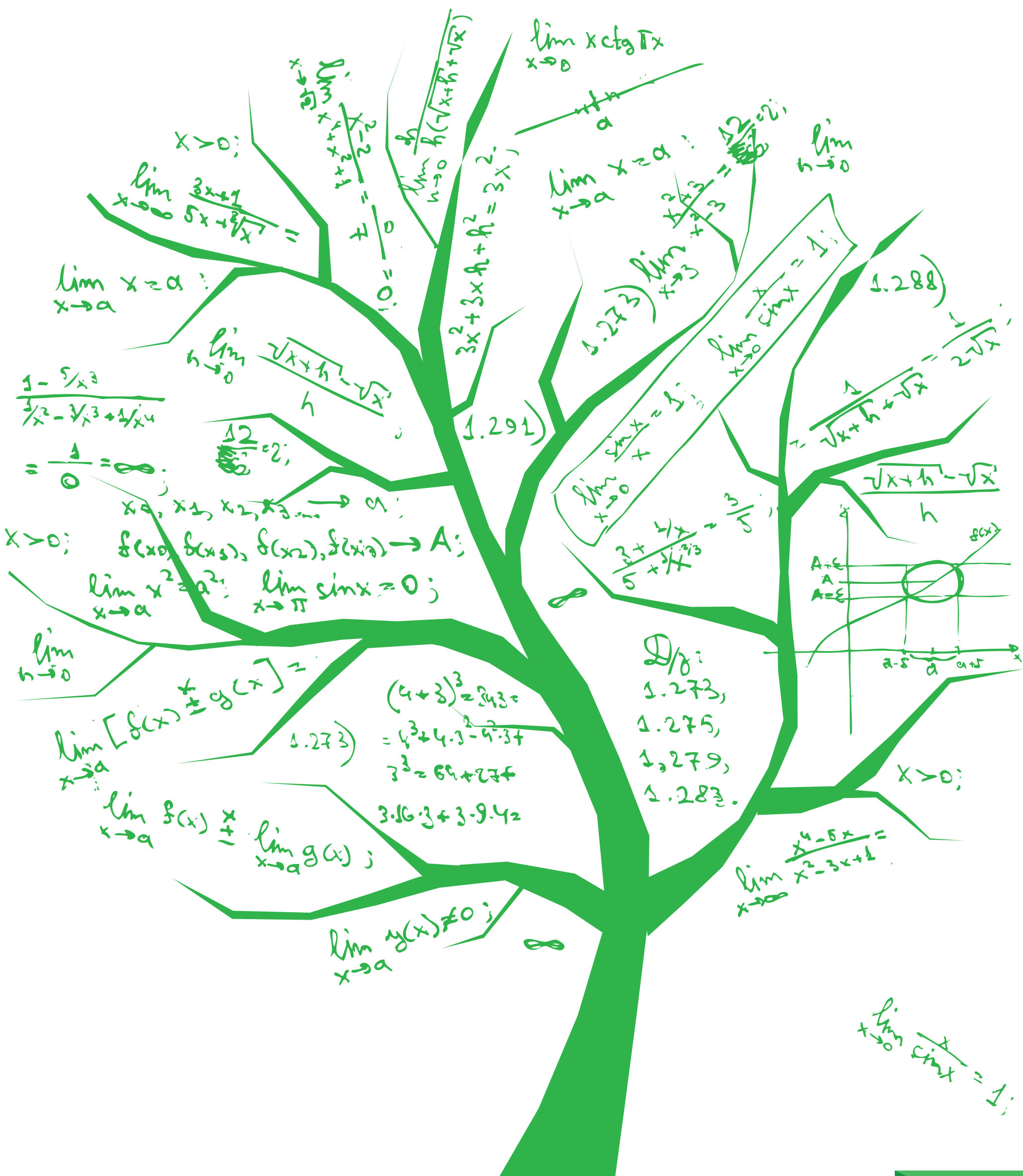
It is because of the parity and interrelationship of this dichotomy that there is an increasing need to incorporate ecosystem values in land management policies in order to develop sound policies for the development of the country. However, the value of natural capital is inadequately understood and monitored; this fosters an undervaluation of existing ecosystems by the markets and governments (Nelson & Daly 2010, Raudsepp-Hearne et al. 2010).

As part of this effort, Conservation International Colombia has carried out (since 2010) a process of compilation, critical analysis and systematization of the available information on economic valuation of ecosystem goods and services studies. This exercise intends to answer the following questions: What do we know about economic valuation of ecosystem goods and services in the country? How have studies on economic valuation of ecosystem goods and services been conducted in Colombia? Which goods and services have been monetarily valuated? Which techniques have been used in these valuation exercises? In what regions of Colombia have studies been conducted? From this viewpoint, is there enough information available to support ecosystem management decisions in Colombia? How and to what end should the available data be used?

While the valuation of ecosystem services in the country has been taking place since the 90's, most research efforts have been made for degree projects (primarily undergraduate and master) and consulting activities, which have not been widely disseminated or published (Seppelt et al. 2011). As a result, their classification, analysis and validation were time-consuming and took about two years. The studies assessed evidenced the quality of the information available in Colombia (at the ending date of this study-2013), revealed the progress made in the country, identified information gaps and contributed to the discussion on future economic valuations of ecosystem goods and services.

Determining the global value of Colombian ecosystems is a complex challenge; the first step is to synthesize and critically analyze the available information. Our intention is to contribute to achieve a greater level of understanding of this complex and controversial issue for Colombia by approaching its assessment using rigorous and innovative methodological statistical procedures.

The results presented for the region of the Colombian Andes are discussed in light of the limitations of the available information. We have used summary values for some of the ecosystem services in the region and suggested future studies of economic valuation of goods and ecosystem services in Colombia.



3. INTRODUCTION

Colombia is faced with the challenge of achieving economic development based on the sustainable management of natural resources and the ecosystem services they provide. In fact, the current National Development Plan (NDP) 2010-2014 projects national economic growth through the promotion of five (5) engines or driving forces of development (agriculture, mining and energy, infrastructure, housing and innovation). These driving forces affect, to a greater or lesser extent, the perpetuity and integrity of the Colombian natural capital creating a dichotomy between environmental and economic growth.

It is because of the parity and interrelationship of this dichotomy that there is an increasing need to incorporate ecosystem values in land management policies in order to develop sound policies for the development of the country (De Groot et al. 2002, Scolozzi et al. 2012, Di Sabatino et al. 2013). However, the value of natural capital is inadequately understood and monitored; this fosters an undervaluation of existing ecosystems by the markets (Nelson & Daly 2010, Balbanera et al. 2012) and governments (Raudsepp-Hearne et al. 2010).

One of the tools considered to right this undervaluation is the economic estimation of biodiversity (MA 2005, TEEB 2010, UK NEA 2011, Farley 2012). However, assessing the approximate value of ecosystem services of the Colombian Andes through specific analyses is a slow process; it is time consuming and expensive and requires amassing a plethora of information. This makes the process unviable to determine the value of Colombia's natural capital and incorporate it into the immediate or short-term development plans.

To address this problem, the benefits transfer method allows the transfer of available information from existing studies conducted in a particular location or context to quickly and economically assess ecosystem services elsewhere. This method entails the **"adaptation of monetary values given to environmental goods through assessments performed in an original investigation (study site), in a similar context (the policy site), to sites in which the value is unspecified"** (Rosenberger & Loomis 2003, Osorio & Correa 2004).

