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INTEGRATING STAKEHOLDERS' DEMANDS AND SCIENTIFIC KNOWLEDGE ON ECOSYSTEM SERVICES IN LANDSCAPE PLANNING

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Abstract

The conflict between conservation and timber production is shifting in regions such as Biscay (Basque Country, northern Spain) where planted forests are no longer profitable without public subsidies and environmentalist claim that public subsidies should be reoriented to the regeneration of natural forest. This paper develops an approach that integrates scientific knowledge and stakeholders' demands to provide decision-making guidelines for the development of new landscape planning strategies while considering ecosystem services. First, a participatory process was conducted to develop a community vision for the region's sustainable future considering the opportunities and constrains provided by the landscape and its ecosystems. In the participatory process forest management was considered an important driver for the region`s landscape development and forest multi-functionality was envisioned as a feasible attractive alternative. The participatory process identified a knowledge gap on the synergies and trade-offs between biodiversity and carbon storage and how these depend on different forest types. Second, to study the existing synergies and trade-offs between biodiversity and carbon storage and disentangle the identified knowledge gap, a GIS-based research was conducted based on spatially explicit indicators. Our spatial analysis results showed that natural forests' contribution to biodiversity and carbon storage is higher than that of the plantations with exotic species in the region. The results from the spatial analysis converged with those from the participatory process in the suitability of promoting, where possible and appropriate, natural forest ecosystems restoration. This iterative learning and decision making process is already showing its effectiveness for decision making, with concrete examples of how the results obtained with the applied approach are being included in planning and decision-making processes.

Key words: Ecosystem services, stakeholder participation, spatial explicit indicators, biodiversity, carbon storage, landscape multi-functionality, forest sustainable management

Introduction

Nowadays, there is a growing need to develop methods for a more integrated and adaptative governance, mainly to provide a better response to the demands of society while minimizing the cost that fulfilling these demands may cause to other services essential for human well-being, such as wood, genetic recourses or fresh water (Mooney et al. 2005). Within this context, the Millennium Ecosystem Assessment explored the link between human well-being, the status of ecosystems and their sustainable use (MA 2005). This relevant assessment aimed to provide policy-makers with scientific information on the consequences of ecosystem changes for ecosystem services (ES) and human well-being (MA 2005). In fact, since the MA started, scientific, political and social concern on ecosystem services has risen significantly, e.g., the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the targets of the Convention of Biological Diversity (CBD) for the year 2020. Despite the increasing scientific and political attention on ES, there is a lack of approach to include this concept in the land use management strategies at landscape scale.

In the last century, many regions have intensified forestry and agriculture practices prioritizing the short-term economic benefits of the land owners. However, the importance of landscapes to maintain biodiversity while fulfilling multiple ES such as timber and food production, water flow regulation or carbon storage is being increasingly recognized (FAO 2003, Otte et al. 2007) and the multi-functionality of landscapes is seen as an opportunity to converge with conservation planning while improving production abilities and ecological functions (Reyers et al. 2012). Due to the existing synergies and trade-offs between different services (Dymond et al. 2012; Hauck et al. 2012; Onaindia et al. 2013a; Gamfeldt et al. 2013) as well as to the different demands of stakeholders, not all ES can be prioritised simultaneously in a region. Thus, compromises in landscape management have to be adopted (Horner et al. 2010). In that decision process social-ecological issues should be considered for a widespread implementation of ES in practical planning and decision-making. In order to do that, a clear understanding of the ecological environment as well as the inclusion of different stakeholders' interests is required (Onaindia et al. 2013a; Thompson et al. 2012).

