Orientation on the mapping of biodiversity values:

A plural perspective

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Abstract

Biodiversity loss is a problem of global concern affecting ecosystem functioning and services provided to humans. The Millennium Ecosystems Assessment approach is built on a conceptual framework that links the services ecosystems provide to society and human welfare. These services can be translated into economic values obtained from market and non-market valuation techniques, where numerous studies have yet measured ecosystems' goods and services in terms of economic revenues. Based on this background information and on the conceptual framework of the Millennium Ecosystem Approach, we compile market and non-market forest values and conduct a world wide meta-analysis where biodiversity loss indicators are also included. This way, our main aim is to explain to what extent biodiversity loss is affecting human welfare through the goods and services ecosystems provide and how this effect is distributed among the globe. We find that endangered flora and fauna do have an effect on ecosystem values depending on the type of services and world geo-climatic regions, where endangered flora is decreasing forest values and endangered fauna is increasing forest cultural values in the higher latitudes.

Keywords: Millennium Ecosystem Assessment, Biodiversity loss, meta-analysis, market valuation, non-market valuation, forests.

1. Introduction

Under the conceptual framework behind the Millennium Ecosystem Assessment (MEA), human well-being is the central focus for ecosystem services assessment (Mooney et al., 2004), also recognizing that biodiversity plays a crucial role in determining the ecosystems' capacity to provide goods and services (MEA, 2003). Changes in biodiversity affect ecosystem functioning and, at the same time, will be reflected in welfare changes. Whiting this framework, direct and indirect interactions exist between biodiversity and welfare through the ecosystem services. Ecosystem goods and services are classified in four categories: provisioning, regulating, supporting, and cultural services (MEA, 2003). While the value of some ecosystem service, such as provisioning, is well known and can be easily obtained from existing markets, other values related to cultural services can be only obtained from non-market valuation techniques, and as a consequence they are not usually considered in management and decision making processes. Indeed, forest degradation and biodiversity loss are seen to be a consequence of these types of market failures (Pearce and Moran, 1994). Based on this premise, the present work makes a first attempt to synthesize the work put forward on market and non-market valuation, at a worldwide level, in the case of forest ecosystem services. The MEA framework is used here as a tool to bridge ecosystem welfare values and biodiversity through a meta-analytical approach.

Evidence suggests that biodiversity loss may accelerate in the future, especially as a result of climate change (Pimm and Raven, 2000; Thomas et al., 2004). By the end of the twenty-first century, climate change and its impacts are expected to be the dominant direct cause for biodiversity loss and changes in ecosystem services globally (MEA, 2005). This growing concern and knowledge about the decline of biodiversity has generated a number of studies describing the importance of biodiversity for ecosystem functioning (Loreau et al., 2001). Based on the need of biodiversity conservation as a way to assure future ecosystem services, our contribution with this paper is to further explore how biodiversity is affecting forest economic values and how these values are distributed in space. Climate Change impacts in ecosystem functioning are known to detriment biodiversity. With the present analysis we want to explore if this damage is also observed in terms of human welfare loss. In this way we will analyze if considering human welfare as a rule for policy decision making is reflecting properly the biodiversity loss effect on ecosystem services.

The present article is structured as follows: first, section 2 underlines the importance of forest ecosystems' goods and services and the conceptual framework under which, biodiversity and ecosystem services can be measured in terms of human welfare. Section 3 presents the data compilation, treatment and methodology. Section 4 presents the main objectives to be conducted. Results are discussed in section 5 ending with some concluding remarks in section 6.