The benefits transfer method is advantageously based on meta-analysis; this statistical summary of study results allows the synthesis of literature on one particular subject and the evaluation of hypotheses in relation to the explanatory variables' effects in creating interest values and uses the estimated meta-analysis model to predict estimated values in space and time (Bergstrom & Taylor 2006, Borenstein et al. 2009, Barrio & Loureiro 2010).

A benefit function transfer is more technically exacting than most benefits transfer exercises, which employ fixed values or averages. A benefit function transfer allows for the adjustment of the differences in the study site and the intervention site, assessment of heterogeneity between and within studies, and search for the systematic relationship between the study values and the study attributes that generated this estimate (Rosenberger & Loomis 2001, Bergstrom & Taylor 2006, Osorio 2006, Borenstein et al. 2009). Thus yielding more sensible functions akin to site conditions and values that are more fitting to the context.

4. METHODOLOGY

To evaluate some of the ecosystem services of the Colombian Andes using the benefit transfer method, we used two approaches. In the first approach, we used the transfer of mean values, in the second, the transfer of meta-regression functions.

We selected the Colombian Andes as the policy site and delimited the area according to the 14 orobiomes of the official map of the IGAC (2010). These biomes are located in 24 departments and 836 municipalities; they occupy about 30% of the Colombian territory (300 mil km2) (Duque-Escobar 2007), and are home to about 74% of the population (DANE 2005).

Fifty-eight studies on economic valuation of ecosystem services in orobiomes of the Colombian Andes were compiled. We selected degree theses (undergraduate, master's and doctoral), technical reports and scientific papers. Because some of the studies used more than one methodology or valued more than one ecosystem or service, from these 58 studies, we obtained 121 values (or economic valuation measures). From each study, we compiled 41 of the variables suggested in the protocol by Ruiz-Agudelo et al. (2011), and divided them into 5 types: a.) Study type variables, b) Type of ecosystem services valued variables, c) Method variables, d) Location variables, and e) Socioeconomic variables.

To ensure a consistency in the evaluated assets and a consistency in the type of measure used, we classified each measure (e.g. willingness to pay-WTP, Opportunity Costs-OC, Travel Costs - TC, etc.) according to the ecosystem service valued and the method used as suggested by Bergstrom & Taylor (2006).

The consistency of biophysical and socio-environmental conditions was analyzed at two levels.

- Initially, to find an adjusted consistency, we classified the type of Andes biome where the study was conducted. Given this classification and that of the valued ecosystem service and the method implemented, we obtained 55 blocks of data.
- Then, by viewing the Colombian Andes as a homogeneous ecosystem, we approached the socio-environmental, biophysical consistency and created 20 blocks of data according to the method type and valued service.

We ascertained the temporal and spatial consistency by standardizing monetary values, such as service value, standard deviation, and average population income, reported in each study, to the existing USD value in 2011. We took into account annual inflation rates and used the exchange rate of $ 1.793,47 COL pesos per $ 1 USD reported (for Colombia) in September 2011. These measures were also homogenized

at a spatial scale, by expressing the values reported in each study, in dollars per household/month, and dollars per ha/month. We performed this conversion by taking into account the number of homes and acres reported in each reference study.

Lastly, studies were spatialized by assigning a geographic coordinate associated to the location where it was conducted. We performed an analysis of the representativeness of these studies, the methods used, and the ecosystem services valued in the areas in which they were conducted.

The transfer was performed using random values that recognize the variability between and within studies for meta-analysis (Borenstein et al. 2009). Initially, we performed an analysis of the summary effect of each block and subsequently if the information permitted, we performed a meta-regression analysis. Because some studies included more than 3 values and their respective variances, of the 55 blocks (data blocks) with specific biome, only 9 blocks could be subject to meta-analysis. Similarly, only 5 of the 20 blocks created for the homogeneous Andes included the complete information to be included in the meta-analysis.

Where meta-regression was possible, we used the transformation Log (x +1) for all the variables. We removed extreme data ends and performed an exploratory analysis based on only 10 explanatory variables that presented the most information (altitude, area, site population, income, homes, home density, age, education, socioeconomic strata and sex).

In developing the models, we took into account all the possible combinations of explanatory variables and measures, household/month, ha/month, or visit for each block. **In total, 1367 models were created, which included all the possible combinations in all the blocks;** however, **only 643 models were analyzed;** these models had more than four measures. Moreover, the heterogeneity analysis showed that the variance observed was real and not a reflection of measure differences as suggested by Borenstein et al. (2009).

We selected the model that best fit the data, considering the Akaike information criterion (AICC) for small samples was chosen. Aicc value was translated in terms of the weight that each model contributes to the block (Wi) and the radius of evidence adjustment (ERVI) (Burnham & Anderson 2003, Anderson et al. 2009). We used the radius of evidence to determine how many times the selected model performs better than another possible contender (Burnham & Anderson 2003).

Three models were selected and transferred to the Colombian Andes. We selected a model for the willingness to pay for water, one, for the willingness to pay for conservation and another for the willingness to pay for recreation. The functions of water availability and conservation were transferred at a municipal level, considering census data provided by the DANE (2005) for each municipality in the Andes region. Recreation functions were transferred to all the protected areas of Colombia based on the map of protected areas by Vásquez & Serrano (2009).

We performed an analysis of the error rate for each transferred value compared to all the values considered in each block.

5. RESULTS

5.1. STATE OF AVAILABLE INFORMATION

The analysis of information representativeness (review of previous studies) for the study area reveals that of the 14 Andes biomes, only 3 (high, mid and low Andes orobiomes) are represented; this accounts for 86% of study area. The biome with the greatest information is the mid Andes orobiome with more than 50% of the available studies, followed by the low Andes orobiome (26%) and high Andes orobiome (11%). However, when the representativeness is analyzed at a municipal scale, only 4.48% of the Colombian Andes have been studied. The areas with the most information are: Medellín, Bogotá, Belmira and Encino (Figure 1).

In this review, we report on 22 valued ecosystem services, but not all of these services are equally represented. There was a tendency towards studies on water availability (supply) and recreation potential (scenic beauty). Most of the services evaluated in Colombia use less than 5 measures. We recorded 13 valuation methods, the most often used is the transfer of benefits, followed by contingent valuation using the willingness to pay (WTP), direct cost, travel cost, opportunity cost, and avoided costs measures. The measures already reported by the benefit transfer were discarded to avoid transferring the already transferred. Of the total 95 explanatory variables reported in all the studies available for Colombia, only the 10 most common and supported were taken into account.

