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Mapping of Forest Biodiversity Values: A Plural Perspective

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Summary
The Millennium Ecosystem Assessment is built on a conceptual framework that links biodiversity to the services ecosystems provide to society. Based on this framework, we first compile market and non-market forest valuation studies and, secondly, explore the potential of an econometric modeling exercise by conducting a world wide meta-analysis. This exercise aims to highlight the mapping of biodiversity indicators and assesses their respective role on the valuation exercise. Our results show that biodiversity loss is having an effect on forest ecosystem values. In addition, these effects reveal to be dependent on the type of services and global geo-climatic regions.

Keywords: Millennium Ecosystems Approach, Biodiversity Loss, Meta-Analysis, Market Valuation, Non-Market Valuation, Forests

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I. 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), 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, are reflected in welfare changes. Within this framework, direct and indirect interactions exist between biodiversity and welfare through 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 services, such as provisioning, is well known and can be easily obtained from existing markets, other values related to cultural services can only be 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 losses are seen to be a consequence of these types of market failures (Pearce and Moran, 1994). Based on this premise, this paper makes a first attempt to synthesize the work conducted on market and non-market valuation, at a global level, in the case of forest ecosystem services. The MEA framework is used 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, particularly 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 of biodiversity loss and changes in global ecosystem services (MEA, 2005). This growing concern and knowledge regarding 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 valuation and how these values are distributed in space. We will explore if this damage is also observed in terms of human welfare loss, and whether we can consider human welfare as a ground rule for policy decision making.

This article is structured as follows: first, section II 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 III presents the data compilation, data treatment and methodology. Section IV contains the main objectives to be addressed while results are discussed in section V, ending with some concluding remarks in section VI.

II. 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. There are approximately 4 billion hectares of forests in the world (FAO, 2005) which amounts to 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,* which consist of products obtained from ecosystems including food, fiber, fresh water or genetic resources; *cultural services,* the nonmaterial benefits that people obtain from the ecosystem; including 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 which are necessary for the production of all other ecosystem services, such as soil formation, photosynthesis, primary production, nutrient cycling and provisioning of habitat (MEA, 2003). All these services rely on the quality and functioning of the ecosystems, where biodiversity is feeding the system, providing these different values. Ecosystem management and future development alternatives depend on the tradeoffs among these services. Figure 1 presents the conceptual framework for the present study, 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 an economic analysis is to present information to decision makers on how society might balance the tradeoffs inherent to resource allocation decisions, including how the benefits might be distributed (Rolfe et al., 2000). There is concern that although international demands for timber and other products are well recognized through export markets, there is no corresponding mechanism to assess 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 on behalf of the local community, which explains their choice to clear forests for other land uses. Although outsiders value the rain forest for its high-use and non-use values, local people receive only a small share of the total value. In relation to this, Rolfe et al. (2000) show 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 in terms of prioritizing 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 evidence, both market and non-market forest values are taken into consideration in the present analysis.

Previous studies valuing ecosystem services focus on a single 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 conclude that forest land had a market value which was 70 per cent lower than comparable cleared land. Portela et al. (2008) also derive non-timber values from revealed preferences, 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. In another study, Lindhjem (2007) reviews stated preference literature in Scandinavia in a meta-analysis over the last 20 years concluding that non-market forest values are insensitive to the size of the forest. Other studies have shown how ecosystem services contribute to economic activity. Richmond et al. (2007) found how the productivity of ecosystems contributes to countries’ GDP, obtaining a positive relationship. Total welfare contribution for ecosystem services has been estimated at $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 loss in biodiversity in warm eco-regions results in about a half percent change in the value of the ecosystem services provided in these regions (Costanza et al., 2007).

Economic impacts of biodiversity loss in forests services have not yet been assessed in a worldwide perspective. This current study provides this empirical exercise. Thus, we compile economic values for forest ecosystem goods and services from both market and non-market valuation techniques, in an attempt to study the role of the bio-climatic distribution of forests and biodiversity loss in the economic values these forests serve.

