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A meta-analysis of economic valuation of ecosystem services in Mexico

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ABSTRACT

This paper provides a comprehensive review of the literature on the economic values for ecosystem goods and services in Mexico. We analyzed 106 studies that estimated an economic value for any given environmental good or service in the country. In total, we coded and classified 352 values according to the Common International Classification of Ecosystem Services (CICES) and the Economics of Ecosystems and Biodiversity (TEEB) ecosystem classification. We then estimated an econometric model to compare the value of different services in different ecosystems. We show that regulation services are more valuable than cultural and provisioning services, that wetlands are more valuable than forests and cultivated systems, and that deforestation for arable land is not cost-effective, because the regulation services of forests are more valuable than the provisioning services of crops. We also calculate the elasticity between the value of ecosystem services that forests provide in Mexico (in USD/hectare per year) and the supply of each ecosystem (in hectares). This elasticity is statistically significant and equal to −0.37. This estimate is relevant in policy terms, since it adds an economic rationale for conservation to other moral and philosophical criteria, especially in areas currently experiencing a high degree of deforestation and degradation.

1. Introduction

Placing an economic value on nature may be a powerful policy tool since it makes invisible benefits from nature to society visible. When these benefits are invisible, there is a risk that policy decisions are made by assuming they have a value of zero or with a complete unawareness of their real value. According to TEEB (2009), making these values visible makes it possible to: (i) compensate those who provide benefits, (ii) modify subsidies that affect natural capital, (iii) internalize environmental losses by establishing rates and prices or enforcing regulations, (iv) create economic value through protected areas, and (v) invest in ecological infrastructure. In every case, more information on the value of nature enhances the policy making process. Even when economic valuation of ecosystem services is not the only way to inform policy makers, yet is a simple way to communicate the value of nature.

Significant progress has been made in recent years in the economic valuation of ecosystem goods and services as borne out by the Economics of Ecosystems and Biodiversity project (TEEB, 2010b). Moreover, ecosystem services is a "rapidly emerging field, which generated over 2400 papers" between 1990 and 2011 (Costanza & Kubiszewski, 2012). Literature reviews and databases have recently been developed to concentrate and systematize the economic values of nature estimated by thousands of authors. For example, de Groot et al. (2012), provide global estimates of the value of ecosystems and their services in monetary units based on a meta-analysis of over 300 case studies.

To our knowledge, the Environmental Valuation Reference Inventory (EVRI) (Environment Canada, 2016) and the Ecosystem Service Valuation Database (ESVD) (ESP, 2014), are the largest sources of information on the economic values of nature. The ESVD contains 1310 registries[1] drawn from 267 single studies, published between 1966 and 2010 (60% between the years 2000 and 2010). The EVRI database contains registries from 4571 studies published between 1971 and 2016 (70% in 2000–2015; and 49% between 2000 and 2010).

This type of literature is usually concentrated in a few countries. For example, five[2] countries account for 26% of all ESVD registries and two for 45% of all EVRI registries.[3] The literature on the

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[1] Each registry represents one economic value.
[2] USA, China, Spain, Australia and the UK.
[3] USA and Canada.

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economic valuation of environmental services is still uncommon and scattered in countries such as Mexico. Although the ESVD contains 26 registries (2%) for Mexico, they are drawn from just four studies, the latest one being published in 2001 (Adger et al., 1994; Barbier & Strand, 1998; Godoy et al., 1993; Perrot-Maître & Davis, 2001). To date, the EVRI contains registries for Mexico from 135 studies (3%).

The importance of ecosystem services for policy making is recognized at the highest level of the Mexican government; where they are considered a pillar of sustainable development (Gobierno de la República, 2012). Furthermore, government officials from the environment sector have often stated the need to know the economic values of nature in order to increase their bargaining power when supporting policies that enhance environmental sustainability, since they usually compete with other sectors lobbying for policies with high short-term economic benefits, but adverse environmental effects (such mining and unsustainable coast tourism).[4]

In this context, the purpose of this paper is to systematically analyze available studies on the economic values of environmental goods and services provided by ecosystems in Mexico. To this end, we analyzed 106 papers, classifying them and identifying the information gaps. To our knowledge, only Perez-Verdin et al. (2016) have done a similar effort. The authors classified 43 papers to identify information gaps and give insights of future research needs. In this paper, we classified a larger set of studies and developed an econometric model which is aimed to generate specific policy recommendations.

2. Materials and methods

Since the end of 2014 and until the end of 2015, we sought available studies related to the economic valuation of environmental goods and services focused in Mexico. We found a set of 33 papers that had already been recorded in the EVRI and subsequently located another set of 73 papers. The search was conducted online using keywords related to the economic valuation of environmental goods and services in Mexico in both Spanish and English. In our search, we prioritized studies from academic journals; however, we included some academic theses and working documents from government agencies (see Table 1).

Table 1
Types of studies included in the review.

Source	Freq.	Percent	Cum.
Journal	55	51.89%	51.89%
Working paper	19	17.92%	69.81%
Government/non-government report	16	15.09%	84.91%
Thesis	7	6.60%	91.51%
Conference paper	5	4.72%	96.23%
Magazine	4	3.77%	100.00%
Total	106	100.00%	

Source: Compiled by the authors using information from (Environment Canada, 2016).

Most of the papers were very recent. Twenty-seven percent were published in the period between 2010 and 2016, another 48% between 2005 and 2009, and the remaining in previous years (Fig. 1). When comparing the publication date of EVRI papers that value environmental services in countries other than Mexico, we found very different scenarios; in the period 2010 to 2015, only 14% of all the papers located were published (Fig. 1).

On the basis of the 106 studies (see Annex E), we gathered 352 economic values of environmental goods or services for/in Mexico. In average, there were 3.3 values per study, and 54 studies (50%) reported only one value. The most common method is contingent valuation and market prices, also, most studies (70%) use primary data in their analysis, regarding the scope of analysis, 78% are site-specific (see more detail in Table 2 and Fig. 2).