In regions such as Biscay, northern Spain, fast growing exotic species (e.g., *Pinus radiata* and *Eucalyptus* sp.) forest plantation has expanded since the 1950's (Rodríguez-Loinaz et al. 2011) covering nowadays 43% of the area, while natural forests remnants are sparse and fragmented, covering only 13%. In the last decade, there has been increasing concern regarding potential negative environmental impacts of those monoculture plantations such as soil loss and compaction, nutrient loss and surface water turbidity (Rodríguez-Loinaz et al. 2013). As a result, landscape management has generated controversy between stakeholders. Landowners favour the pine and eucalyptus plantations trying to maximise their economic benefits, whereas environmentalists bet on the regeneration of natural forests. Currently, nature managers find themselves in a situation where this potential conflict between conservation and timber production is confronting new realities and therefore new decisions need to be made. Moreover, due to the globalisation of the timber market and other factors, forest plantations in the area are no longer as profitable as they used to be, e.g., the value of timber production fell by 80% between 2005 and 2011 (Basque Government 2011), and their subsistence depends heavily on public subsidies (Rodríguez-Loinaz et al. 2013). As a consequence, carbon incentives have become an opportunity for land owners to maintain the profitability of these plantations. In light of these changes, new strategies of land management based on social demands and scientific knowledge are needed to create landscapes that are sustainable in the long term, considering the six sustainability dimensions proposed by Musacchio (2009) at the landscape scale (namely those concerning environment, economic, equity, aesthetics, experience, and ethics) and understanding the idea of a 'sustainable landscape' in terms of the way it functions, and whether that functionality is sufficient to maintain the output of services that people need or value (Potschin and Haines- Young 2011).

Within this context, this work attempts to develop an approach that integrates scientific knowledge and stakeholders' demands to provide decision-making guidelines for the development of new strategies for land and forest management towards a more sustainable landscape. In doing so, we expect to further develop the understanding of how ES information can be integrated in planning and decision-making. The proposed approach consist of a two-step process: 1) a participatory process with local stakeholders to develop a community vision for the region's sustainable future considering the opportunities and constrains provided by the landscape and its ecosystems, as well as to identify key drivers and research needs; and 2) a scientific research to address the lack of knowledge that is needed to design, implement and regulate effective policies.

Methodology

Study area

This study was carried out in the county of Biscay (2213 km^2; 1.2 million inhabitants), located in the north of the Iberian Peninsula (43º 46´ to 42º 92´ N, 03º 45´ to 02º 40´ W) (Fig. 1). The region has a mountainous topography: in half of the territory there are slopes greater than 30%, and the altitude varies from 0 to 1500 m above sea level. The climate is temperate and humid, being regulated by the Cantabrian Sea. The principal characteristics of this climate are its slight thermal oscillations (average temperature 12.5 ºC), uniform rainfall distribution throughout the year (average annual rainfall 1,200 mm), and a relative lack of frost.

Currently, more than half of the surface of Biscay (56%) is dominated by forest, mainly by exotic plantations (*Pinus radiata* and *Eucalyptus* sp., 39% and 4% of the area, respectively). The main natural forest types in Biscay are Cantabrian evergreen-oak forests (*Quercus ilex*), mixed oak forests (*Quercus robur*) and beech forests (*Fagus sylvatica*). These forests represent the potential vegetation of approximately 80% of the region, but currently they only cover 13% of the area (Basque Government 2009; Fig. 1).

#Figure 1 approximately here#

Participatory process

The participatory process used here consisted of combining different participative methods (Pereira et al. 2005; Patel et al. 2007; Palomo et al. 2011), namely a structured questionnaire and a workshop held after a stakeholder selection process (Palacios-Agundez et al. 2013). The structured questionnaire was designed to identify the key drivers of change and the potential for successful intervention, which were analyzed later in the workshop. The questionnaire was sent by mail to 285 local stakeholders a month before the workshop was implemented. Stakeholder selection is crucial for the outcome of any participatory process (Kok et al. 2007). We therefore selected a wide variety of stakeholders including the four groups that others studies about participatory processes suggested that should be represented: policy makers, business representatives, citizens, and experts (van Asselt and Rijkens-Klomp 2002).

The workshop was held on 17th and 18th of June 2010, for approximately eight hours each day. In the workshop, the participants were divided into 4 heterogeneous groups of approximately 10 participants including at least one representative of the research group and an experienced local facilitator in each group. Participants first discussed the key drivers of change in the Biscay social-ecological system and later in a plenary session developed a list of the most relevant ones. Once the main drivers of change were identified, four possible future scenario outcomes were described and characterized in terms of the provision of ES and human well-being. Identifying the desirable and undesirable outcomes, participants described a sustainable target scenario for Biscay with the time horizon set on 2050, and planned how it could be achieved by defining management strategies and identifying research needs (Quist and Vergragt 2006) (see Palacios-Agundez et al. 2013 for further detail).