III. METHODOLOGY AND DATA ANALYSIS

A database with 65 studies and 248 value estimates has been analyzed with respect to the socioeconomic values derived from the services provided by these worldwide ecosystems[2] (a list of the studies is presented in Table 1). A systematic procedure 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 a specific service to each economic value. Moreover, each forest type 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 using the IUCN red list database: threatened flora and fauna indexes (IUCN, 2007). Finally, methodological and context characteristics linked to the valuation studies were introduced. From this set of studies, special attention is given to the links between forest services, biodiversity indicators and geo-climatic regions. We use the distribution of the forest values in a spatial dimension with latitudes in order to explore the differences of the global distribution of such values.

With the described dataset, and following previous studies on meta-analysis for ecosystem values (Brander *et al.*, 2007; Ghermandi et al., 2007; Woodward and Wui, 2001), a benchmark OLS regression is estimated to explore the links between the forest values and the different forest services, their distribution and relationship to biodiversity. In order to control for the panel structure of our data, the benchmark OLS model has been extended to a random effects GLS model.

The dependent variable in our model is measured as the estimated value per hectare per year reported by each original study. These values have been converted and updated 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 5), such that:

(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), while *u* represents a vector of residuals. A double log model is finally estimated due to a better statistical fit. This functional form has proved to be the best specification in terms of statistical performance and according to the results provided in a box-cox test[3].

Forest specific variables are summarized and described in Table 2. Explanatory variables reflect the forest study area (*lnha*), the type of forest (*mediterranean, boreal, tempconif, tempmix, tropicalwet* and *tropicalmix*), and the type of ecosystem service provided (cultural, provisioning and regulating) following the MEA classification. Finally, due to the nature of the data, the type of ecosystem service provided was divided into cultural services (*cultural*) and non-cultural services (*noncult*). Geo-climatic and biodiversity specific variables are summarized in Table 3. Meteorological variables were introduced in the dataset indicating minimum annual temperatures for the country (*mint*) as well as annual precipitation (*precip*). Each study is also classified according to their latitudinal position into wide geo-climatic regions, and in relation to the distribution of forest values in our sample, where some studies were undertaken in the tropics (*lat_3030*) while others were undertaken on temperate latitudes (*lat_3060*). Finally, biodiversity indicators were added to the dataset in form of endangered species indexes (*flora* and *fauna*) from the IUCN red list (IUCN, 2007). These indexes measure the relative abundance of the threatened species. Mean values for these biodiversity indexes in each global latitudinal region are depicted in Table 4. From this table we can observe that the range of endangered fauna is bigger in sub-tropical latitudes while endangered flora has a larger index in the tropics. Context variables are presented in Table 5, where study variables, such as the method employed in assessing the economic value, the year of publication or the continent where the study takes place are included. The valuation method is introduced in the form of four variables (*revealed, market, nonmarket* and *othermethod*), while the year of study has been coded in two periods, *decade1* for studies conducted before 1997, and *decade2* for studies conducted after 1997. Finally, an economic variable is introduced to account for the income level of the country where the study took place (*lnGDP*) (IMF, 2007; World Bank, 2007).