We classified each value according to the type of ecosystem being valued and the ecosystem service it represents. The classification of ecosystem services used was the Common International Classification of Ecosystem Services (CICES) from the Biodiversity Information System for Europe (BISE) (Haines-Young & Potschin, 2013) at a second level. This classification incorporated a number of previous classifications systems such as the Millennium Ecosystem Assessment (MA, 2005) and the TEEB matrix (TEEB, 2010a). Regarding the ecosystem classification, we took the classification of the Economics of Ecosystems and Biodiversity (TEEB, 2010a).

The CICES includes 48 ecosystem services broken down into 20 groups, 8 divisions and 3 sections (Annex A). The TEEB ecosystem classification includes 37 specific ecosystems divided into 11 general ecosystems (Annex B). In other words, the CICES has four levels and the TEEB classification two.

The classification by ecosystem type was made by taking ecosystems as suppliers of goods and services, with the exemption of the four values related to water as a nutrition input, which we assigned to urban ecosystems. The reason of this classification if because there were three studies (four values) that undertook willingness to pay (WTP) studies in having better quality tap water that were made in urban settings.

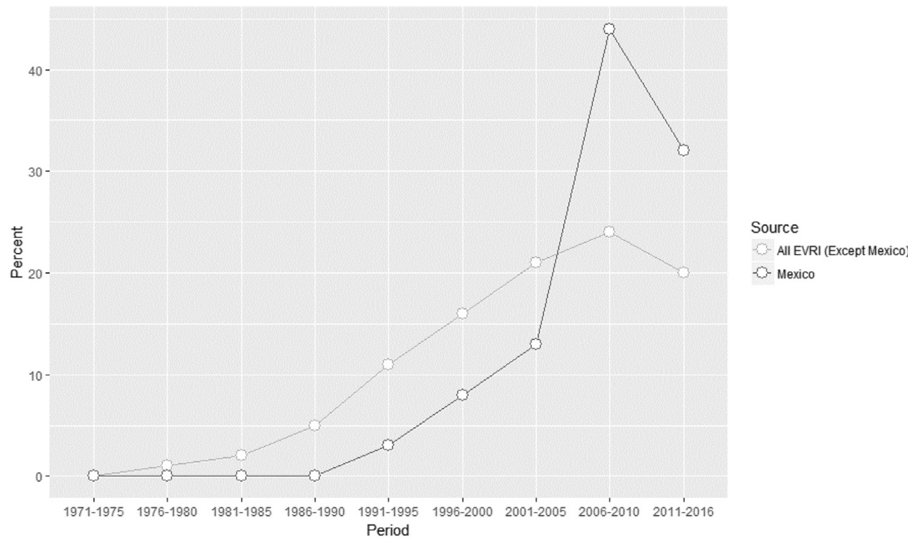
In the case of lakes and river, we assigned five values (in four studies) to lakes and rivers as providers of clean water or as regulators of the chemical conditions of water, yet the original studies did not establish this link, but we inferred in the text of these studies. We established a link in the studies that valued water as an input for crop production (Margulis, 1992; Scott et al., 2000; Zetina-Espinosa et al., 2013) and as regulators of toxic substances (Qi et al., 2014). Elsewhere, the classification process was straightforward.

There is enormous diversity in the way values are reported in each study. The majority of them (48%) state an economic value per hectare (of a certain ecosystem) per year, 13% per person per year, 9% per household per year, 7% per visit (once), while the rest have another unit. As for the different currencies from various years reported in the studies, we converted all values to December 2015 USD by considering the historical series of the exchange rate for the Mexican peso with other currencies and the historical Mexican price index. This was completed using information from the Central Bank of Mexico (*Banco de México*). The conversion was made by converting the value of year t to pesos and then adjusting by the price index of Mexico to 2015.

With this initial dataset, we specified an econometric model that has the economic value of ecosystem services as dependant variable (expressed in 2015 USD per hectare per year), and as independent variables the extent of the area that provides the service, the number of persons that demand it and other indicators (dummies) that distinguish the method of valuation, the type of ecosystem and the service provided, and if the area of study is inside or outside a Natural Protected Area (NPA). We considered only those observations that are expressed in USD per hectare per year ($n = 170$) to avoid mixing different measurement units. To choose which dummies to include in the model we tabulated the observations for each ecosystem and service to identify for which ecosystem and ecosystem services we had more information.

For the case of ecosystems, we included coastal systems ($n = 13$), cultivated ($n = 24$), forests ($n = 24$), wetlands ($n = 38$) and other ecosystems ($n = 6$), which include grass rangeland

[4] Personal communication with officials from the National Commission of Natural Protected Areas (Spanish acronym-CONANP) and the National Institute of Ecology and Climate Change (Spanish acronym INECC).



Source: Compiled by the authors using information from (Environment Canada, 2016).

Fig. 1. % of papers by publication year.

Table 2
Method, data and scope of studies.

Concept	Studies	%
Method		
Contingent Valuation	43	41
Market Price	25	24
Meta-analysis	12	11
Travel cost method-single site	7	7
Change in productivity	4	4
Revealed preference - life satisfaction	4	4
Choice experiment	3	3
Accounting records	2	2
Other	2	2
Theoretical/calibrated model	2	2
Benefit transfer	1	1
Hedonic property	1	1
Total	106	100
Data		
Primary	74	70
Secondary	18	17
Meta/synthesis analysis	14	13
Total	106	100
Scope		
Site Specific	83	78
All of Mexico	23	22
Total	106	100
Countries		
Only Mexico	82	77
Certain countries	13	12
Global	11	10
Total	106	100
Regions		
Country studies	23	22
Central South	25	24
Metropolitan Area of Mexico City*	14	13
Northwest	17	16
Central West	9	8
Peninsula	9	8
North	7	7
Gulf	5	5
Northeast	4	4
South Pacific	4	4
Mixed	3	3
Total	106	100

Source: Compiled by the authors. *Included in Central South Mexico.

(n = 1), marine and open ocean (n = 4) and urban (n = 1). For ecosystem services, we chose the most general categorization, which distinguishes between cultural services (n = 38), provisioning (n = 79) and regulation and maintenance (n = 46). As base categories in the regression we kept the forest and the regulation services dummies, to make interpretations of coefficients relative to this ecosystem and services. Also, we interacted the cultivated ecosystems dummy with the provisioning dummy to distinguish between cropland and other provisioning services that are generated in other ecosystems different to arable land.