2. Valuation of Forest Goods and Services

Forests worldwide are known to be critically important habitats in terms of the biological diversity they contain and in terms of the ecological functions they serve (CBD, 2001). There are approximately 4 billion hectares of forests in the world (FAO, 2005) which is the 30.5% of land area. Their provision of goods and services plays an important role in the overall health of the planet and is of fundamental importance to human economy and welfare. The MEA classifies ecosystem goods and services in: *provisioning services*, that consist on products obtained from ecosystems including food, fibre, fresh water or genetic resources; *cultural services*, the nonmaterial benefits that people obtain from the ecosystem, like the aesthetic experience, recreation or spiritual enrichment; *regulating services*, including benefits obtained from the regulation of ecosystem processes, such as air quality regulation, climate regulation, water regulation, erosion regulation, pollination or natural hazard regulation; and *supporting services*, those that are necessary for the production of all other ecosystem services, like soil formation, photosynthesis, primary production, nutrient cycling and provisioning of habitat (MEA, 2003). All these services rely on ecosystems quality, where biodiversity is feeding the system providing these values. Ecosystem management and future development alternatives depend on the tradeoffs among these services. Figure 1 presents the conceptual framework for the present approach, where biodiversity and ecosystem services are linked to welfare changes. Under this framework, global changes caused by human activity such as climate change, alteration of biochemical cycles or land use changes, are affecting ecosystem functions and biodiversity. As a consequence of these alterations, ecosystem goods and services also change, producing an impact on human welfare. This impact can be measured in terms of the economic values these ecosystem services provide to humans.

The primary role of economic analysis is to present information to decision makers about how society might balance the tradeoffs inherent in resource allocation decisions, including how the benefits might be distributed in any allocation of resources (Rolfe et al., 2000). There is concern that although international demands for timber and other products are well recognised through export markets, there is no corresponding mechanism to recognise international demands for conservation and preservation of the cultural values. Godoy et al. (2000) illustrate this issue conducting an economic valuation of tropical forests services. They obtain a low economic value for the rain forest to local people. This explains their choice to clear forests for other uses. Although outsiders value the rain forest for its high-use and non-use values, local people receive a small share of the total value. In relation to this, Rolfe et al. (2000) obtain that, depending on the circumstances of the conservation proposal, foreigners can hold substantial non-use values for rainforest preservation in other countries relative to preservation options in their own country. Their results provide a tool for decision makers to use in prioritising rainforest preservation options. This evidence demonstrates the importance of non market values, such as non-use values and recreation in the overall assessment of preservation proposals, both for tropical forests and non-tropical forests. Based on this, both market and non-market forest values are taken into consideration in the present analysis.

Previous studies valuing ecosystem services are focussed on one type of forest or on one type of economic value. For example, Chomitz et al. (2005) value biodiversity 'hotspot' areas in Brazil examining data from a survey of property values, relating land price to land characteristics. As a result, they obtain that forest land had a market value 70 per cent below comparable cleared land. Portela et al. (2008) derived non-timber values also from revealed preferences' approach, based on actual choices of forest owners for different management schemes. These forest goods were almost twice as large as timber revenues for private non-industrial forests. On another approach, Lindhjem (2007) reviews stated preference literature in Scandinavia in a meta-analysis for the last 20 years finding that non-market forest values are insensitive to the size of the forest. Broader studies have shown how ecosystem services contribute to economic activity. Richmond et al. (2007) found how ecosystems' productivity contributes to countries' GDP, finding a positive relationship. Total welfare contribution for ecosystem services has been estimated in $33 trillion per year[1] (Costanza et al., 1997). From the MEA framework we know that these ecosystem services are supported by ecosystem functioning, where biodiversity plays a crucial role (Mooney et al., 2004). However, a scarce number of studies look specifically at the links between biodiversity and the ecosystem services' economic revenues. Costanza et al. (2007) are an exception, where ecosystems' Net Primary Production is explained in terms of biodiversity richness. As a result they find that a one percent in loss in biodiversity in warm eco-regions results in about half a percent in the value of the ecosystem services provided by these regions (Costanza et al., 2007).

[1] This estimate has been criticized for the scaling up procedure employed (Bockstael et al., 2000)

Economic impacts of biodiversity loss in forests services has not been yet assessed in a worldwide perspective, neither for different ecosystem services, and the present study provides such an example. In this paper we compile values for forest ecosystem goods and services from both market and non-market valuation techniques, on a worldwide attempt to study the role of the bio-climatic distribution of forests and biodiversity loss in the economic values these forests serve. Within this framework, a new tool is developed to study the economic impacts of forest redistribution due to climate change impacts.