IV. OBJECTIVES AND HYPOTHESES

A previously stated, our aim is to study the interactions between forest ecosystems, forest values and biodiversity, and how these interactions vary in global latitudinal regions. Our main objective is thus to study in depth the interactions between forest ecosystems and biodiversity and explore whether these interactions vary in space. To address this empirical question, we have set up three main hypotheses. The first one explores the role of biodiversity loss in economic benefits derived from ecosystem services. Since biodiversity richness is positively related to net primary production, we expect our biodiversity loss indicators of endangerment status to also be significant in explaining negative ecosystem values effect. However, our sample is larger than that of Costanza et al. (2007) and includes many types of ecosystem services, encompassing cultural, regulating and provisioning. We can expect high indexes of threatened biodiversity to have a negative impact on the benefits derived from the ecosystem service, since endangered species are indicators of the ecosystem conservation status. This impact however may depend on the type of ecosystem service we are valuing. Costanza et al. (2007) find a positive link between biodiversity richness and provision of services. However, we have no a priori expectations of how biodiversity is affecting cultural or regulating services. Based on this fact, our second hypothesis refers to whether the employed biodiversity indicators are influencing forest benefits in a statistically significant way, depending on the type of service provided. Our third and last hypothesis 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 human welfare we proceed by introducing the cross products of the different biodiversity indicators and the ecosystem services in the regression. In this way, we compute the joint effect of the biodiversity status together with 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 yet been considered in literature, and has important implications for policy analysis and resources reallocation.

V. RESULTS

With the described dataset we proceed with the estimation of the meta-regression of worldwide forest ecosystem values. The baseline model is an Ordinary Least Square (OLS) model, while in order to explore the panel nature of our data, a Generalized Least Square (GLS) model with random effects was estimated following Wooldridge (2003). Baseline specification model results are split in Table 6. The model specification provides a better model fit for the OLS specification, obtaining a R^2 of 0.54. This baseline model serves as a first attempt to synthesize market and non-market forest valuation studies. Main findings conclude that the estimated coefficient of the forest area (*lnha*) is negative and shows significant marginal decreasing utility with the provision of additional hectares. This result has been found in previous meta-analyses of ecosystem values such as Ghermandi et al. (2007) or Woodward and Wui (2003) for wetlands, and even for forest values in Lindhjem (2007), as well as in non-market valuation literature (Loomis et al., 1993). The type of forest also has a significant effect on forest values. Tropical forests and temperate conifer forests are related to higher values, in respect to the omitted variable temperate broadleaf forests (*tempbroad*). Bearing in mind that *allservices* is the omitted variable; the results show that values obtained from a single ecosystem service are lower than values obtained from more than one ecosystem service. This result falls in line with our expectations and contradicts the possibility of an embedding effect, where valuing two goods separately yields a greater value than the sum of both (Loomis et al., 1993). The meteorological variables resulted as significant in the previous regression, where minimum temperature (*mint*) is related to higher forest values while precipitation has a negative effect on forest values, as obtained from the GLS model. Another finding from the baseline model is that the methodology used in the primary study does not affect the estimated economic values. Studies conducted on tropical latitudes (*lat_3030*) are associated with lower values. Additionally, the per capita income is not statistically significant. Another non-significant variable is the time of the study, where studies conducted in the first decade are not significantly different than studies conducted in the most recent decade.

As the main objective of study, special attention is given when assessing the effect of the biodiversity indicators on forest values. We find that biodiversity endangerment indexes are holding different signs, where endangered fauna (*fauna*) is not statistically significant in explaining forest values, and endangered flora (*flora*) is neither statistically significant in the model. This result may indicate that additional analysis is needed in order to link biodiversity losses to forest ecosystem values. As we discussed earlier, biodiversity loss could be affecting ecosystem services in a different way, and exploring this possible effect is worthwhile.

In order to have a deeper understanding of these previous results, we explore in a second step if Biodiversity loss is affecting forest services depending on the regions. Table 7 presents the joint effects of endangered biodiversity, ecosystem services and geo-climatic regions. The first two columns correspond to the OLS model while a third and a last column correspond to the GLS model. The models result in a similar R^2 of 0.59 and 0.56, where all variables carry the expected signs and statistical significance. The marginal decreasing values, in respect to size variable and the lack of significance of the income and time variable are common to all model specifications. Following our empirical objectives, from Table 7 we conclude that threats to fauna and flora are affecting forest values differently depending on the latitudes and on the type of ecosystem service valued. The threatened fauna index variable is negative in the higher latitudes (over 30 degrees), both in cultural and non-cultural forest ecosystem services. This estimate shows the implicit or shadow prices 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. In boreal and temperate areas the implicit price of endangered fauna is different to that found in other regions. These relative estimates show that this price is lower at higher latitude regions.