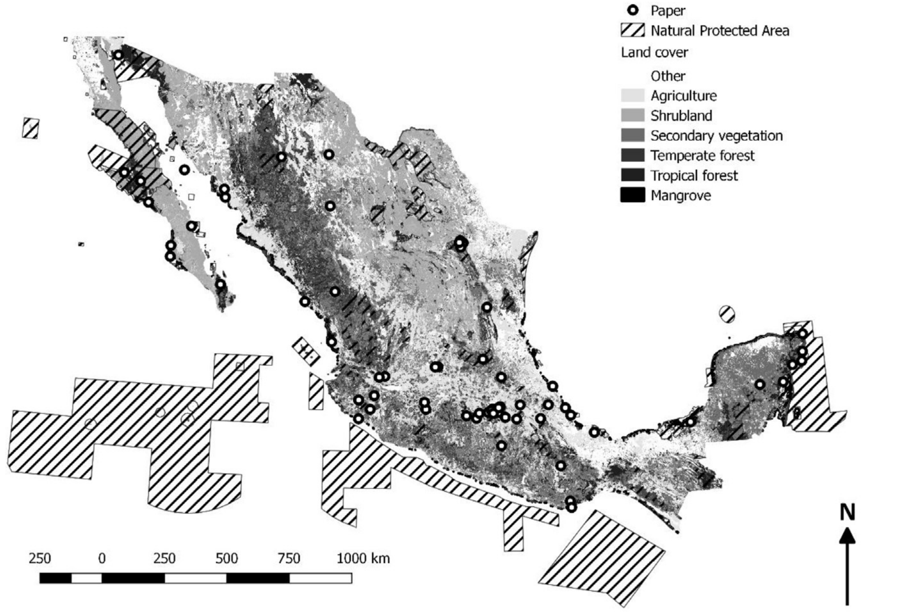
For the case of valuation methods, we have information for all 170 observations. We define 4 categories: contingent valuation (n = 6), market prices (n = 59), meta-analysis or benefit transfer (n = 98) and other valuation methods (n = 7) which include accounting records (n = 1), change in productivity (n = 1), theoretical/calibrated models (n = 1) and travel cost method (n = 4). We took as base category in the regression the meta-analysis/benefit transfer dummy. We do not have an ex-ante hypothesis for these indicators, as we expect that the method does not have an influence on the economic value of the ecosystem service.

The extent of the area that provides the service (stock) is expressed in hectares and is available for 164 of 170 observations, which 83 of them (51%) were obtained directly from the study in which the value was obtained. For the other observations, we used official sources to assign the extent of the area[5]. Demand variable is expressed in terms of people which receives the service. We have information for 168 of 170 cases and for 45 of them (27%) the information was obtained directly from the study. The data for rest of observations was assigned from official sources[6]. The expected sign of the stock variable is negative, since we expect diminishing returns to scale for this variable. In the case of the demand variable we expect a positive sign, since if more consumers exist the service would be more valuable for them.

The indicator variable for NPA distinguishes between services that are provided inside or outside a NPA. This variable is relevant

[5] We used data from land use and vegetation charts, published by the National Office of Statistics – *Instituto Nacional de Estadística y Geografía* (INEGI).

[6] We used data from National Censuses for different years (depending on the year of the study) to obtain the population in a buffer of 30 km. This Censuses are reported by the National Office of Statistics – *Instituto Nacional de Estadística y Geografía* (INEGI).



The 83 site specific studies are mapped. The number of dots on the map is less than 83 because some of the studies shared the same location.
Source: Compiled by the authors.

Fig. 2. Distribution of specific locations valued. The 83 site specific studies are mapped.

since population inside NPA is commonly very low or inexistent; thus, as we wanted to test the hypothesis that there is a different effect of demand inside and outside NPA we interacted this dummy with the demand variable.

We chose a log-log specification as follows:

$$\begin{aligned}\ln(y) = {} & \alpha_0 + \alpha_1 \ln(stock) + \alpha_2 \ln(demand) \times inNPA \\ & + \alpha_3 \ln(demand) \times outNPA + \alpha_4 Coastal + \alpha_5 Wetland \\ & + \alpha_6 Cultivated \times Provisioning + \alpha_7 Other\ Ecos + \alpha_8 CV \\ & + \alpha_9 MarketPrices + \alpha_{10} Other\ method + \alpha_{11} Provisioning \\ & + \alpha_{12} Cultural + \in \end{aligned} \tag{1}$$

where y stands for the economic value of ecosystem services, *stock* is the extent of the area that provides the service, *demand* is the number of persons that demand the service, *NPA* indicates if the service is provided inside or outside a NPA, CV stands for Contingent Valuation method and the names of the other variables are self-explained (see Annex C for definitions of variables).

The final set for the econometric model includes 141 observations that have full information for all variables. The summary statistics are presented in Table 3. For the dependant variable, we tested if it is distributed normally, we found that this is the case as the skewness and kurtosis parameters of this variable is consistent with a normal distribution.[7] In Fig. 3 we present a histogram and a kernel density estimation[8] to show graphically the distribution of the dependant variable.

3. Results

We did a first estimation for the whole sample and obtained a significant result for the stock variable and for some dummies (see Table 4 model 1).[9] To further evaluate our model, we made an analysis of outliers, to identify observations that could being affecting the estimation.[10] Results are presented in Table 4 (model 2). In model 3 (Table 4) we estimated a robust regression by taking observations within a same study as clusters, we find that this specification only improves significance of the previously significant coefficient and makes significant the demand variable at a 99.9% level of confidence. We also tested endogeneity with a Durbin-Wu-Hausman test, after an instrumental variables regression, which takes demand and stock variables as endogenous covariates and takes the dummies in the equation (1) (without interactions) as instruments. We did not find evidence of endogeneity.[11] A consistent finding between models is the robustness of the sign and significance of the stock coefficient. We conclude that there is indeed a strong statistical relationship between the economic value of ecosystem services and the extent of the area that provides them. It is worth to mention that we tested different specifications of the

[7] The probability of the skweness and kurtosis parameters are respectively 25% and 71%. The Chi-squared parameter for the joint test of both parameters has a probability of 47%.

[8] We set an optimal bandwidth size.