3. Methodology and Data Analysis

A database with 67 studies and 248 value estimates has being analyzed on behalf of the socioeconomic values derived from the services provided by these world wide ecosystems[2] (a list of the studies is presented in Table 1). A systematic work has been developed in defining the variables to be used in the analysis. Specifically, exploring the MEA classification for ecosystem services as well as assigning each service an economic value. Moreover, each forest has been classified into a biome type and additional indicators of biodiversity and climatic variables were added to the dataset. Biodiversity loss indicators were constructed from the IUCN red list database: threatened flora and fauna indexes (IUCN, 2007). Finally, methodological and context characteristics of the values were introduced. From this set of studies, special attention is put to the links between forest services, biodiversity indicators and geo-climatic regions. The distribution of the forest values in space with latitudes permit us to explore the differences in forest values that can be attributed to their distribution.

With the described dataset and following previous work on meta-analysis for ecosystem values (Brander *et al.*, 2007; Ghermandi et al., 2007; Woodward and Wui, 2001), a simple OLS regression is conducted to explore the links between the forest values and the different forest services, their distribution and relation to biodiversity. The dependent variable in our model is the estimated value per hectare per year reported by each original study. These values have been converted and actualized to €2008. Forest values are thus explained by the forest services characteristics, geo-climatic and biodiversity indicators and finally, context characteristics (summarized in Tables 2, 3 and 4), such that:

[2] EVRI database and IUCN database for forest studies have been employed.

(1) $Y = \alpha + \beta_f X_f + \beta_g X_g + \beta_c X_c + u$

Where *Y* is the value per hectare per year, *a* is the constant term, the *betas* represent the vectors of the coefficients in the regression model to be estimated and associated with the following types of explanatory variables: forest specific (X_f), geo-climatic and biodiversity specific (X_g) and context specific (X_c), with *u* representing a vector of residuals. A double log model is finally conducted due to better model fit.

Forest specific variables are summarized in Table 2. Variables were created for the forest study area, the type of forest and the type of ecosystem service valued (following MEA classification). Geo-climatic and Biodiversity specific variables are summarized in Table 3. First, meteorological variables were introduced in the dataset indicating maximum and minimum annual temperatures for the country as well as annual precipitation. Each study is also classified attending to the latitude in four geo-climatic regions, according to the distribution of forest values in our sample. Finally, biodiversity indicators were added to the data in form of endangered species indexes (flora and fauna) from the IUCN red list (IUCN, 2007). Context variables are presented in Table 4 where study variables such as the method employed for assessing the economic value, the year of publication or the continent where the study takes place are included. Also, economic variables indicating the income level of the country (IMF, 2007) are included in the specification.

4. Main objectives to test

With the described dataset, our aim is to assess in economic terms the supporting function of biodiversity in providing forest ecosystem services. We have four main objectives of interest in our study. First one relates to the role of biodiversity loss in explaining economic benefits derived from ecosystem services. As we have seen, biodiversity is part of ecosystem functioning, where its richness is affecting economic revenues from the services it supports (Costanza et al., 2007). Since biodiversity richness is positively related to net primary production, we expect our biodiversity loss indicators of endangerment status to be also significant in explaining ecosystem values. However, our sample goes beyond Costanza et al.'s study and includes many types of ecosystem services, including cultural, regulating and provisioning. We could expect threatened biodiversity to have a negative impact on the benefits obtained by ecosystem services. This impact however may depend on the type of ecosystem service we are valuing. Costanza et al. (2007) found a positive link between biodiversity richness and provisioning services. However, we have no a priori expectations of how biodiversity is affecting cultural or regulating services. Based on this, our second objective is whether our biodiversity indicators are influencing forest benefits depending on the type of service. Third, we expect each type of ecosystem service to provide different revenues depending on its distribution on the globe. Cultural services from tropical forests may be different from cultural services provided by temperate ones. To test this hypothesis we will include in the analysis the joint effect of ecosystem services and geo-climatic regions. This is a first step to further explore if biodiversity loss has a different effect on forest values depending on forests distribution. Fourth and last objective addresses the spatial dimension of the biodiversity effect we are studying. We expect our biodiversity indicators to depend on the geo-climatic region of the world since each region is characterized by different climatic and socioeconomic characteristics that may affect final economic outputs obtained from ecosystem services.