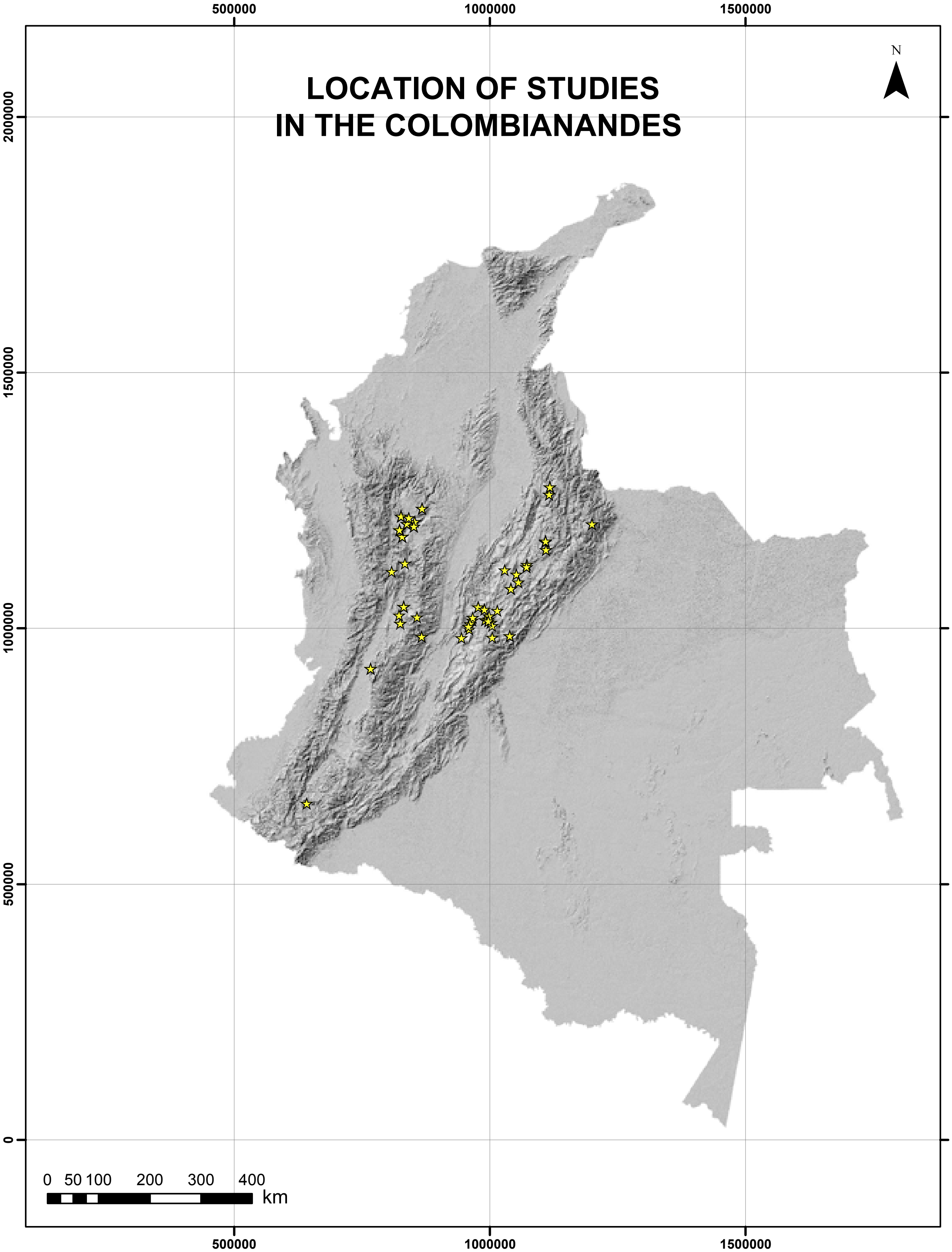


Figure 1. Measure location and representativeness in the biomes of the Andes of Colombia

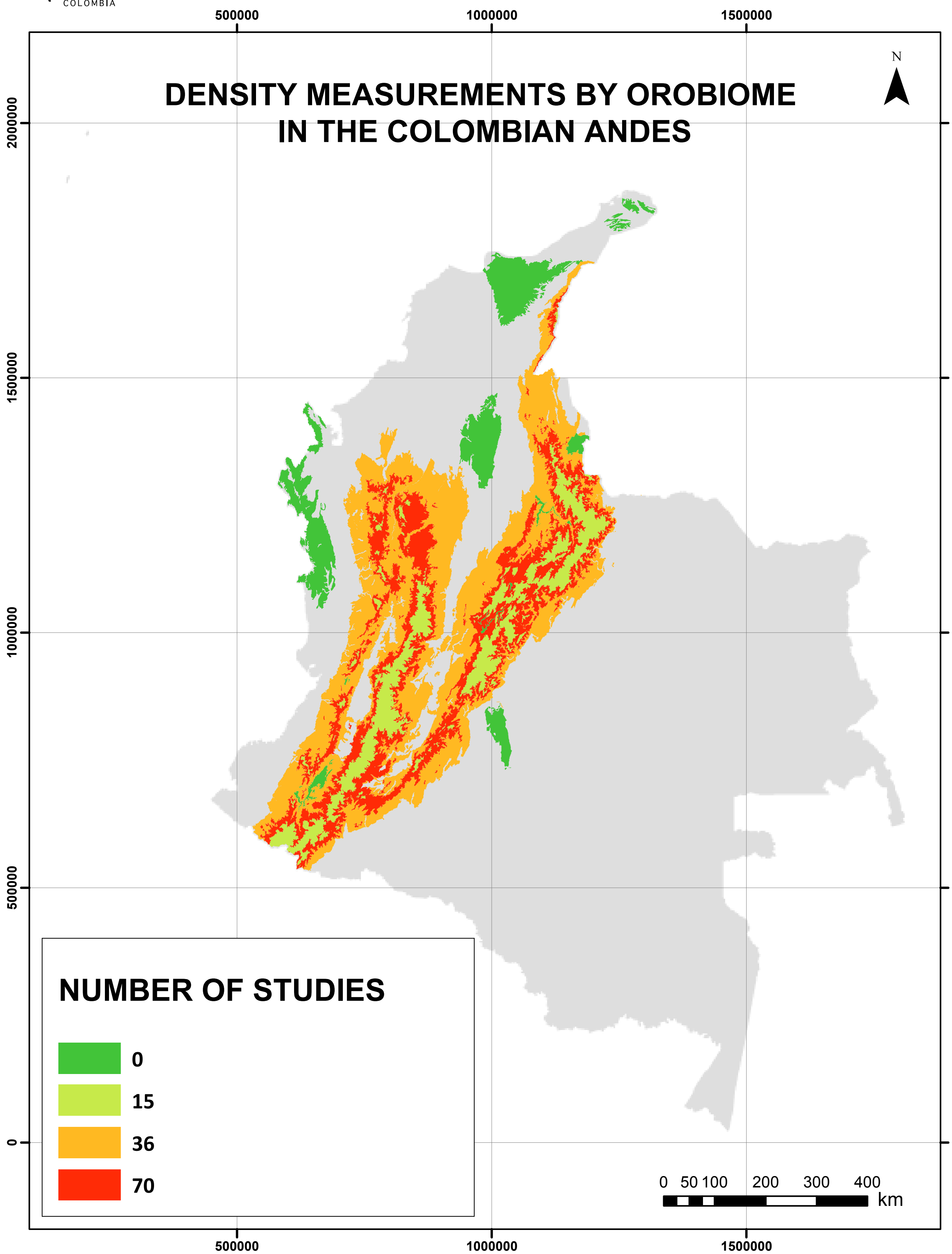


Figure 1b. Measure location and representativeness in the biomes of the Andes of Colombia

5.2. TRANSFER OF MEAN VALUES

5.2.1. Water Availability (supply)

The meta-analysis of the most stringent blocks to valuate water availability indicates that the standard effect is greater when the opportunity cost methodology is used and when the assessment is made by hectare. The value approximation of this service is higher in the mid Andes orobiome, followed by the low orobiome and is lowest in the high Andes orobiome; seeing that communities in the highlands openly benefit from a good quality and abundant service while communities in the lowlands experience the effects of pollution and scarcity generated by the communities above. Moreover, the effect of large cities located in the mid Andes directly affects the willingness to pay (these cities aggregate the greatest demand (see Figure 2).