Scientific research: spatial analysis

We designed a GIS-based approach for mapping and quantifying biodiversity and carbon storage based on spatially explicit indicators to study the existing synergies and trade-offs between both on forest ecosystems. The software used for the geoprocessing was ArcGIS 9.3 (ESRI 2009). The forest system units were defined using the Habitats EUNIS map of the Basque Country in a scale of 1:10,000 (Basque Government 2009), which has been created using EUNIS level 4 or beyond for forest systems (EEA 2002). For this study, the 54 forest habitats in the area were aggregated into: (1) natural forests including mixed oak forest, Cantabrian green oak forest and beech forest as well as (2) forest plantations including conifer and eucalyptus plantations (Fig. 1).

Biodiversity was mapped and quantified using three spatially explicit indicators: native plant species richness, vertebrate species richness and threatened animal species richness. The native plant species richness was measured as the total number of native plant species in each forest type, and was calculated based on the literature from the study area (Onaindia et al. 2013a) (Table 1). The vertebrate species richness was obtained from the National Biodiversity Inventory database (10x10 km UTM grid cells) of the Spanish Ministry on Agriculture, Food and Environment (MAAMA 2008). The threatened animal species richness was extracted from the threatened animal species in the Basque Country distribution map in 10x10 km UTM grid cells (Basque Government 2012).

#Table 1 approximately here#

For carbon storage, we mapped the amount of carbon stored in living trees and soil in the forest systems. For the valuation of C stored in the soil, we used the "Inventory of organic C stored in the first 30 cm of the soil" of the Basque Country (Neiker-Ihobe 2004). This map was obtained by means of interpolation techniques from more than a thousand samples of organic C concentrations (g kg−1) and soil bulk density (g cm−3) after combining the samples according to land uses (e.g., coniferous forest, broadleaf forest, grasslands and scrublands). The C stored in living trees was obtained as follows (IPCC 2003):

$$CB = V * BEF * (1+R) * D * CF$$

where *CB* is the carbon stocks in living biomass (includes above- and belowground biomass), tonnes C ha^{-1}; *V* is the merchantable volume, m^3 ha^{-1}; *BEF* is the biomass expansion factor for each species, without units; *R* is the root-to-shoot ratio to include belowground tree biomass, without units; *D* is the basic wood density, tonnes of dry matter dm m^{-3} merchantable volume; and *CF* is the carbon fraction of dry matter, tonnes C (tonne dm) $^{-1}$. The merchantable volume data for the different forests was obtained from the Forest Inventory in 1:10,000 scale of the Basque Country for the year 2011 (Basque Government 2013). The wood densities were obtained from the forests of the northern Iberian Peninsula (CPF 2004; Madrigal et al. 1999), and the biomass expansion factors were obtained from the study region (Montero et al. 2005). Finally, we created a total carbon storage map by combining the maps of C stored in soil and living trees.

In order to detect spatial synergies and trade-offs between carbon storage and biodiversity, we calculated the differences in carbon storage per hectare and natural plant species richness between native forest and plantations using t-tests. To analyze the effect of forest type on animal diversity we calculated the proportion of forest system units in each 10 km^2 grid cell. Then, relationships between animal richness (expressed as the number of threatened animal species and as the number of vertebrate species) and forest types were modelled using General Linear Models (GLM). The log-link function and a Poisson error distribution were used for richness variables (Crawley 2007). All values are reported as the mean ± standard error of the main factors, and the magnitude of the effects was calculated as the estimated difference from the intercept. All statistical analyses were implemented in the R software environment (version 2.15.2; R Core Team 2012).

Results

Participatory process

A total of 66 stakeholders took part in the participatory process. The workshop participants included public-administration technicians and policymakers, researchers and local experts from different backgrounds, members of environmental associations, environmental education professionals, and representatives from the agriculture and the forestry sectors. Participants identified forest management as one of the most important drivers of change in the Biscay landscape (Table 1). They considered that a change is necessary in the existing timber production model in Biscay due to its current lack of profitability. Moreover, the majority highlighted the need to go beyond the merely timber production goals towards promoting structural and functional diversity in forest systems. They also considered that sustainable forest management should ensure ES supply, and many of them perceived natural forests as important providers of ES (Table 1). In fact, a key point in the sustainable target scenario chosen by participants was landscape multi-functionality. In this scenario, it was considered that apart from timber production to maintain the landowners' economic benefits, other ES should be promoted, mainly biodiversity and carbon storage, to maximise the benefits for society. Participants proposed the recovery of natural forest in sites that are not necessarily meant for commercial purposes (e.g., public lands) as well as the diversification of tree species in forest plantations, expanding to new markets and maximising both benefits, societal and economical. To achieve this scenario, participants identified the need for a strategic landscape planning and management (Table 1), and requested more scientific knowledge on the synergies and trade-offs among ecosystem services, biodiversity and carbon storage, in order to inform and implement sustainable forest management.