[9] For this model, we tested its specification; specifically, we made a Ramsey RESET test and a multicollinearity (variance inflation factor - VIF) test. We found a probability of 50% for the Ramsey RESET, which has as null hypothesis that the model has no omitted variables. We also found a mean VIF of 2.61, which indicates no problems of multicollinearity (also any of the VIF parameters for each variable exceed a value of 10, which could indicate a problem).

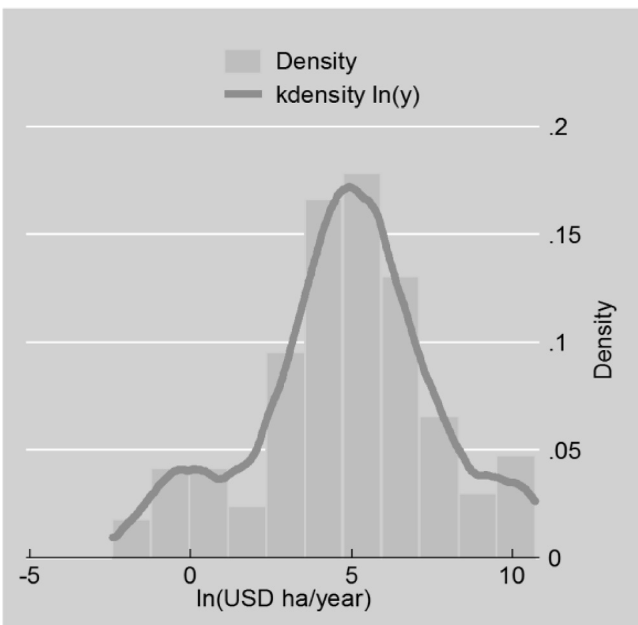
[10] In particular, we did a DFBETA analysis, which measures how much influence has an observation on a given coefficient of the regression; a DFFIT analysis, which measures how much an observation affects the whole model; and a Covariance Ratio analysis, which measures the effect of observation on standard errors (Torres-Reyna, 2007). Our criterion to identify an outlier was to exclude an observation that failed to pass any of the three afore-mentioned tests. After this process, we selected 103 of 141 (73%) valid observations and estimated again the model in equation (1). The DFBETA analysis identified 35 outliers, the DFFIT analysis 10 outliers and the Covariance Ratio 13 outliers, also, only 4 observations failed all 3 tests.

[11] For this test, we find a probability of 38% for the Durbin score and of 39% for the Wu-Hausman parameter, which indicate that both variables are exogenous. To have some insights of the validity of instruments we independently regressed demand and stock variables as a function of the afore-mentioned dummies and we find significant results with a high R^2 parameter for each. The R^2 for each regression is of 56% in the case of demand and of 70% in the case of stock.

Table 3
Summary statistics of observations included in regression.

Variable	Obs	Mean	Std. Dev.	Min	Max
ln(y)	141	4.84	2.82	−2.42	10.71
ln(stock)	141	12.42	3.21	6.40	17.28
ln(demand) × out NPA	141	10.47	6.99	0	18.45
ln(demand) × in NPA	141	2.49	4.37	0	14.11
Forests	141	0.52	0.50	0	1
Coastal	141	0.08	0.27	0	1
Wetlands	141	0.27	0.45	0	1
Cultivated x Provisioning	141	0.13	0.33	0	1
Other Ecos	141	0.01	0.08	0	1
Meta-analysis/benefit transfer	141	0.57	0.50	0	1
CV	141	0.04	0.19	0	1
Market price	141	0.35	0.48	0	1
Other method	141	0.04	0.19	0	1
Provisioning	141	0.48	0.50	0	1
Cultural	141	0.20	0.40	0	1

Source: Own elaboration.



Source: own elaboration

Fig. 3. Histogram and kernel density estimation of ln(y).

model, by including and excluding different dummies of ecosystem services at different levels of aggregation (e.g. including four-level ecosystem services classifications).[12]

Furthermore, we tested if the way we generated the stock variable affected results, so we regressed only observations in which the stock was reported in the original study. By doing this we only confirmed the significant effect of the stock variable. Results are reported in Table 4 (model 4). In fact, the absolute magnitude of the stock variable increases in this specification, which is an indication that the value of stock that we assigned to the observations, in which this value was not reported in the study, is reducing the magnitude of this coefficient. This is the case, when we estimate the model taking only these kind of observations, the coefficient of the stock variable becomes non-significant (Annex D). So, in the worst case, we are underestimating the coefficient of this variable.

We obtained mixed results for the demand variable. In model 2 and 3, which are respectively the model without outliers and the clustered-robust model, we find a significant and the expected effect of this variable on the economic value of ecosystems services. However, this significance is reduced in model 5 (which only considers those values in which the demand was reported in the original study) and model 6 (explained below). Finally, this variable is non-significant in models 1 and 4. When regressing the model with observations where we imputed the value of demand the coefficient becomes significant at a 99% confidence level (Annex D). Again, it is likely that we are underestimating the effect of this variable.

The underestimation of these effects (stock and demand) is likely to arise because of the reduced number of observations that we have. However, we can conclude that there is a strong negative effect of the stock variable.

Another strong finding is that cultural services have in average a lower value than regulation services. In all models the sign of this variable is negative and significant at a 99% level of confidence. Also, (a less robust) finding is that provisioning services have a lower value than regulation services, but are more valuable than cultural services. These findings have relevant consequences in terms of policy, which are discussed next.

As expected, the method of valuation does not affect the economic value of ecosystem services (see model 1). In the rest of models, we did not include the method of valuation because by including it a problem of collinearity arose (except for the dummy of market prices). We decided to omit even the market prices dummy because it did not give additional information (was non-significant when including it). When comparing the models with and without this dummy we found that all other coefficients did not vary substantially. An exemption to the latter was the demand variable out of NPA, in the case when omitting the dummy of market prices, became slightly significant (at 95% level) in models 5 and 6.[13]

Provisioning services are statistically significant in four of six models. Finally, we find in 4 of 6 models, that wetlands are more valuable than forests. We discuss implications of these results with more detail next.