To test the effect of biodiversity loss in welfare we proceed by introducing the cross products of the biodiversity indicators and the ecosystem services in the regression. This way, we will see the joint effect of biodiversity status and the value of the ecosystem services and how these values are distributed in space. The effect of this biodiversity loss in ecosystem values has not been yet considered and has important implications for policy analysis and resources reallocation.

5. Results

With the described dataset we proceed with the meta-analysis of worldwide forest ecosystem values. Baseline specification model results are split in Table 5. This baseline model serves as a first attempt to synthesize market and non-market forest valuation studies. From this model, we observe that all types of ecosystem services are found to play a significant role in forest values. The type of forest also affects forest values where, respect to the temperate forests, all types of forests produce higher values except the boreal ones (that are not significant). Forest area is negative and significant showing marginal decreasing utility with additional hectares. This result is in accordance with the economic theory and has been found in previous meta-analyses of ecosystem values such as Ghermandi et al. (2007) or Woodward and Wui (2003) for wetlands.

As the main objective of study, attention is made to see the effect of the biodiversity indicators on forests values. We find that biodiversity endangerment indexes are holding different signs, where fauna is not statistically significant explaining forest values and flora is negative and statistically significant in the model, pointing to the fact that the more endangered flora species the lower the forest value is. Biodiversity loss, in terms of endangered plant species is found to decrease ecosystem values. This result goes in line with previous findings where biodiversity richness (not endangerment) was positively related to ecosystem values (Costanza et al., 2007). As we have discussed, biodiversity loss can be affecting ecosystem services in a different way and exploring this possible effect is worthwhile. To explore this link, in a second approach we introduce the joint effect of forest services and biodiversity indexes in form of cross products. This way we will see to what extent biodiversity loss is affecting forest values depending on the specific ecosystem service. These approaches are presented in Tables 6 and 7, for fauna and flora indexes respectively. The endangered fauna and the endangered flora indexes are multiplied by the type of ecosystem service. From Table 6, we see how the fauna index is not affecting forest values depending on the ecosystem service type. From Table 7, we find the same result for flora index, where its effect on forest values is not dependent on the type of ecosystem service. In order to understand this result we will see on a third step if ecosystem services vary depending on their distribution on earth. If so, this could be explaining why our flora and fauna indexes are not significant when explaining the different forest ecosystem services, as obtained from Tables 6 and 7.

A third approach is then developed to study if forest goods and services have different values depending on their distribution. As such, we continue by calculating the cross effects between forest services and geo-climatic regions. The results provided by this approach are presented in Table 8[3]. The estimated results show that forest regulating services do not depend on the geo-climatic area under consideration. However, the monetary value of the cultural and provisioning services from forest ecosystems do depend on the geo-climatic area under consideration. In particular, according to the estimated results, provisioning services show a relatively higher value in the tropics, than else place else. Finally, as far as the cultural services are covered, estimations show that they are valued lower in subtropical than else place else.

Finally, and on evidence of what has been found for the ecosystem services distributional results, biodiversity effects on forest services are now analyzed depending on the regions. In Table 9[4] we show the joint effects of endangered fauna, ecosystem services and geo-climatic regions[5]. We can

[3] Missing cross products were dropped from the analysis due to the low number of observations.
[4] As in Table 8, missing cross products were also dropped from the analysis due to the low number of observations.
[5] The same exercise was replicated for the flora index, although no significant evidence was found and is thus omitted in the paper.

see that, for cultural ecosystem services, threats to fauna are affecting forest values differently depending on the latitudes. The threatened fauna index variable is positive in the higher latitudes (over 45 degrees). These estimates show the implicit or shadow price of fauna, explained in terms of its impacts on the forest ecosystem goods and services. It shows that the implicit price of fauna, an indicator of endangered fauna, is only statistically significantly different when explained in terms of the spatial impacts on cultural values. Furthermore, estimation results show that this transmission mechanism is not the same across the globe. It shows that in boreal and temperate areas the implicit price of endangered fauna is different and in a statistically significant way than in others. The relative estimates show that this price is higher at higher latitude regions. Also, in these regions endangered fauna is lower than in other latitudes as depicted in Table 10. One may argue that the scarcity of endangered fauna could be influencing its high value as founded in this meta-analysis.