#Table 1 approximately here#

Scientific research: spatial analysis

Carbon storage in plantations ranged from on average 139 tC ha-1 in coniferous to 220 tC ha-1 in eucalyptus plantations (Table 2). In contrast, in natural forests carbon storage ranged from 151 tC ha-1 in Cantabrian green oak to 212 tC ha-1 in beech forests. Overall, natural forests held more carbon than plantations (t-value = 2.43, p-value = 0.023), being 187 tC ha-1 the total mean carbon storage in natural forests and 140 tC ha-1 in plantations (Table 2). Native plant species richness per forest type ranged from 30 in eucalyptus plantation to 79 in mixed oak forest (Table 2), and was significantly higher in natural forests than in forests plantations (77 ± 3.79 vs. 54 ± 21.92; z-value = 7.29, p-value = 0.003).

#Table 2 approximately here#

The GLM results showed that both biodiversity indicators (i.e., threatened animal species richness and vertebrate species richness) were significantly positively related with the area of natural forests (Table 3a); indicating that grid cells with greater natural forest areas preserve more vertebrate and threatened animals species richness. Regarding differences among forest types (Table 3b), although there is only a significant positive relationship between vertebrate species richness and beech forest area (Table 3b), species richness of threatened animal species was significantly positively related to beech forest and Cantabrian green oak forest areas (Table 3b). On the contrary, threatened animal species and vertebrate species richness showed no significant relationship with coniferous and eucalyptus plantations (Table 3b), and forest plantations showed a non-significant negative relationship (Table 3a).

#Table 3 approximately here#

Discussion

The cooperation between scientists and stakeholders

The traditional role of scientists as informants to policy-makers on technical advice is changing. The role of stakeholders is more and more recognised and many scientists consider that useful scientific knowledge emerges from the cooperation of scientists and practitioners (Beunen and Opdam 2011). Process-based decision models facilitate better modelling of human decisions in natural systems (An and López-Carr 2012). However, regional and local actors groups involved in the landscape planning usually make insufficient use of scientific knowledge of the ecological system that is being changed (Opdam et al. 2008). To fill this gap, scientists can contribute to conflict management by providing objective information and helping to justify management plans and actions (McCool et al. 2007).

In our study area, conservationists and land owners have opposing views about biodiversity conservation plans and current timber production strategies. Besides, planted forests are no longer profitable without public subsidies and landowners perceive carbon storage as a market opportunity. Consequently, the participatory process showed that a wider understanding on the forest ES and on the synergies and trade-offs between biodiversity and carbon storage is required. Solid scientific knowledge was therefore demanded as a decision-making tool that would provide added value to the overall knowledge co-generation process and would help towards multi-sector consensus on land use policies. In fact, identifying such synergies and trade-offs enables users of forest ecosystems to understand and balance the pros and cons of different management scenarios (Gamfeldt et al. 2013).

A key element for the success of the approach used here was the stakeholders' engagement from the start in an iterative learning and decision making process. This collaborative process resulted in the willingness to search for the most appropriate and sustainable response options considering the local socio-economic conditions as well as the opportunities and constrains provided by the landscape and its ecosystems. The participatory process therefore identified the knowledge gap and guided the directions for future research. Interestingly, the added value of the scientific knowledge was recognised for promoting landscape planning towards the sustainable target scenario described by participants.

In this process it was also crucial to incorporate the conceptual framework of ecosystem services, because this allowed participants to better understand the different potential benefits of ecosystems (Hauck et al. 2013) and showed where potential conflict areas and opportunities were located. During the process, all participants learned from each other and became able to better understand different points of view. This was particularly relevant for those actors who initiate, promote, implement or are affected by land management changes. However, several aspects of the forest management issue (e.g., the role of forest plantations and natural forest for the carbon storage ecosystem service) remained uncertain and multi-functionality of forests was identified as a key aspect where a broader agreement was needed, as many landowners defend monoculture plantations and are reluctant to change their current timber production strategies.