[12] We decided to include the most general categorization of ecosystems services because when we included more specific classifications we had little variation in these dummies. That is to say, we had few ones and a lot of zeros in each category. However, these dummies did not affect the significance and sign of the stock variable, yet some problems with multicollinearity arose (high *t*-values and high variance inflation factors). Thus, we decided to include only very broad categories of ecosystem services.

[13] We want to thank an anonymous reviewer for this recommendation.

Table 4
Estimation results.

Variable	ln(y) Base model (1)	ln(y) Without outliers (2)	ln(y) Clustered (3)	ln(y) Restricted stock (4)	ln(y) Restricted demand (5)	ln(y) GHG (6)
ln(stock)	-0.5974^{***}	-0.3722^{***}	-0.3722^{**}	-0.7754^{***}	-0.5784^{**}	-0.3677^{**}
	(−5.66)	(−4.70)	(−3.37)	(−4.84)	(−3.75)	(−4.45)
ln(demand) x out NPA	0.0867	0.149^{***}	0.149^{***}	−0.055	0.3213^{*}	0.0931^{*}
	(1.35)	(3.41)	(5.34)	(−0.23)	(2.53)	(2.55)
ln(demand) x in NPA	0.0169	0.105	0.105^{*}	−0.055	0.244	0.038
	(0.18)	(1.41)	(2.17)	(0.84)	(1.47)	(0.54)
Coastal	−1.844	0.464	0.464	−0.616	–	0.677
	(−1.70)	(0.54)	(0.47)	(−0.58)	–	(0.78)
Wetlands	0.286	1.960^{***}	1.960^{**}	2.01^{*}	1.236	2.222^{***}
	(0.45)	(3.78)	(3.20)	(2.51)	(1.47)	(4.28)
Cultivated x Provisioning	1.716^{*}	1.631^{**}	1.631^{**}	1.971	2.362^{**}	1.405^{**}
	(2.44)	(3.30)	(3.20)	(1.52)	(3.42)	(2.73)
Other Ecos	5.955^{*}	–	–	–	–	–
	(2.58)	–	–	–	–	–
CV	−1.7	–	–	–	–	–
	(−1.45)	–	–	–	–	–
Market price	−0.86	–	–	–	–	–
	(−1.19)	–	–	–	–	–
Other method	−0.4	–	–	–	–	–
	(−0.33)	–	–	–	–	–
Provisioning	-1.117^{*}	-1.168^{**}	−1.168	-2.266^{***}	−0.627	-0.804^{*}
	(−2.28)	(−3.00)	(−1.72)	(−4.21)	(−1.06)	(−2.07)
Cultural	-2.140^{***}	-2.905^{***}	-2.905^{***}	-1.829^{**}	-2.875^{**}	-2.570^{***}
	(−3.87)	(−6.99)	(−4.91)	(−2.93)	(−3.16)	(−5.96)
Constant	12.45^{***}	8.123^{***}	8.123^{***}	14.978^{***}	7.833^{***}	8.454^{***}
	(6.24)	(6.67)	(5.08)	(4.58)	(4.87)	(6.82)
N	141	103	103	49	27	103
R2	0.4506	0.6759	0.6759	0.6694	0.7201	0.6595
R2-adjusted	0.3991	0.6484	–	0.6033	0.6170	0.6305
F	8.75	24.51	–	10.12	6.98	22.76
Prob > F	0.000	0.000	–	0.000	0.000	0.000
df (Model)	12	8	–	8	7	8
df (Residual)	128	94	–	40	19	94
df (Total)	140	102	–	48	26	102
Root MSE	2.18	1.44	1.44	1.23	1.09	1.48

Source: own elaboration. *t* statistics in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
Note: Some variables are omitted in some models because there is no variation in them.

A final model was estimated (Table 4 model 6).[14] We tested if those observations associated to greenhouse gas emissions (GHG) affected our results. In our database, we assigned the value of the demand variable equal to the total population of Mexico for GHG observations; however, we can argue that the demand for these cases is the entire World. We estimated the model by assigning the total population of the World as the value of the demand variable. As we can see, results are not qualitatively different to model 2. However, the significance of the demand variable is reduced to 95%. Given the results of our models we base our discussion mainly on model 2. We choose this model because its R-squared is high (68%), outliers are excluded, and degrees of freedom are relatively high (94). However, as Table 4 shows, all models are generally consistent in terms of signs and statistical significance of coefficients. Also, specification tests were passed by all 6 models.

Based on our model, we generated a matrix of ecosystems and their services. We obtained each value of this matrix by fitting the regression results of model 2, evaluating at average values of the stock, demand and NPA variables and by assigning the value of 0 or 1 to each dummy, depending on the ecosystem service that we want to predict. This matrix is shown in Table 5. Our main interest is to compare qualitatively the values of this matrix, because each value depends on other characteristics (stock, demand, if the area is in an NPA and other unobservable characteristics) and a quantitative comparison would require more precision to define these attributes. However, it is worth to note that the predicted values of provisioning services on cultivated land and forests are not very different to actual revenues on this kind of ecosystems in Mexico.

In Table 6 we present a similar matrix than the shown in Table 5 but based in model 1 (which includes the whole sample). Comparing both tables we found three significant differences. First, the model without outliers (model 2) indicates that provisioning services from cultivated ecosystems are more valuable than this kind of services from wetlands, which is the contrary that we found in model 1. Second, the value of cultural services is much higher in model 1 than model 2 (by more than twofold). Third, in model 2, the value of services from forests are less than in coastal ecosystems, which is the contrary for model 1. Therefore, the outliers in our sample affect the results in three ways: (i) overestimating the value of cultivated services, (ii) overestimating the value of cultural services, and (iii) overestimating the value of services from forests.

With these results, we find that:

(i) Regulation services are the most valuable services. Even though regulation services have a higher value than provisioning or even cultural services, land use is commonly changed to arable land. This is a myopic decision, which ignores the economic value of regulation services. Therefore, if the market does not recognize this value it is justified that public resources are devoted to preserve regulation services. The amount that is economically efficient to assign to preservation is at most the difference between the regulation service value and its opportunity cost. Even if we can

[14] For all 6 models we did a Ramsey RESET and a VIF test, obtaining satisfactory results.

Table 5
Economic value matrix of ecosystems and their services (USD/ha/year) (model 2).