6. Concluding Remarks

The MEA is focussed on the links between human well being and the world's ecosystems. This framework has been employed to link biodiversity loss and forest ecosystem values in a meta-analysis of worldwide forest valuation studies. This exercise constitutes a first attempt to link biodiversity loss to the economic consequences of the change in ecosystem services this biodiversity loss produces. Also, values were collected for many different forest ecosystem types and services; both form market and non-market valuation techniques on a worldwide perspective.

Results evidence the complexity of dependencies between biodiversity loss, forest ecosystem services and their value to humans. The models show how biodiversity loss can be indirectly affecting forests values and how this effect varies with the geographical distribution of forests. Endangered flora is negatively related to forest revenues in general, but apparently, not depending on the type of ecosystem services, neither on its distribution. On contrast, endangered fauna is found to have an effect on ecosystem values that is not dependent on the ecosystem service. When considering geo-climatic regions, endangered fauna is producing higher values for cultural services in some of the regions, in concrete on the higher latitudes. These regions are also those having the lower proportion of endangered species in their fauna. In particular, endangered fauna affects cultural values where endangered fauna is positively related to forest values.

These results are a first attempt to link biodiversity loss with ecosystem revenues employing the MEA conceptual framework that links biodiversity to ecosystem functioning and ecosystem services provided to humans. Results indicate that human welfare derived from forest ecosystem services is affected by biodiversity loss. This constitutes however an anthropocentric approach were only human well being is considered in the analysis. However, important implications for policy analysis relating to resource allocation and conservation priorities can be derived. Further analyses will confirm these findings together with other predicted impacts due to climate change.

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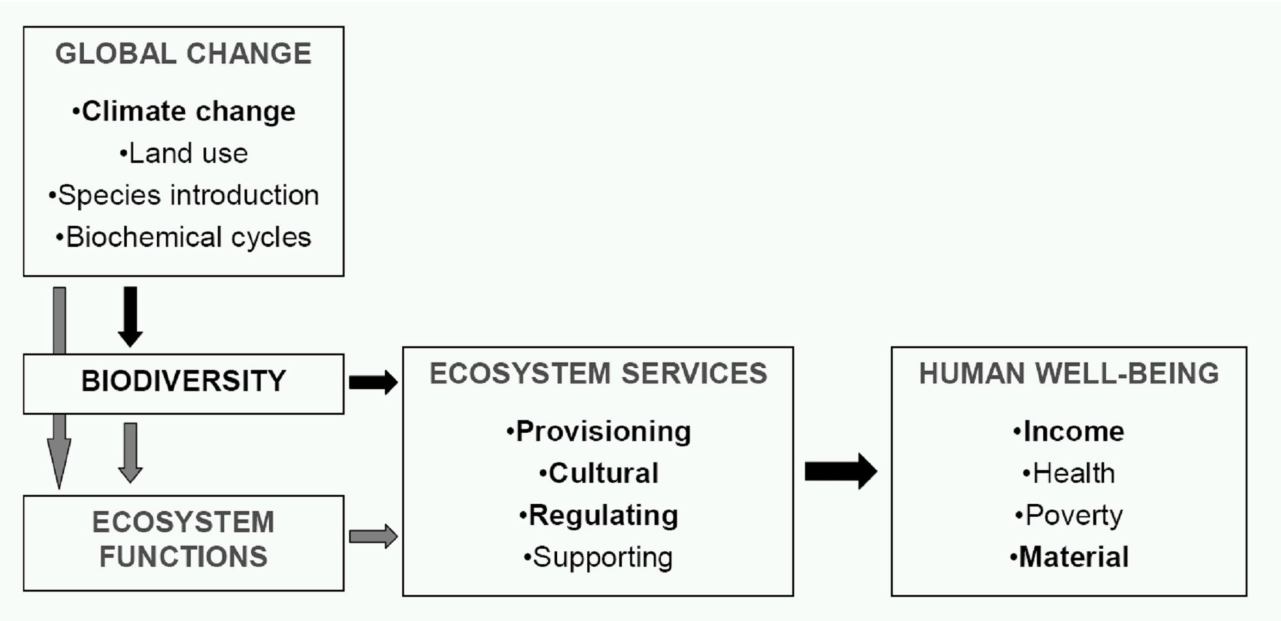
Annex. Figures