Another key issue was the use of spatially explicit information. The application of scientific knowledge to landscape planning at the local level requires site-specific interpretations that may be addressed with a high level of spatial detail. While science aims for generic and universal rules, the validity of such generalities is limited at the local level, and problem solving requires a reinterpretation of generic rules in the local context (Beunen and Opdam 2011). While general technical guidance for environmental planning can be useful at the state level, it can be less useful at the local scale (Azerrad and Nilon, 2006). In the study area, the outputs generated in the form of maps showing where the conflict areas and opportunities were located, helped managers explore solutions and generate new knowledge. The scientific information was considered of great interest by stakeholders for both consensus building and problem solving, even though other studies have observed a more sceptical attitude towards scientific knowledge (Beunen and Opdam 2011).

Trade-offs between carbon storage and biodiversity

The identification of knowledge gaps during the participatory process was followed by an analysis of spatially explicit indicators to disentangle the synergies and trade-offs between biodiversity and carbon storage on forest ecosystems. Here, the results showed that natural forest area had positive effects on both carbon storage and biodiversity. First, the mean carbon storage per hectare in natural forest was greater than in forest plantations. These results are in agreement with Rodríguez-Loinaz et al. (2013), who demonstrated that substituting existing exotic plantations by native species plantations or natural woodlands has a great potential for increasing carbon sequestration in the same region. Second, native plant species richness was slightly greater in natural forests than in forest plantations. Further, the positive relationship between natural forest area and species richness of vertebrate and threatened animal species suggests that natural forest, especially beech and Cantabrian green oak forest, are important spots to preserve vertebrate diversity and the threatened animal species. These results are in agreement with Onaindia & Michelena (2009) who, in the same region, found that the total number of species in the understory vegetation was higher in natural forests than in pine plantations. According to these results, the natural forest restoration might be a valid option for carbon storage and biodiversity conservation in this region, especially considering degraded sites or areas where forest plantations are not highly profitable (Onaindia et al. 2013b). Similarly, recent studies in regions such as Costa Rica, Vietnam, Chile and Ecuador showed that landscapes experiencing increases in natural forest also experienced an increase in the potential to support native floristic biodiversity, as well as an increase in the carbon stored above and below ground (Hall et al. 2012). The conservation of natural forests is essential for biodiversity conservation (Kessler et al. 2012); however, natural forests are fragmented and sparse in Biscay being one of the main drawbacks for their preservation. As a consequence, the restoration actions should focus on increasing natural forest area as well as on the inter-connectivity of existing natural forest patches.

The lack of knowledge identified during the participatory process was complemented by scientific approaches using spatially explicit analyses. On this basis, solutions for carbon sequestration and biodiversity conservation are possible while natural forest interconnectivity is increased, favouring landscape multi-functionality. This might be achieved using management plans based on sound science and agreed by a wide-range of multi-sector stakeholders.

Contribution of the proposed approach for decision-making

An important question in scientific research is the impact of science in decision making, and more specifically in landscape planning. At the local level of landscape planning there is dissatisfaction among citizens and experts about the outcomes of decision-making in governance (Beunen and Opdam, 2011). The development of our approach specifically could contribute to give more insight to politicians in their role as decision makers. Based on the results of the participatory process, we consider that it might be the right moment to promote a change in forestry policies. The results from the spatial analysis converged with those from the participatory process in the suitability of promoting natural forest ecosystems restoration where possible (e.g., public forest) and appropriate (e.g., high slopes or other adverse conditions for intensive management). To promote this change and favour forest multi-functionality, participants suggested that new financial mechanism and incentives should be created. Public administration could lead this change by using public lands to restore natural forest, redirecting subsidies to landowners to promote native tree plantations or facilitating other financial mechanism. In fact, this approach provides decision makers with tools to work in changing management policies and practices towards a more sustainable landscape. In forested areas of Finland, stakeholders also emphasised the importance of the national sustainable forestry policy and its financing instruments as a means to level and mitigate trade-offs (Hauck et al. 2013). Some experiences like this have also been proposed in agro-environment schemes (Schouten et al. 2013).

The local administration has found the applied approach relevant and useful for decision-making, and the results obtained are already being included in planning and decision-making processes in the area. The recently approved policy strategy of the County

Council of Biscay named *Biscay 21: a Sustainability Strategy for the County Council of Biscay* (DFB 2012) includes the elaboration of a *Forest Ecosystem Service Catalogue and Guidebook* that aims to include actions on the ground and recommendations to favour forest multi-functionality. In addition, the Technical Plans for Sustainable Forest Management, a compulsory administrative tool regulated by the County Council of Biscay, must be drawn up in accord with these specifications.