The recovery of threatened and endangered fauna species has been given important economic values in previous studies taking place in the temperate regions (Loomis and White, 1996). One may argue that a high endangerment index may be related to threats to fauna, and thus resulting into lower economic values, as obtained from this meta-analysis. In contrast, the results show that endangered flora is increasing non-cultural values. This might be related to the fact that many of the existing flora is extracted for economic activities, and as such, deforestation and economic exploitation turn into the loss of flora species (Rolfe et al., 2000). This loss of flora species is reflected on a high endangered flora index, which increases the value of remaining forest ecosystems, given that a higher scarcity of exploited species tends to raise the value of the remaining ones.

VI. CONCLUDING REMARKS

The MEA focuses 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 losses to the economic consequences of their change in ecosystem services this biodiversity loss produces. Values were also collected for many different forest ecosystem types and services; both from market and non-market valuation techniques in a collection of worldwide studies.

Results highlight the complexity of dependencies between biodiversity loss, forest ecosystem services and their value to humans. The models show how biodiversity loss can indirectly affect forests values and how this effect varies with the geographical distribution of forests. Both endangered flora and endangered fauna are found as statistically significant in explaining forest values when considering both, the forest ecosystem service and the region. Endangered fauna is related to lower forest values and endangered flora, in contrast, is related to higher forest values.

These results are a first attempt to link biodiversity loss with ecosystem revenues employing the MEA conceptual framework, which 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 losses. This constitutes however, an anthropocentric approach where only human well being is considered in the analysis. Nevertheless, important implications for policy analysis relating to resource allocation and conservation priorities can be derived. Further analyses may confirm these findings together with other predicted impacts due to climate change.

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Tables

Table 1: List of studies

1. Aakerlund (2000)	34. Kaiser and Roumasset (2002)
2. Anthon and Thorsen (2002)	35. Kniivila (2004)
3. Balick and Mendelsohn (1992)	36. Kniivila et al. (2002)
4. Bann (1997)	37. Kontoleon and Swanson (2003)
5. Bateman and Lovett (2000a)	38. Kramer and Mercer (1997)
6. Bateman and Lovett (2000b)	39. Kramer et al. (1995)
7. Bateman et al. (1996)	40. Kramer et al. (2003)
8. Bellu and Cistulli (1995)	41. Lienhoop and MacMillan (2007)
9. van Beukering (2002)	42. Mahapatra and Tewari (2005)
10. van Beukering et al. (2003)	43. Mallawaarachchi et al. (2001)
11. Bienabe and Hearne (2006)	44. Mogas et al. (2006)
12. Bonnieux and Le Goffe (1997)	45. Monela et al. (2005)
13. Bostedt and Mattsson (2006)	46. Murthy et al. (2005)
14. Campos and Riera (1996)	47. Naidoo and Adamowicz (2005)
15. Chase et al. (1998)	48. Ninan and Sathyapalan (2005)
16. Christie et al. (2001)	49. Nowak et al. (2007)
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18. Dubgaard (1998)	51. Phillips et al. (2008)
19. Edwards-Jones et al. (1995)	52. Raunikar et al. (2006)
20. Emerton (1999)	53. Ricketts et al. (2004)
21. ERM (1996)	54. Rosales et al. (2005)
22. Garber-Yonts et al. (2004)	55. Samuel and Thomas (1996)
23. Garrod and Willis (1997)	56. Sattout et al. (2007)
24. Godoy et al. (2000)	57. Scarpa et al. (2000)
25. Gurluk (2006)	58. Shahwahid et al. (2003)
26. Hanley and Ruffel (1993)	59. Shechter et al. (1998)
27. Hanley et al. (1998)	60. Siikamaki (2007)
28. Hanley et al. (2002)	61. Simpson et al. (1996)
29. van der Heide et al. (2005)	62. Verma (2000)
30. Horne et al. (2005)	63. Walsh et al. (1984)
31. Horton et al. (2003)	64. Wang et al. (2007)
32. Hougner et al. (2006)	65. Zandersen et al. (2005)
33. Howard (1995)	

Table 2: Data Descriptive Analysis: 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 and Services	*cultural*	Cultural (1); rest (0)	0.584
	noncult	Provisioning or Regulating (1); rest (0)	0.36
	*allservices**	Cultural and Provisioning and Regulating (1); rest (0)	0.05

*Variables that were omitted in the model.