Figure 1: Conceptual framework for biodiversity and climate change effects on welfare under the ecosystem services approach.



Source: Adapted from MEA, 2005.

Annex. Tables

Table 1: List of studies

1. Aakerlund (2000)
2. Anthon and Thorsen (2002)
3. Balick and Mendelsohn (1992)
4. Bann (2003)
5. Bateman and Lovett (2000a)
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13. Chase et al. (1997)
14. Christie et al. (2001)
15. Costello and Ward (2006)
16. Dubgaard (1998)
17. Edwards-Jones et al. (1995)
18. Emerton (1999)
19. ERM (1996)
20. Garber-Yonts et al. (2004)
21. Garrod and Willis (1997)
22. Godoy et al. (2000)
23. Gurluk (2006)
24. Hanley and Ruffel (1993)
25. Hanley et al. (1998)
26. Hanley et al. (2002)
27. Horne et al. (2004)
28. Horne et al. (2005)
29. Horton et al. (2003)
30. Hougner et al. (2006)
31. Howard (1995)
32. Kaiser and Roumasset (2002)
33. Kniivila (2004)
34. Kniivila et al. (2002)
35. Kontoleon and Swanson (2003)
36. Kramer and Mercer (1997)
37. Kramer et al. (1995)
38. Kramer et al. (2003)
39. Lienhoop and MacMillan (2006)
40. Mahapatra and Tewari (2005)
41. Mallawaarachchi et al. (2001)
42. Mogas et al. (2006)
43. Monela et al. (2005)
44. Murthy et al. (2005)
45. Naidoo and Adamowicz (2005)
46. Ninan and Sathyapalan (2005)
47. Nowak et al. (2007)
48. Oumar and Bishop (2006)
49. Phillips and Silverman (2007)
50. Raunikar et al. (2006)
51. Ricketts et al. (2004)
52. Rosales et al. (2005)
53. Samuel and Thomas (1996)
54. Sattout et al. (2007)
55. Scarpa et al. (2000)
56. Shahwahid et al. (2003)
57. Shechter et al. (1998)
58. Siikamaki (2007)
59. Simpson et al. (1996)
60. van Beukering (2002)
61. van Beukering et al. (2003)
62. van der Heide et al. (2005)
63. Verma (2000)
64. Walsh et al. (1984)
65. Wang et al. (2007)
66. Zandersen et al. (2005)
67. Phillips and Silverman (2007)

Table 2: Summary characteristics of the data. Forest Services Characteristics

Forest Services Characteristics			**Mean**
Forest Area	*lnha*	Natural logarithm of forest size (in hectares)	11.71
Type of Forest	*mediterranean*	Mediterranean (1); rest (0)	0.12
	boreal	Boreal (1); rest (0)	0.05
	tempconif	Temperate coniferous (1); rest (0)	0.21
	tempmix	Temperate other (mixed, broadleaf, etc.)(1); rest (0)	0.23
	tropicalwet	Tropical wet (1); rest (0)	0.25
	tropicalmix	Type of forest: tropical dry, tropical grasslands	0.13
Forest Ecosystem Goods	*cultural*	Cultural (1); rest (0)	0.64
and Services	*provisioning*	Provisioning (1); rest (0)	0.29
	regulating	Regulating (1); rest (0)	0.18
	allservices	Cultural and/or Provisioning and/or Regulating (1); rest (0)	0.05