Ecosystem/Service	Provisioning	Regulation	Cultural	Total
Coastal	121	212	119	212
Wetlands	198	239	195	347
Cultivated	144	–	–	–
Forests	117	205	115	205
Total	252	360	202	142

Source: Own elaboration.
Note: margin values are not the sum of each column or row, they are obtained by choosing the proper dummies in our model.

Table 6
Economic value matrix of ecosystems and their services (USD/ha/year) (model 1).

Ecosystem/Service	Provisioning	Regulation	Cultural	Total
Coastal	147	252	386	252
Wetlands	184	298	481	315
Cultivated	212	–	–	–
Forests	170	291	446	291
Total	198	273	417	293

Source: Own elaboration.
Note: margin values are not the sum of each column or row, they are obtained by choosing the proper dummies in our model.

calculate this difference with the information in Table 5 (61 USD/ha/year), we should recall that these estimations are based on average values and that our database do not necessarily represents all ecosystems and services in Mexico. Therefore, specific studies are necessary to determine a more precise value of compensation for regulation services. Nevertheless, our database may help to inform decision making, if a study of a specific ecosystem and service exists in it.

(ii) Wetlands are the most valuable ecosystem. Wetlands have the highest economic value compared to any other ecosystems in our analysis. Furthermore, the economic value of regulation services of wetlands is the highest of all ecosystem services values compared with other ecosystems, and the same is true for provisioning and cultural services; wetlands are even more valuable in terms of provisioning services than arable land. In terms of policy, this is very relevant because this ecosystem is very scarce, even though they provide important services of all kind to people. One can claim that conventional coastal tourism development, which frequently implies to deforest mangroves, can outweigh the economic value lost by deforesting this ecosystem (something that cannot be analysed with our data); however, more efficient decisions can be taken if already deforested or arable land is used to develop touristic infrastructure, or by adopting other sustainable practices in this sector, for example, by building infrastructure behind mangroves or even by offsetting lost mangroves. To establish specific recommendations in this regard is beyond of the scope of this study; however, our findings indicate that we should take care when a decision implies to deforest wetlands, as the scarcer they are, the most valuable they become, and very high economic costs would arise, such as the affectation of very valuable infrastructure because the lack of a natural barrier that protect them against hurricanes and storms.

(iii) The value of regulation services in forests is higher than the value of arable land, and the value of provisioning services in arable land is higher than the value of provisioning services from forests. Conversion of forest to arable land is not efficient, and worse, if only the value of provisioning services from forests is considered in decision-making, people will choose to convert forest to arable land. This result explains well the Mexican context, in which every year template and tropical forests are converted to cropland. In Mexico, agriculture is characterized by a very low use of technology, very low investment in capital, and intensive and extensive use of land. Farmers commonly decide to convert forests to cropland because they need short-run revenues, which are obtained through crops; however, land is soon eroded and more land is needed eventually. Also, farmers frequently do not have resources to invest in technology and lack access to credit (UNCTAD, 2013). This combination creates strong incentives to change land use. Thus, a mechanism of compensation is needed to preserve regulation services from forests. Mexico is a successful case of payment for ecosystem services (PES) schemes. Since 2003, a government program exists that compensates people who own forests by paying an amount that is closer to their opportunity cost (i.e. crops). Alix-Garcia, Sims, & Yañez-Pagans (2015) has shown that this mechanism is effective in deterring deforestation. However, deforestation persists, so our findings help to support the importance of this program and also give more insight of the difference of value between regulation services from forests and cropland revenues; this difference is of 125 USD/ha/year. Even though this is a very rough estimate, it is worth to compare it with the current level of payments made by the PES program in Mexico. For 2017, the pay is between 30 and 55 USD/ha/year, which is far lower than our estimation of 144 USD/ha/year of economic value of provisioning services in cropland. Therefore, we recommend to revise this level of payment to increase economic efficiency. Provisioning services from forests are lower than cropland value; however, provisioning services can be compatible with the preservation of regulation services. If a sustainable extraction of tangible goods from forests is adopted, not only the value of regulation services is granted, but more economic value is obtained with sustainable practices in their extraction. The same is true for cultural services, because if well managed, they do not compete with regulation services.

(iv) The value of cultural services is lower than any other service. Cultural services, such as recreation and existence service appear to be less valuable than provisioning and regulation services. It is important to note that in our final model we do not have information of economic values of recreation services in important conventional touristic destinations in Mexico (e.g. Mexican beaches). Therefore, the economic importance of this activity is not captured in our model. In contrast, a possible explanation of the low value we find is that recreation services may be less valuable than provisioning or regulation services in low-scale touristic activities, such as small eco-touristic projects. In any case, as mentioned before, preserving regulation services in not necessarily incompatible with preserving cultural services. Thus, the same conclusion of above is valid.

(v) Our data reveal that outliers can bias results significantly, especially in cultural services. This finding may be consistent with common critics of economic valuation of cultural services, which indicate that respondents do not give accurate responses (TEEB, 2010a). Therefore, caution should be taken with decisions taken with information based in this kind of studies. As TEEB (2010a) recommend, a deliberative monetary valuation method may be a better option.

(vi) We do not make any inference for coastal ecosystems for two reasons: first, the number of observations in model 5 is reduced (6 of 102) and its coefficient is not statistical significance in any model.

4. Discussion

We consider that the most important finding of our study is that regulation services are more valuable that provisioning and cultural services. This is very relevant because if little or no compensation is made for these services, economic decisions will be suboptimal. If the providers of regulation services are not compensated for the benefits they provide, more ecosystems will be degraded or deforested and eventually important economic activities, such as agriculture, tourism and industry will be affected. For example, obtaining crops will be costlier, less visitors will arrive to the Country and costly water purifying processes will be required.