The summarized values of willingness to pay, by biome, range from $ 0,43 to $ 4,83 USD 2011 per household per month, and from $ 0,06 to $ 5,57 USD 2011 per hectare per month.

Although there is a greater willingness to pay for water availability in the mid Andes, this amount does not cover the opportunity cost required to provide the service for a hectare in the higher areas (OC= $461,702 USD 2011/ha – vs - WTP = $2,42 + 0,5 USD 2011/ha).

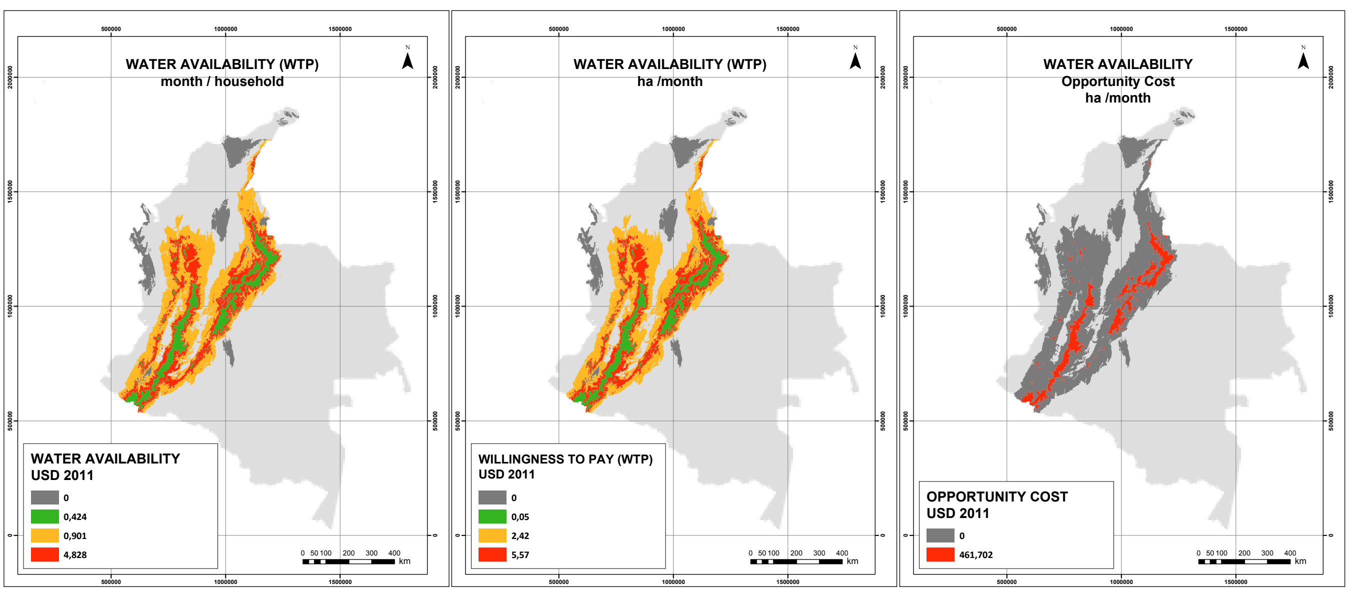


Figure 2. Spatialization of the values established by median value transfers for water availability in the evaluated Andean orobiomes.

5.2.2. Recreation (scenic beauty)

The meta-analysis of the blocks to evaluate recreation services indicated that the highest average effect in the studies was found in the high Andes orobiome ($10,049 USD 2011/visit), followed by the low orobiome ($8,88 USD 2011/visit) and the lowest value was found in the mid orobiome ($3,79 USD 2011/visit). **The average effect of the willingness to pay for recreation in the high orobiome is almost tree 3 times higher than in the mid orobiome**. Despite their conceptual differences, no large differences between the values given by the different methods used were observed for recreation use (Figure 3).

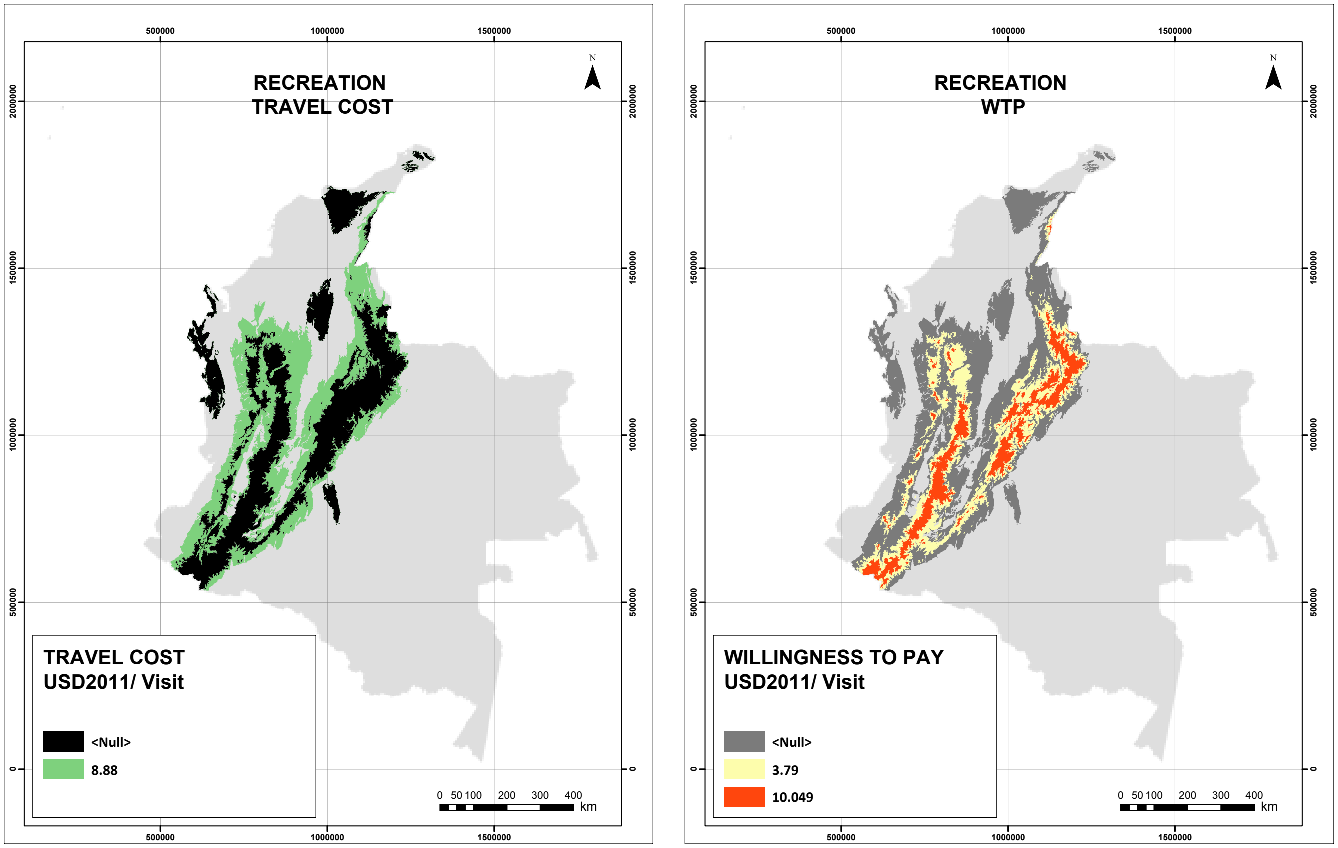


Figure 3. Spatialization of the values found by median value transfers for recreation in the Colombian Andes.