Table 3: Summary characteristics of the data. Geo-Climatic and Biodiversity Indicators

Geo-Climatic and Biodiversity Indicators			**Mean**
Meteorological	*precip*	Mean annual precipitation (period 1961-1990)	1164.45
	maxt	Mean annual max temperature (period 1961-1990)	20.97
	mint	Mean annual min temperature (period 1961-1990)	7.15
Regions	*lat_3030*	Latitude between -30° and 30° (1); rest (0)	0.36
	lat_3045	Latitude between 30° and 45° (1); rest (0)	0.29
	lat_4560	Latitude between 45° and 60°(1); rest (0)	0.30
	lat_60	Latitude > 60° (1); rest (0)	0.04
Biodiversity Indicators	*fauna*	Rate of threatened fauna species (N threatened/N total) 0-100	13.78
	flora	Rate of threatened flora species (N threatened/N total) 0-100	54.11

Table 4: Summary characteristics of the data. Context Characteristics

Context Characteristics			**Mean**
Environmental Valuation Method	*revealed*	Revealed preferences techniques (TC, HP, etc.) (1); rest (0)	0.10
	market	Market prices techniques (1); rest (0)	0.24
	nonmark	Non-market methods (stated preferences) (1); rest (0)	0.43
	othermethod	Other method (1); rest (0)	0.23
Year of Publication	*decade1*	Study conducted before 1997 (1); rest (0)	0.33
	decade2	Study conducted after 1997 (1); rest (0)	0.67
Income	*GDP per capita*	Natural logarithm of the domestic GDP	3.14

Table 5: Baseline Specification Model for the Meta-Analysis

lnval	**Coefficient**	**p-value**
lnha	-0.4301***	0.000
mediterranean	3.1002**	0.007
boreal	2.1626	0.125
tempconif	2.1392*	0.026
tropicalwet	6.5172***	0.001
tropicalmix	6.7787***	0.001
hotspot	0.6721	0.410
cultural	1.9162**	0.005
provisioning	1.2959*	0.038
regulating	2.0320***	0.000
revealed	0.8228	0.381
market	-0.1641	0.851
nonmark	1.9900*	0.023
precip	-0.0008	0.270
maxt	0.2096*	0.086
mint	-0.0181	0.812
fauna	0.0741	0.198
flora	-0.0288*	0.058
lat_3045	1.3351	0.481
lat_4560	7.9310***	0.000
lat_60	4.1815	0.147
decade2	-0.5388	0.329
domesticgdp	-0.0562	0.364
constant	-2.8115	0.465
N	172	
$\mathbf{R^2}$	0.6085	
Adj. $\mathbf{R^2}$	0.5476	

Table 6: Cross effects with fauna index and ecosystem services

lnval	**Coefficient**	**P-value**
lnha	-0.4025***	0.000
mediterranean	3.2725*	0.014
boreal	1.3173	0.367
tempconif	1.6118	0.102
tropicalwet	6.8947***	0.001
tropicalmix	7.4773***	0.001
hotspot	1.0132	0.241
cultural	0.6437	0.712
provisioning	2.7588*	0.052
regulating	3.9461**	0.005
revealed	1.5135	0.145
market	-0.5439	0.581
nonmark	2.2340*	0.014
precip	-0.0005	0.482
maxt	0.1741	0.158
mint	-0.0157	0.837
gef	-0.0086	0.492
fauna	0.1450	0.149
faunacult	0.0750	0.421
faunaprov	-0.0606	0.482
faunareg	-0.1174	0.159
flora	-0.0330*	0.033
lat_3045	1.7553	0.384
lat_4560	9.3766***	0.000
lat_60	6.2392*	0.051
decade2	-0.2521	0.658
domesticgdp	-0.0576	0.369
constant	-4.2049	0.301
N	172	
R^2	0.6221	
Adj. R^2	0.5512	