Involving local actors in decision making processes will result in more sustainable social-ecological systems (Schultz et al. 2007). However, it takes several years for a region with conventional forest management to change management strategies to more sustainable ones, thus the results presented here are not but the first steps of a longer iterative learning and decision making process. These first steps, however, serve as a consistent basis to go further into the implementation of the proposed changes through an iterative knowledge co-generation process that has already started, where those involved are part of the knowledge generation process, and guarantees for its usefulness, applicability and relevance (Johnsen 2005). In fact, landscape design created collaboratively by scientists and practitioners improves the impact of landscape science in society and enhances the saliency and legitimacy of landscape ecological scientific knowledge (Nassauer and Opdam 2008).

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Tables with captions

Table 1 Summary of the main results obtained in the participatory process.

Questionnaire results (% of respondents)	Participants' perception on forest systems and their services	Most relevant drivers of change	Sustainable target scenario description	Management proposals
34.29% explicitly mentioned forest aspects on their open answers Highest potential for successful intervention among drivers of change: - Indirect driver: Primary sector development (88.57% assigned the highest value); - Direct driver: Forest management (85.71% assigned the highest value)	Natural forests have a higher potential to provide ES to society than exotic plantations Currently some important ecosystem services, such as the aesthetic value of landscape diversification, are not sufficiently reinforced The applied forest management type is relevant for the quality and quantity of ES Current lack of profitability: new business options (e.g., diversification of species)	Governance and institutional coherence Land and urban planning Primary sector development Forest management Ecosystems degradation Innovation and science Participatory policy making model	Proactive work is performed from the local to the global scale and vice versa Landscape multi-functionality is key in this scenario: biodiversity and carbon storage are enhanced Local sustainable productivity is promoted Sustainable forest management is reinforced, and the quality and variety of forest are improved Autochthonous ecosystems and their functionality are conserved and recovered Society uses scientific knowledge to protect ecosystem functionality Education, local participation and knowledge society	Coherence between policy and actions is needed: governments at different scales have an important role to play Strategic landscape planning and management is needed New financial mechanism and incentives should be created Changes in forest management and landscape planning should be promoted in an integrative and proactive way Public lands are used to recover natural forest ecosystems Research and traditional knowledge recovery are essential Public awareness on the importance of Landscape multi-functionality should be reinforced: - Promotion of environmental education from early stages - Scientific and local knowledge should be spread to society through educational campaigns

Number of participants: Questionnaire on drivers of change = 35, Workshop =55, TOTAL (counting each individual just ones) = 66.

Table 2 Total mean carbon storage per hectare and plant richness values expressed as the total number of native vascular plant species per forest type. The dominant species in each forest system type are shown in parenthesis. Values are mean±standard deviations.

Forest system	**Mean Total Carbon (tC.ha-1)**	**Plant richness values**
Beech forest (*Fagus sylvatica* L.)	212.75 ± 12.33	73
Mixed oak forest (*Quercus robur* L.)	195.17 ± 14.67	79
Cantabrian green oak forest (*Quercus ilex* L.)	151.65 ± 13.78	72
Coniferous plantations (*Pinus radiate* D. Don)	139.70 ± 15.71	61
Eucalyptus plantations (*Eucalyptus globulus* Labill.)	220.98 ± 10.97	30
Natural forest	187.94 ± 24.44	77 ± 3.79
Forest plantations	147.10 ± 27.96	54 ±21.92

Table 3 GLM summary statistics for biodiversity indicators: number of threatened animal species and number of total vertebrate species at the Biscay County. a) Natural forest *vs.* forest plantations; and b) different forest types considered.