5.2.3. Conservation (bequest value and existence)

The meta-analysis for willingness to pay conservation ecosystem services in the mid Andes orobiome showed that the amount payable per hectare ($13.960,68 USD 2011/visit) is over three thousand times greater than the willingness to pay per household ($3,999 USD 2011/visit). These values per hectare are highly influenced by extreme values obtained from studies 12 and 13 conducted in the Bogotá wetlands (**Please see:** http://www.conservation.org.co/?page_id=6303). These studies take into account the entire population of the nation's capital (more than 7 million dwellers and about a million and a half households) making the willingness to pay per hectare extremely high.

The valuation of the conservation service (bequest and existence values) is higher than that of all the other services; this suggests that conservation assembles a whole range of benefits including bequest and existence values. In Figure 4, we see that there is a greater willingness to pay for preserving higher areas, because of the number of essential services they provide and the perception of importance given by the communities to these services.

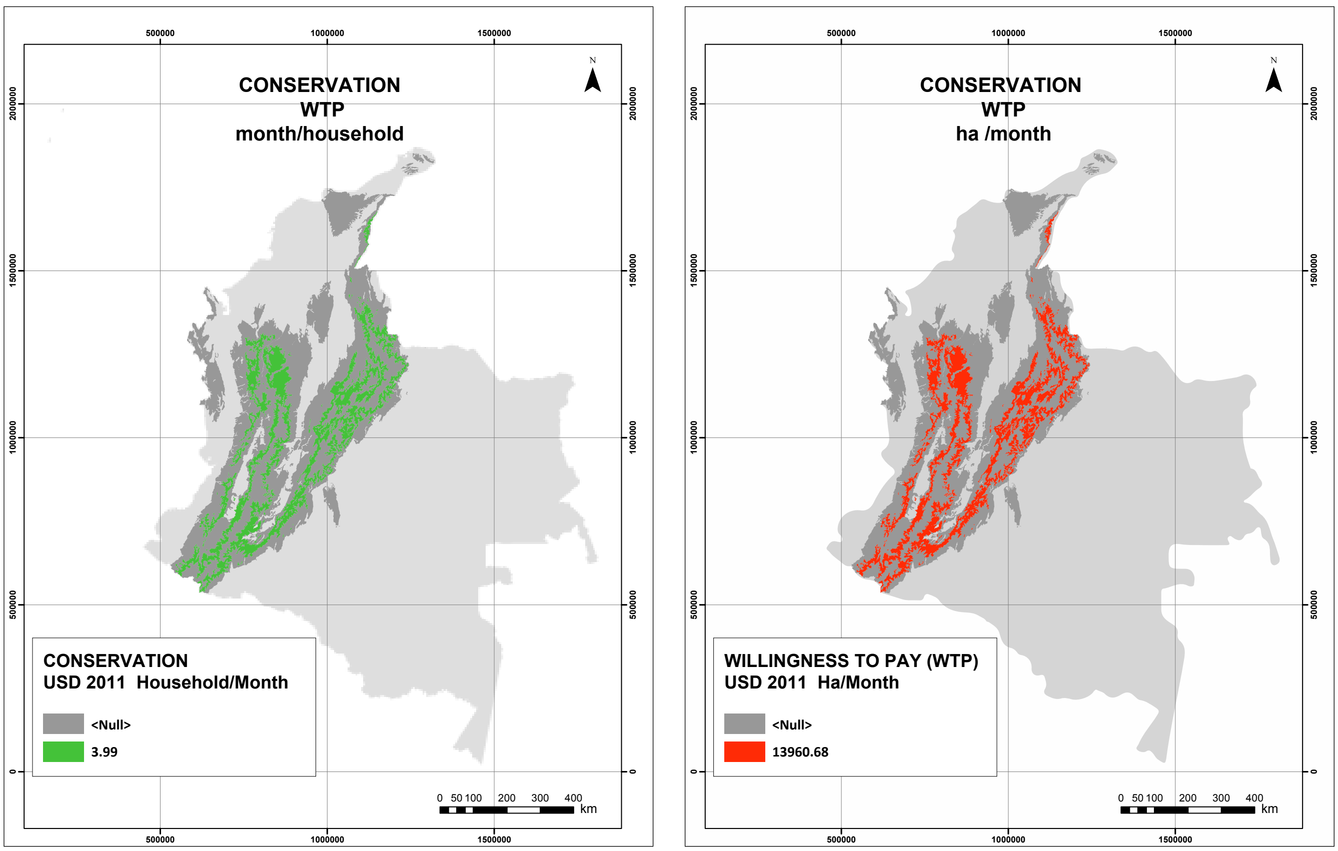


Figure 4. Spatialization of the values obtained by the transfer of median values for conservation.

The total value of the Andes orobiomes ecosystem services (that could be addressed in this study), valued by the transfer method of mean values in the analyzed baseline rose to **$105.775´974.313, 69 USD 2011**. The value of water availability in the Andes was **$76´501.474,83 USD 2011**. Recreation service was $ 70´664.446,7 USD 2011, and the value of willingness to pay for conservation (mid Andes Orobiome communities) totaled **$105.628´808.392,20 USD 2011** (Table 1).

If we strictly consider only ecosystem services (water and recreation), the value of these, for the valued orobiomes of the Colombian Andes, rises to **$ 147´165.921, 49 USD 2011**.

OROBIOME	Extension by Ha	WTP WATER		WTP RECREATION		WTP CONSERVATION		TOTAL ANDES OROBIOMES USD
		Average USD 2011/ha/ month	Orobiome value USD 2011	Average value USD 2011/ha/ month	Orobiome value USD 2011	Average value USD 2011/ha/ month	Orobiome value USD 2011	
Lower Andes orobiome	14´035.898	$ 2,43	$ 34´107.232,14					$34´107.232,1
Mid Andes orobiome	7´566.165	$ 5,57	$ 42´143.539,05	$ 3,79	$28´675.765,4	$13.960,68	$105.628´808.392,20	$105.699´627.696,60
High Andes orobiome	4´178.394	$ 0,06	$ 250.703,64	$10,05	$ 41´988.681,3			$ 42´239.384,9
TOTAL - USD		$	76´501.474,83	$	70´664.446,7	$	105.628´808.392,20	$105.775´974.313,69

Table 1. Valuation of Andes orobiomes by transfer of average effect. Values are expressed in 2011 USD.

We compared the values found in each orobiome against the values of the studies involved in the analysis. We observed that the greatest transfer error is in the opportunity cost (OC) per hectare followed by the month; further errors did not exceed 100% (Table 2). We noted that the percentage of error correlates with the amount of data being considered and its distribution. For the availability of water, the greatest errors were found in comparison with the studies of the mid and lower orobiomes. In recreation, the most prevalent errors are related to studies of the mid and high orobiomes.