Table 7: Cross effects with flora index and ecosystem services

lnval	**Coefficient**	**P-value**
lnha	-0.3957***	0.000
mediterranean	2.7779*	0.033
boreal	2.2481	0.114
tempconif	2.1510*	0.026
tropicalwet	6.4523***	0.001
tropicalmix	6.4212**	0.003
hotspot	0.8066	0.383
cultural	5.1103*	0.065
provisioning	4.4244	0.111
regulating	1.5605	0.561
revealed	0.8702	0.372
market	0.0213	0.981
nonmark	2.0919*	0.021
precip	-0.0010	0.183
maxt	0.2401*	0.056
mint	0.0004	0.996
gef	-0.0099	0.432
fauna	0.1075	0.109
flora	0.0190	0.678
floracult	-0.0560	0.221
floraprov	-0.0566	0.231
florareg	0.0134	0.766
lat_3045	1.5101	0.472
lat_4560	8.1715***	0.000
lat_60	4.1755	0.170
decade2	-0.3948	0.480
domesticgdp	-0.0748	0.239
constant	-6.9075	0.151
N	172	
R^2	0.6215	
Adj. R^2	0.5505	

Table 8: Cross effects with ecosystem services and geo-climatic regions

lnval	**Coefficient**	**p-value**
lnha	-0.4268***	0.000
mediterranean	2.8445*	0.014
boreal	1.9128	0.178
tempconif	2.2422*	0.021
tropicalwet	5.9810**	0.002
tropicalmix	6.4221**	0.002
hotspot	0.5964	0.464
cultural	6.9490*	0.021
provisioning	-0.6679	0.583
regulating	1.7586*	0.056
cultlat_3030	-4.7047	0.121
cultlat_3045	-5.8838*	0.051
cultlat_4560	3.5336*	0.063
provlat_3030	2.7989*	0.043
reglat_3030	0.8681	0.451
revealed	1.5918	0.114
market	0.0738	0.940
nonmark	2.0225*	0.026
precip	-0.0007	0.340
maxt	0.2245*	0.067
mint	-0.0132	0.864
fauna	0.0876	0.129
flora	-0.0291*	0.053
lat_3045	2.8495	0.171
decade2	-0.2700	0.632
domesticgdp	-0.0896	0.164
constant	-4.1693	0.286
N	172	
R^2	0.6212	
Adj. R^2	0.5532	

Table 9: Cross effects with fauna index, ecosystem services and geo-climatic regions

lnval	**Coefficient**	**P-value**
lnha	-0.4908***	0.000
mediterranean	2.3231*	0.095
boreal	1.3668	0.359
tempconif	1.7986*	0.083
tropicalwet	6.2792**	0.003
tropicalmix	7.2307***	0.001
hotspot	0.8964	0.291
cultural	0.0898	0.962
provisioning	2.0611	0.206
regulating	4.0184*	0.018
revealed	1.6999*	0.099
market	-0.0881	0.930
nonmark	2.1506*	0.022
precip	-0.0006	0.400
maxt	0.1754	0.163
mint	-0.0226	0.769
fauna	0.0740	0.493
*fauna*cult*lat_3030*	0.1986	0.171
*fauna*cult*lat_3045*	0.0676	0.474
*fauna*cult*lat_4560*	0.6994*	0.059
*fauna*cult*lat_60*	1.2485*	0.098
*fauna*prov*lat_3030*	0.0158	0.894
*fauna*prov*lat_3045*	-0.0614	0.479
*fauna*reg*lat_3030*	-0.1365	0.313
*fauna*reg*lat_3045*	-0.1094	0.206
flora	-0.0512**	0.011
lat_3045	2.8549	0.211
lat_4560	4.8343	0.226
decade2	-0.3741	0.511
domesticgdp	-0.1028	0.125
constant	-0.9442	0.830
N	172	
R^2	0.6349	
Adj. R^2	0.5572	

Table 10: Distribution of the fauna index with geo-climatic regions

	Fauna index
Latitude -30 30	12.99
Latitude 30 45	22.84
Latitude 45 60	7.23
Latitude 60	5.12