Table 3: Data Descriptive Analysis: Geo-Climatic and Biodiversity Indicators

Geo-Climatic and Biodiversity Indicators			**Mean**
Meteorological	*precip*	Mean annual precipitation (period 1961-1990)	1164.45
	mint	Mean annual min temperature (period 1961-1990)	7.15
Regions	*lat_3030**	Latitude between -30° and 30° (1); rest (0)	0.36
	lat_3060	Latitude > 30° (1); rest (0)	0.63
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

*Variables that were omitted in the model.

Table 4: Distribution of the fauna and flora indexes with geo-climatic regions

Latitudinal regions	**Fauna index**	**Flora index**
Latitude -30 30	12.99	60.57
Latitude 30 45	22.84	55.79
Latitude 45 60	7.23	20.01
Latitude 60	5.12	15.00

Table 5: Data Descriptive Analysis: Context Characteristics

Context Characteristics			**Mean**
Forest value	*lnval*	Value per hectare per year given by the study (€2008)	3.76
Environmental Valuation	*revealed*	Revealed preferences techniques (TC, HP, etc.) (1); rest (0)	0.10
Method	*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	*lnGDP*	Natural logarithm of the country of study GDP (€2008)	3.14

*Variables that were omitted in the model.

Table 6: Baseline Specification Models

	Baseline model			
	OLS model		**Random Effects model**	
lnval	**Coeff.**	**t-value**	**Coef.**	**t-value**
lnha	-0.5053 (0.0743)	-6.80***	-0.5925 (0.1174)	-5.05***
mediterranean	0.2639 (0.9102)	0.29	-0.5850 (1.1895)	-0.49
boreal	0.8563 (1.2191)	0.70	-0.5135 (1.5976)	-0.32
tempconif	1.3528 (0.7570)	1.79*	0.1353 (1.0656)	0.13
tropicalwet	3.4046 (1.7103)	1.99*	1.2847 (1.8248)	0.70
tropicalmix	3.8946 (1.8846)	2.07*	1.6825 (2.0287)	0.83
hotspot	0.9345 (0.7307)	1.28	1.1071 (0.9982)	1.11
cultural	-2.6568 (0.9581	-2.77**	-3.3401 (1.7969)	-1.86**
noncult	-3.4460 (0.9504	-3.63*	-3.6297 (1.4792)	-2.45**
revealed	0.2930 (0.9718)	0.30	0.1021 (1.1882)	0.09
market	-0.3849 (0.9031)	-0.43	0.0051 (1.3650)	0.01
nonmark	1.1175 (0.8931)	1.25	1.0206 (1.2965)	0.79
precip	-0.0012 (0.0007)	-1.61	-0.0009 (0.0005)	-1.69*
mint	0.1382 (0.0568)	2.43*	0.1125 (0.0763)	1.47
fauna	-0.0571 (0.0395)	-1.45	-0.0385 (0.0449)	-0.86
flora	-0.0214 (0.0144)	-1.49	-0.0145 (0.0119)	-1.22
lat3030	-3.2605 (1.9711)	-1.65*	-2.7569 (1.9094)	-1.44
decade2	-0.8528 (0.5789)	-1.47	-1.0305 (0.9238)	-1.12
lnGDP	0.4762 (0.4218)	1.13	0.3638 (0.4626)	0.79
constant	9.8376 (4.3848)	2.24*	13.1310 (4.0515)	3.24***
N	172		172	
$\mathbf{R^2}$	0.54		0.51	
Adj. $\mathbf{R^2}$	0.49			

(***) indicates statistical significance at α=0.001; (**) indicates statistical significance at α=0.01; and (*) indicates that the variable is statistically significant at α=0.1.