		AVERAGE ERROR
WATER AVAILABILITY	WTP - MONTH	62.6%
	WTP - ha	51.9%
	OC - MONTH	558.3%
	OC - ha	1.024,2%
RECREATION	WTP - VISIT	51.5%
	CV - VISIT	49.27%

Table 2. Average error of mean effect transfer

5.3. FUNCTION TRANSFER FOR BLOCKS IN THE ANDEAN REGION AS A HOMOGENEOUS REGION

5.3.1. Functions found for water availability (offer)

Of the 511 models tested, those which showed the best performance in light of the national baseline, were those that considered age and sex.

$$\text{willingness to pay for water (ha/month)} = 0.306\log(\text{age}+1) + 0.056$$

The model explaining the willingness to pay per hectare depending on age was the most parsimonious of all (AICC = 17.84) followed closely by sex (AICC= 17.913). These two models amass 29% of the relative weights of all models (Wi =0.148 + 0.142) and account for 43 % of the variance of the data (R2).

The relationship of age and sex with the willingness to pay for water availability per ha/month shows a negative correlation with sex (Rs = -0.8) and a positive, but smaller correlation with age (Rs = 0.33). This indicates that, with fewer men, the willingness to pay is higher. That is, women are more willing to pay for the service, especially if they are adults.

5.3.2. Functions found for recreation (scenic beauty)

We tested a total of 73 models, using the following explanatory variables: height (masl), area, income and local population. For the recreation service, the meta-regression functions showed that the models that explain the valuation of recreation in terms of the area or elevation (masl) are those with the best performance and are the most parsimonious. Largely, based on the information analyzed in the national baseline, the willingness to pay is contingent on the area.

$$\text{willingness to pay per visit} = 0.085\text{Log}(\text{Area}+1) + 1.371$$

Based on the analyzed information, the relationship between willingness to pay per visit and the area is positive in these models (Rs = 0.60); this indicates that, as the area that offers the recreation service is larger; the willingness to pay for access to it is also greater.

5.3.3. Functions found for conservation (bequest value and existence)

The models found for the willingness to pay for conservation, included the explanatory variables of altitude (masl), area, local population, household and household density because of the scarcity of variable data. The models that presented the best performance were those that explained the willingness to pay for conservation in terms of the variables related to population size.

$$\text{willingness to pay for conservation} = 0.845 \log(\text{household}+1) - 3.293$$

Where there is a positive relationship with population (Rs = 0.798), that is, when there is a higher concentration of the population there is a greater willingness for conservation.

Figure 5 shows the value distribution when applying the transfer functions displaying the best performance to the municipalities of the Colombian Andes.

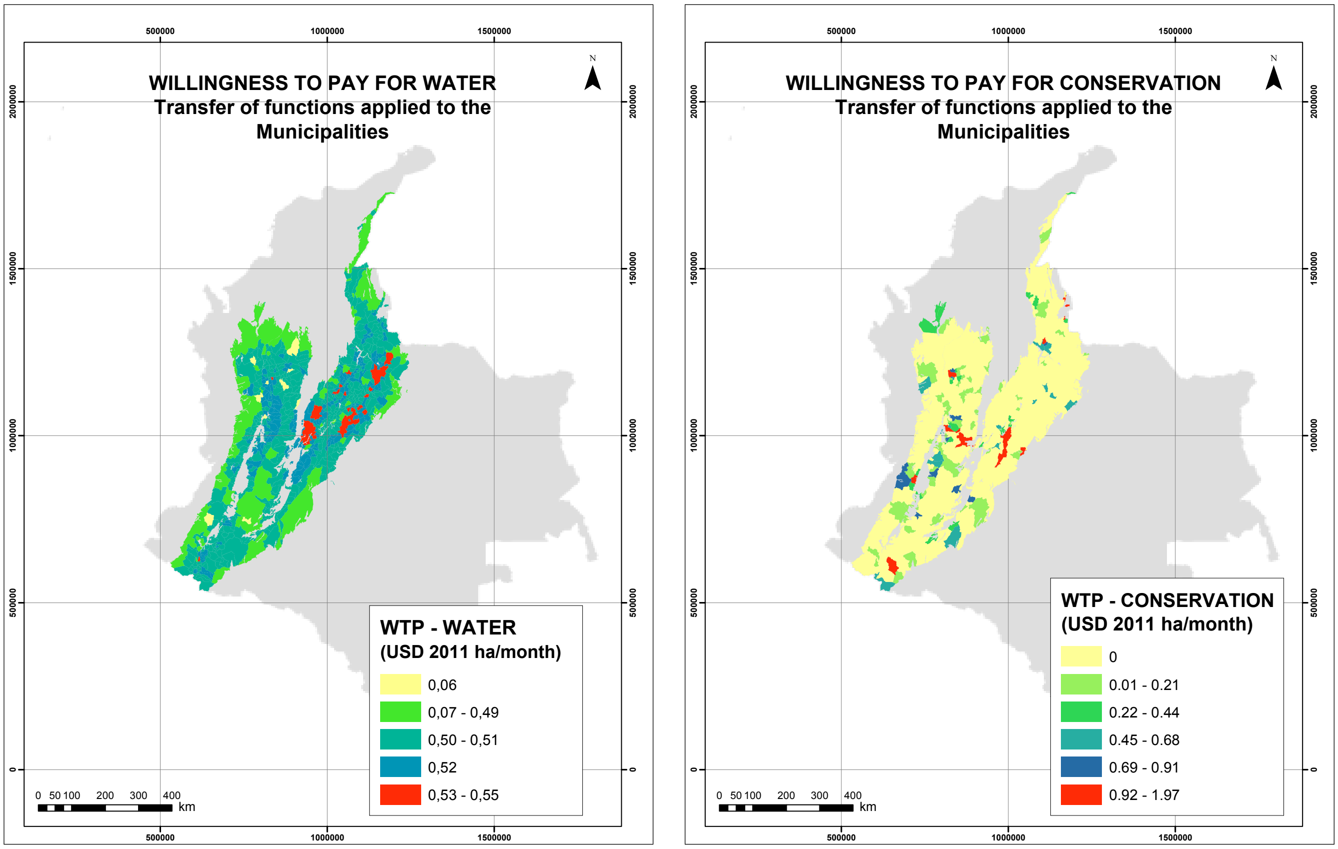


Figure 5. Valuation of the Colombian Andes in keeping with the transfer of functions applied to the municipalities. A) Willingness to pay for water, B) Willingness to pay for conservation.

We found that the willingness to pay for water is highly variable in the municipalities of the Andes; the highest values are concentrated in the eastern cordillera while the willingness to pay for conservation is concentrated in large cities (Figure 5 b in red: Bogotá, Medellín, Pasto, Ibague, Bucaramanga, Cucuta, Cali and Manizales).

Meanwhile, because recreation in natural settings is concentrated in these service areas, recreation functions were transferred to the protected areas of Colombia. The values obtained show a higher value in national natural areas than in regional and local areas (Figure 6).