Another important finding is the consistency of the results with economic theory. We find that the economic value of ecosystem services is greater as the extent of the ecosystem is less. Unfortunately, for the case of the demand variable we do not have enough information to obtain a robust effect. This lack of significance may be related to (i) a wrong identification in the studies of beneficiaries of the ecosystem service under analysis, and (ii) to the high variability of economic values that come from contingent valuation studies, that may be generated from a poor description of the ecosystem service in this kind of studies. In this sense, our model gives more information about the supply side of ecosystem services than from the demand side. It seems that studies that focus on biophysical quantifications are more robust than other kind of studies that rely on contingent valuation methods. This finding is relevant because a lot of effort has been made in Mexico to conduct contingent valuation studies. In this sense, an inter-disciplinary approach may be a better option. A specific recommendation is to base the analysis in bio-physical techniques, when analyzing regulation services, in observable market prices for provisioning services, and using state-of-the-art techniques (a mix of quantitative and qualitative approaches) in the case of cultural services.

To our knowledge, Perez-Verdin et al. (2016) is the only similar study for Mexico. The authors found important gaps of information, in particular a lack of studies related to pollination, medicine and bioenergy. As they, we do not have information on these topics. We also find important gaps of information. For example, almost none of the studies focus on shrubland and arid vegetation, yet a large extension in Mexico is covered by this type of ecosystems. For this, we are not able to raise any conclusion on the value of such services although they presumably provide important ones. One of the central findings of Perez-Verdin et al. (2016) is the lack of validity tests and consistency between studies. We agree with them, we found difficulties to classify some studies, as the ecosystem service that is valued is sometimes vague or sometimes the studies value bundles instead of isolated ecosystem services. In addition, often times they do not specify an econometric model, something that we do. The specification tests and the magnitude and statistically significance of our results give us confidence. We find that our results correspond to economic intuition. We consider that we found consistency in our estimates despite the issues with the data that we have mentioned. Moreover, our results are congruent with de Groot et al. (2012).

We recognize that our model is an imperfect approximation to the economic value of ecosystem services in Mexico. One major challenge in our work was to homogenise studies with different scope, methods and definitions of ecosystem services. It would be relevant to have a common classification system of ecosystem services and methods, to precisely define who is the beneficiary of the service at stake and correctly characterize the area that provides it. We found several studies that cannot be used in the analysis because we were not able to classify some of these characteristics. In addition, several studies value a bundle of ecosystem services, rather than a specific service, which is a problem particularly in contingent valuation studies, because people get confused at the time of stating their willingness to pay for a bundle that is broad, diffuse and, in general, non-marketable.

Summing up, our specific recommendations are:

1. To focus research agenda on having a better knowledge of the economic value of regulation services. This information can serve as a basis to build a scheme of compensation of regulation services.
2. To avoid as far as possible land use change in wetlands. Services provided by this ecosystem appear to be the most valuable. Any unavoidable deforestation in these areas should be compensated by an area that provides an equivalent amount of ecosystem services.
3. To revise the scheme of payment for ecosystem services in Mexico, because the current level of payments appears to be far lower than the actual value of the services that forests provide. This revision should be based on technical information rather than on political issues or inertia in public budget assignment.
4. To promote an inter-disciplinary approach in economic valuation of ecosystem services. Specifically, we recommend to base research of regulation services in bio-physical models, provisioning services in market prices techniques, and cultural services in mixed qualitative and quantitative techniques. From our perspective this is a way to rank research needs; however, if enough research funds are available, an inter-disciplinary approach is beneficial independently from the service under study.

Our policy recommendations are based on a non-representative sample of ecosystem services in Mexico. To partly address this issue, we checked if our results correspond to the Mexican context by describing the incentives that farmers have to invest in activities involving deforestation in order to obtain short-run revenues. However, to have more precise estimates of the value of ecosystem services both, more information and adaptation to local contexts are needed.

We continue registering recent papers that have been done since we made our search (2014–2015). We are currently building an online tool to browse and register more studies. Presently, the tool is in early stages and can be accessed at http://52.2.244.41/value. Our intention is to continuously update information regarding economic valuation of ecosystem services in Mexico.

5. Conclusions

The economic valuation of ecosystems services has taken impetus in last years in Mexico. Unfortunately, the big effort put on this kind of studies commonly does not have a corresponding impact on decision making. As an example, Waite et al. (2015) estimate that only 17 of more than 100 studies of this kind have had an impact on policy terms in the Caribbean. Within Mexico, we identified as of 2015, more than 100 studies of economic valuation of ecosystem services. It is beyond the scope of this study to determine the impact that they had had on Mexican policy; however, we can give some insights that would confirm the same result for the Caribbean. First, the scope of this kind of studies is seldom linked to meet the information needs of policy makers. Second, some studies are very specific to a local context, which limits the generalization of results in terms of federal environmental policy. Third, very few efforts had been made to consolidate this kind of studies in Mexico. As far as we know, only Perez-Verdin et al. (2016) made a similar effort by analysing 43 studies in Mexico, yet they did not develop an econometric model to the information they collected. Our model gives some useful information to tackle these issues, we suggest some specific policy recommendations, and we obtain some general results that arise from consolidating the information that has emerged in Mexico related to economic valuation of ecosystem services.

From a broader perspective, a very important question arise, should we continue to invest research funds in economic valuation of ecosystem services? There are several issues related to economic valuation. For example, as we discussed previously, contingent valuation studies are commonly flawed because of the difficulty to define precisely the ecosystem service under analysis. Our results are congruent with this premise, we did not find a significant effect of the demand variable. Given that the impact of economic valuation studies in public policy is very low and important methodological issues are present, it seems that economic valuation should be rethought. After doing this work we consider that economic valuation is a powerful tool when communicating the importance of ecosystem services to other sectors of the government, for example, the ministry of finance; however, we also think that it is more relevant to have reliable estimates of the volume of services that an ecosystem provides. We have available complex models to estimate this kind of volumes (see http://www.aboutvalues.net/), yet lack of critical information to use these models is present. For example, the Soil and Water Assessment Tool (SWAT) is a very good model that has evolved for 30 years, however, in Mexico we do not have complete information on soils and vegetation characteristics, which impedes to use the model effectively for policy purposes. We consider that research efforts should be focused on estimating volumes of regulation services and to invest wisely in cultural services studies. By invest wisely we refer to avoid supporting research based on criticized contingent valuation techniques which are prone to generate inaccurate information.

Despite these issues, our policy recommendations are valid. The consistency of the results regarding the higher value of regulation services compared to provision and cultural services and the higher value of wetlands compared to other ecosystems makes sense from economic and policy perspectives. We consider that we obtained the best statistic inferences that the data permit.