T*able 7: Models with Cross Effects with Biodiversity Indexes, Ecosystem Services, and Geo-Climatic regions*

	Biodiversity*Ecosystem services*latitudes			
	OLS model		**Random Effects model**	
lnval	**Coeff.**	**t-value**	**Coeff.**	**t-value**
lnha	-0.4486 0.0812	-5.53***	-0.5579 0.1405	-3.97***
mediterranean	0.5824 0.9082	0.64	0.1069 1.3034	0.08
boreal	1.4881 1.2588	1.18	0.5427 1.7442	0.31
tempconif	2.0109 0.7917	2.54*	1.1782 1.3649	0.86
tropicalwet	6.6074 1.9532	3.38***	4.8104 2.1184	2.27*
tropicalmix	7.9289 2.2306	3.55***	5.8470 2.7379	2.14*
hotspot	1.2993 0.8958	1.45	1.5870 1.3799	1.15
cultural	1.4583 5.2572	0.28	-0.8221 3.7920	-0.22
noncult	-2.6493 5.1288	-0.52	-4.7262 3.5267	-1.34
revealed	1.5987 1.0923	1.46	1.2329 0.9298	1.33
market	-0.2409 1.0308	-0.23	0.2074 1.3328	0.16
nonmark	2.1980 1.0723	2.05*	1.9459 1.0228	1.90*
precip	-0.0022 0.0008	-2.68**	-0.0020 0.0008	-2.40*
mint	0.2496 0.0646	3.86***	0.2303 0.1129	2.04*
fauna	0.2130 0.1835	1.16	0.1713 0.1430	1.20
*fauna*cult*lat3030*	-0.1037 0.2880	-0.36	-0.0919 0.4391	-0.21
*fauna*cult*lat3060*	-0.3159 0.1861	-1.70*	-0.2540 0.1541	-1.65*
*fauna*noncult*lat3030*	-0.1686 0.2013	-0.84	-0.1552 0.1780	-0.87
*fauna*noncult*lat3060*	-0.4489 0.2004	-2.24*	-0.4635 0.2449	-1.89*
flora	-0.1010 0.1078	-0.94	-0.1035 0.0711	-1.46
*flora*cult*lat3030*	-0.0670 0.1064	-0.63	-0.0346 0.0803	-0.43
*flora*cult*lat3060*	0.0943 0.1098	0.86	0.0995 0.0738	1.35
*flora*noncult*lat3030*	0.0137 0.1034	0.13	0.0356 0.0550	0.65
*flora*noncult*lat3060*	0.1986 0.1228	1.62	0.2380 0.1043	2.28*
lat3030	0.0371 3.2604	0.01	0.0451 2.5777	0.02
decade2	-0.8914 0.5830	-1.53	-0.9439 0.9682	-0.97
lnGDP	0.9820 0.4523	2.17*	0.8320 0.6551	1.27
constant	-0.5096 7.0774	-0.07	5.0420 6.6390	0.76
N	172		172	
R^2	0.59		0.56	
Adj. R^2	0.51			

(***) indicates statistical significance at α=0.001; (**) indicates statistical significance at α=0.01; and (*) indicates that the variable is statistically significant at α=0.1. ES=Ecosystem Service.

Figure titles

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

Source: Adapted from MEA, 2005.

Grouped Footnotes

[1] This estimate has been criticized for the scaling up procedure they employed (Bockstael et al., 2000)
[2] EVRI database and IUCN database for forest studies have been employed.
[3] Box cox test resulted in a value of 217.84 which is well above the critical level at 1% χ^2 (19,0.01)=38.58.

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