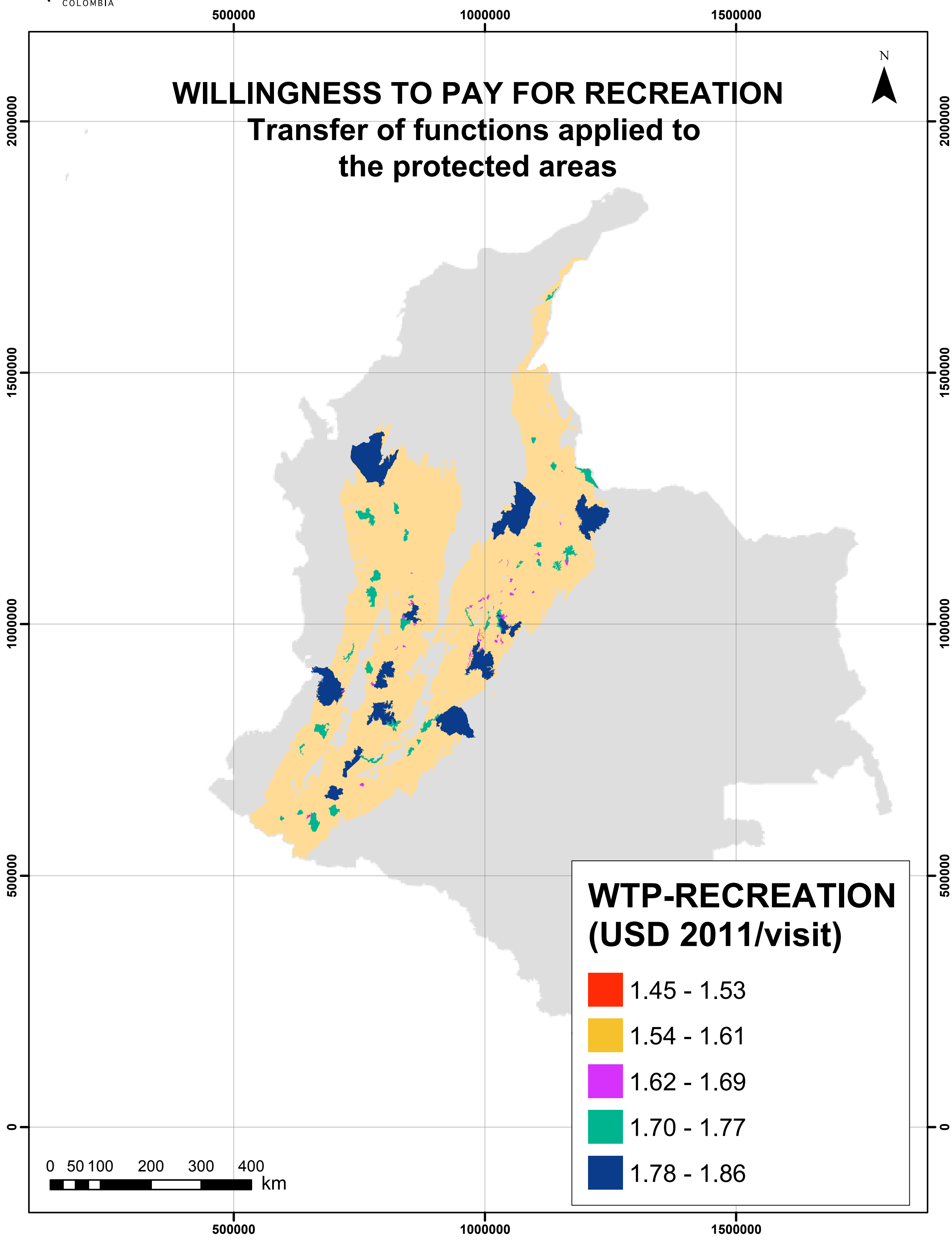


Figure 6. Values obtained for the recreation ecosystem service in protected areas in Colombia by function transfer. A) Willingness to pay per visit.

Under the constraints of the national baseline, this value transfer allows us to find the indicative value for these specific services of the ecosystems of the Colombian Andes, which is $ 338.937´632.975,54 USD 2011. The major contributor is the willingness to pay for conservation while the willingness to pay for water only amounts to $ 1.190´115.047,11 USD 2011 (Table 3).

ASSESSED SERVICE	TOTAL VALUE (USD 2011)
WATER AVAILABILITY	$ 1.190´115.047,11
CONSERVATION	$ 337.747´517.928,43
TOTAL COLOMBIAN ANDES - USD	$ 338.937´632.975,54 *

Table 3. Total valuation of the Colombian Andes. The values per hectare were extrapolated. * Because recreation is valued per visit and no estimate exists, from a national baseline, on the average number of annual visits for each national, local and regional protected area, the recreation service could not be extrapolated per hectare.

The comparison of the error value and the studies shows that the errors found through the meta-regression functions were higher than those found by the mean value (Table 4). This because of the scarce significance of the found equations, influenced by a restriction in the number of studies, their variability, and the amount of information available in the explanatory variables.

MEASUREMENT	%AVERAGE ERROR
WTP* - WATER AVAILABILITY	187.73 %
WTP - CONSERVATION	101.93 %
WTP - RECREATION AREA	74%
TC *- RECREATION AREA	67.58 %

Table 4. Average errors found by function transfer. WTP* - Willingness to pay. TC* - Travel costs.

6. DISCUSSION

6.1. METHODOLOGICAL LIMITATIONS

The appraisal of the studies chartered an understanding of the quality of the information available in Colombia at the time of this study (2013). It allowed us to determine the progress made in the country, and detect information gaps to contribute to the discussion of future steps in the economic valuation of ecosystem goods and services.

Determining the total value of Colombian ecosystems is a complex task; the synthesis of studies is challenging, as is their variability, compounded with the lack of documented ecosystem services and ecosystem valuation experiences.

The presentation, collection and variability of data had made the synthesis of valuation exercises in the country, to the date of this study (2013), challenging. The high variability of the studies reviewed made it difficult to conduct a transfer of benefits from strict economic models based on a utility theory such as SUT or WSUT1. To develop these models, information is needed on the socioeconomic characteristics of individuals and the ecosystem services, which in many cases, is unreported (Bergstrom & Taylor 2006). Accordingly, we used the NSUT2 approximation model. This model presents exploratory variables related to economic theory; however, the connections between these variables and the underlying utility function are not explicitly specified. It incorporates variables from multiple scientific information sources which otherwise not be considered by a strict utility theory model, enhancing the preference formation framework (Spash & Vatn 2006). Despite opting for the most developmental and yielding, there is still a long way to go in pursuit of a more comprehensive framework including environmental variables. Most of the studies reviewed have failed to address other modeling options that could shed a more accurate light on the actual provision of ecosystem services, their interrelationships and offer feedback (Nelson et al. 2009).

Additionally, the low representation of valuation exercises in the Colombian Andes poses a challenge. Only 3 of the 14 Andes orobiomes have been valuated; this limits the evaluation to smaller scales such as ecosystems, coverage and even municipalities (studies have been conducted in only 4.48% of the municipalities), and inflict the risk of regionalization errors when performing benefits transfers (Rosenberger & Stanley 2006). Because this region supports 74% of the Colombian population (DANE 2005), and sustains mega infrastructure projects such as dams, viaducts, and mining undertakings, which inflict huge challenges to the conservation of ecosystem relicts, it is vital that we generate better ecosystem valuations to include the in the develop of local policies to be implemented in the region.