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Appendix Annex A. Common International Classification of Ecosystem Services

Section	Division	Group	Class
Provisioning	Nutrition	Biomass	Cultivated crops
			Livestock and their outputs
			Wild plants, algae and their outputs
			Wild animals and their outputs
			Plants and algae from in-situ aquaculture
			Animals from in-situ aquaculture
		Water	Surface water for drinking
			Ground water for drinking
	Materials	Biomass	Fibers and other materials from plants, algae and animals for direct use or processing
			Materials from plants, algae and animals for agricultural use
			Genetic materials from all biota
		Water	Surface water for non-drinking purposes
			Ground water for non-drinking purposes
	Energy	Biomass-based energy sources	Plant-based resources
			Animal-based resources
		Mechanical energy	Animal-based energy
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals
			Bio-chemical detoxification/decomposition/mineralization in land/soil, freshwater and marine systems including sediments; decomposition/detoxification of waste and toxic materials e.g. waste water cleaning, degrading oil spills by marine bacteria, (phyto) degradation, (rhizo)degradation etc.
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems

Annex A (*continued*)

Section	Division	Group	Class
			Dilution by atmosphere, freshwater and marine ecosystems
			Mediation of smell/noise/visual impacts
	Mediation of flows	Mass flows	Mass stabilization and control of erosion rates
			Buffering and attenuation of mass flows
		Liquid flows	Hydrological cycle and water flow maintenance
			Flood protection
		Gaseous/air flows	Storm protection
			Ventilation and transpiration
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal
			Maintaining nursery populations and habitats
		Pest and disease control	Pest control
			Disease control
		Soil formation and composition	Weathering processes
			Decomposition and fixing processes
		Water conditions	Chemical condition of freshwaters
			Chemical condition of salt waters
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations
			Micro and regional climate regulation
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings
			Physical use of land-/seascapes in different environmental settings
		Intellectual and representational interactions	Scientific
			Educational
			Heritage, cultural
			Entertainment
			Aesthetic
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Spiritual and/or emblematic	Symbolic
			Sacred and/or religious
		Other cultural outputs	Existence
			Bequest

Source: (Haines-Young & Potschin, 2013).

Appendix Annex B. TEEB ecosystems classification

General	Specific
Marine/Open Ocean	Marine/Open Ocean
	Open Ocean
	Coral reefs
Coastal Systems	Coastal Systems (Excluding Wetlands)
	Seagrass/algae beds
	Shelf sea
	Estuaries
	Shores (rocky & beaches)
Wetlands	Wetlands - general (coastal & inland)
	Tidal Marsh (coastal wetlands)
	Mangroves (coastal wetlands)
	Floodplains (incl. swamps/marsh) (inland wetlands)
	Peat-wetlands (bogs, fens, etc.) (inland wetlands)

(*continued on next page*)

Annex B (*continued*)

General	Specific
Lakes/Rivers	Lakes/Rivers
	Lakes
	Rivers
Forests	Forests-all
	Tropical rain forest (tropical forest)
	Tropical dry forest (tropical forest)
	Temperate rain/Evergreen (temperate forest)
	Temperate deciduous forests (temperate forest)
	Boreal/Coniferous forest (temperate forest)
Woodland & shrubland	Woodland & shrubland ("dryland")
	Heathland
	Mediterranean scrub
	Various scrubland
Grass/Rangeland	Grass/Rangeland
	Savanna, etc.
Desert	Desert
	Semi-desert
	True desert (sand/rock)
Ice/Rock/Polar	Ice/Rock/Polar
Cultivated	Cultivated
	Cropland (arable land, pastures, etc.)
	Plantations/orchards/agro-forestry, etc.)
	Aquaculture/rice paddies, etc.
Urban	Urban

Source: (TEEB, 2010a).

Appendix Annex C. Variable definitions

Variable	Definition
ln(p)	ln(value)
ln(stock)	ln(extent of area of the ecosystem)
ln(demand) x out NPA	ln(demand reported in the study or people living in a radius of 30 km if not reported) (for areas that are outside a Natural Protected Area)
ln(demand) x in NPA	ln(demand reported in the study or people living in a radius of 30 km if not reported) (for areas that are inside a Natural Protected Area)
Coastal	Coastal ecosystems
Wetlands	Wetlands ecosystems
Forests	Forests ecosystems
Cultivated x Provisioning	Cultivated ecosystems that provide food
Other Ecos	Other ecosystems (grass/rangeland, marine/open ocean, and urban)
CV	Contingent valuation method
Market price	Market price valuation
Other method	Other method (accounting records, change in productivity, theoretical/calibrated model, travel cost single site)
Provisioning	Provisioning services
Regulation	Regulation services
Cultural	Cultural services

Appendix Annex D. Auxiliary models

Variable	ln(y) Stock not reported (1)	ln(y) Demand (2)
ln(stock)	−0.1708	−0.4712**
	(−0.79)	(−3.37)
ln(demand) x out NPA	0.1126*	0.1483**
	(2.23)	(2.91)
ln(demand) x in NPA	−0.1248	0.1418
	(0.61)	(1.41)
Coastal		−0.437
		(−0.33)
Wetlands	2.6392	1.246
	(1.94)	(1.30)
Cultivated x Provisioning	1.258	1.099
	(1.50)	(1.33)
Other Ecos	–	–
	–	–
CV	–	–
	–	–
Market price	–	–
	–	–
Other method	–	–
	–	–
Provisioning	−0.494	−1.301*
	(−0.96)	(−2.535)
Cultural	−3.493***	−2.934***
	(−6.68)	(−5.95)
Constant	5.50	9.8640***
	(1.52)	(4.48)
N	54	76
R2	0.6604	0.6890
R2-adjusted	0.6088	0.6519
F	12.78	18.55
Prob > F	0.000	0.000
df (Model)	7	8
df (Residual)	46	67
df (Total)	53	75
Root MSE	1.44	1.55

Source: own elaboration. *t* statistics in parentheses; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
Note: Some variables are omitted in some models because there is no variation in them.

Appendix Annex E. Complete lists of studies considered in the meta-analysis

The list below cites all the studies that were considered in our meta-analysis. The database used in our analysis can be provided by the authors by request.

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