1 SUT=strong structural utility theoretic approach, WSUT=weak structural utility theoretic approach.
2 NSUT= Non-structural utility theoretic approach

Obtaining the total economic value has another limitation. The studies have focused on water derived services, especially water availability for populations, ignoring others such as cultural services and even services such as the provision of items such as firewood, and the regulation of fishing, logging, pollination, and biological control, among others. The information reported on the 22 services valued in Colombia is so irregular and incomplete, that a meta-analysis was only possible for three services (water, recreation and conservation willingness), which further demonstrates the long way that remains before achieving a total economic value.

The deficiencies and gaps in information for Colombia may prompt the three errors cited by Rosenberger & Stanley (2006): uniformity errors, measurement errors associated with information representativity and regionalization errors. The variation in ecosystem conditions within a single coverage or unit of analysis (uniformity errors) is enough to produce sizeable errors in setting the prediction, similarly, sampling errors and extrapolation from studies of small regions (generalization error) can also lead to further reductions in the ability to adjust primary data (Eigenbrod et al. 2010). By the way in which the information block was raised, we attempted to compensate for these types of errors.

To manage the risks of regionalization errors, we only considered studies conducted in ecosystems of the Colombian Andes, but because of the broad scales of the biomes, the risk of regionalization persists, even more so when the Andes are considered as a single homogeneous system. We attempted to avoid the risk of measurement errors by scrutinizing and cautiously handling atypical data from studies conducted in disparate places. We also created study blocks, which applied the same valuation method; this segregation precludes the comparison of measurements from different utility functions (Bergstrom & Taylor 2006). However, within each valuation method used there are other methodological factors or decisions made by each investigator, which were not reported extensively in the studies, making the error nevertheless important (Rosenberger & Stanley 2006).

Considering the previous, the authors would like to make some recommendations regarding the information requirements necessary to perform a transfer of benefits so that the information yielded from the studies can be maximized and can ensure the three types of consistencies necessary to reduce the risk of error (Johnston et al. 2006). **Please see:** http://www.conservation.org.co/?page_id=6303

As a first step, we suggest the creation of an online database for the valuation of Colombian ecosystems in which the information collected through strict methodological protocols is standardized (ERVI 2007). This database will produce a catalogue of valuation projects to create a national unit and provide common, comparable and adaptive information to be used to perform transfers using better-adjusted models and generating more reliable results to be included in policy development country. Concurrently, it will contribute to other studies across multiple contexts to provide a better understanding of tropical systems and preferences of users in developing countries (McComb et al. 2006).

6.2. BENEFIT TRANSFERS APPLIED TO THE COLOMBIAN ANDES

The application of benefit transfers to the Colombian Andes had three purposes: to summarize and evaluate existing and available valuation studies, to determine the variables that influence the values, and to employ meta-analytic model based predictions. Each of these stages depends on the degree of accuracy and level of information attained, as the "the transfer can only be as accurate as the primary studies" (Brookshire & Neill 1992, Wilson & Hoehn 2006). Consequently, the predictive level of benefit transfers is compromised according to data analysis and limitations. Only an approximation can be made to incorporate the value patterns assigned to the ecosystem services of the Colombian Andes, and develop a magnitude comparison between the results obtained by different methods.

In the first analysis, we considered the Andes as heterogeneous systems influenced by altitudinal variations and biotic conditions that in one way or another condition sociocultural practices and characteristics, this allowed us to produce more befitting measures. In continuously representing value in the orobiomes, this type of transfer assumed a uniformity error (Rosenberger & Stanley 2006); however, the intention was to show an approximation to the distribution of values (Rosenberger & Loomis 2003, Loomis & Rosenberger 2006). The differences in orders of magnitude revealed that highest benefit associated with water availability was found in the mid Andes orobiome, where the water resource requirement is highest due to demographic demands and the topography of steep slopes impedes its collection. This pattern in benefit measure is revealed in both the household/month and the ha/month approach. These values show a market disparity when compared to the opportunity cost of one hectare in the high Andes orobiome, where the service originates because the cost is not enough to be offset by the willingness to pay in lower altitude orobiomes.

This apparent market disparity can be supported by remarking that an acre not only provides a single service, but its conservation represents a provision of bundled services. In other words, the conservation of a given hectare of orobiome provides a wide range of ecosystem services. As such, when we analyzed the benefit measure reflected in the willingness to preserve a hectare, the value is much higher; this indicates that in the concept of an individual, the conservation of an ecosystem is highly valued because it encompasses a wider range of benefits.

Because the willingness to pay for conservation is considerably higher, this measure of benefit also involves the recreation ecosystem service. Spatialization reveals that the greatest recreation benefit is found in the high Andes orobiomes; this area is a preferred location for leisure and research activities. These higher orobiomes include the paramos, which are recognized nationally for their biological endemism and are vital for the sustainability of communities (water supply, etc.). The paramos are also recognized for their cultural importance and their unparalleled scenic beauty (Morales et al. 2008).

The use of study site spatially sensitive models produced additional estimates that revealed the spatial variability of transfers by mean values and identified priority ecosystem services supply and demand sites (Bateman et al. 2006, Eigenbrod et al. 2010). This information can be used to direct the development of future strategies for the maintenance of key ecosystem services (Naidoo et al. 2008). For instance, the maps obtained by function transfers allowed us to categorize recreation service offers and determine a higher appreciation for areas of national character. Similarly, we observed the variability of the conservation benefit measure and its concentrated demand in larger cities.

We found that socioeconomic variables such as sex, age, and population strongly influence the models obtained for the valuation of water availability and conservation. Variables such as income that we expected would be determinants were not important. In most of the available studies, income was similar, generally nearing minimum wage; therefore, other demographic variables became determinants. Demographics such as age and sex revealed that adult women have higher willingness to pay; this is upheld by the increased level of awareness and penchant for the wellbeing of the household in women. With age, women often have children and contemplate their offspring's future welfare and as a result are more likely to pay for ecosystem services.

Population density was key in the willingness to pay for conservation. The largest proportion was concentrated in large cities; this is indicative of a perceived wellbeing in urban populations. This availability in major cities can potentially be used to generate compensation policies for other ecosystems. Conversely, the assessment of recreation services was contingent on physical variables such as altitude and area, indicating that the valuation of recreation depends on the location's attributes and does not respond to socioeconomic conditions. Preference or higher valuation of spaces with large extension indicates that larger areas may be more attractive than smaller areas; in turn, recreation valuation at higher altitudes of the Colombian Andes indicates a strong fondness towards the paramos.

To conclude, the approximation of the economic value of ecosystem services considered in the Colombian Andes, yields values between 106 and 339 trillion USD of 2011 (gross, w/o discount rate corrections); this is still an undervaluation of the total economic value as it does not include the full range of ecosystem services provided by the Colombian Andes.

The variability of these values indicates that the transfer method has a significant effect on the estimated value (Johnston et al. 2006). A greater valuation was achieved using the function transfer method found than using the mean value, making it once again evident that in considering spatial variability a more precise valuation of ecosystem services is obtained.

Despite these differences, the analysis of the orders of magnitude of the values yielded results that enable offset markets, since the amounts obtained can generate a market between the supply and demand sectors. However, these proxy values still underestimate the true value of the Andes ecosystems, as (due to the previously mentioned limitations) only some of the ecosystem services were considered.

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