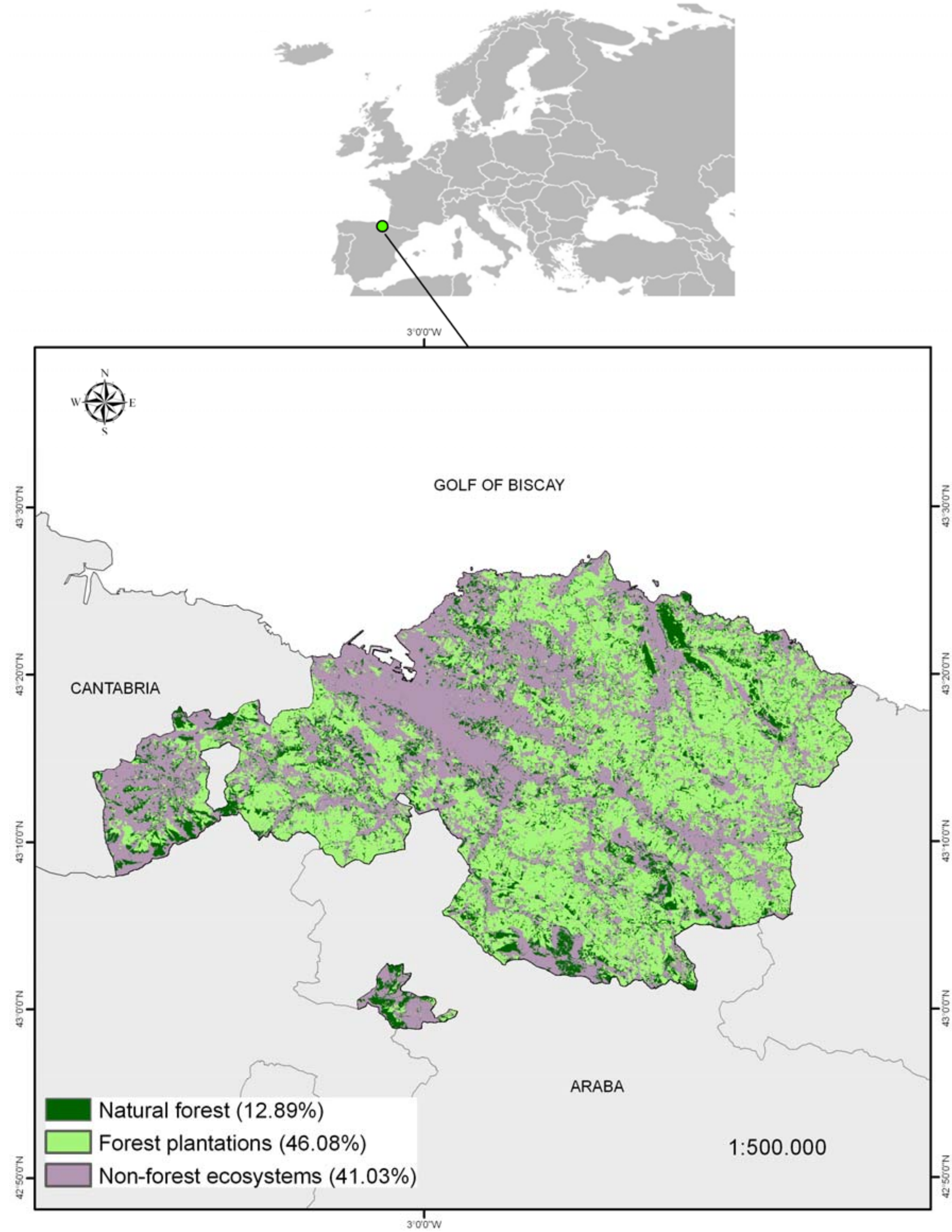
Independent variables	Number of threatened animal species			Number of total vertebrate species		
	Estimate ± SE	z-value	p-value	Estimate ± SE	z	p
a)						
Intercept	2.73 ± 0.21	13.00	<0.001***	4.82 ± 0.09	53.89	<0.001***
Natural forest	4.81 ± 1.33	3.62	<0.001***	1.25 ± 0.58	2.14	<0.032**
Forest plantations	-0.32 ± 0.27	-1.19	0.234	-0.14 ± 0.11	-1.26	0.207
b)						
Intercept	2.45 ± 0.43	5.69	<0.001***	4.73 ± 0.17	27.54	<0.001***
Mixed oak forest	0.07 ± 0.04	1.86	0.063	2.09 ± 1.46	1.43	0.154
Cantabrian green oak forest	0.042 ± 0.02	2.48	0.013*	0.83 ± 0.74	1.12	0.263
Beech forest	0.07 ± 0.02	2.98	0.003**	2.28 ± 1.12	2.03	0.042*
Coniferous plantations	-0.01 ± 0.01	-0.20	0.839	-0.07 ± 0.14	-0.47	0.639
Eucalyptus plantations	0.01 ± 0.01	0.98	0.326	0.13 ± 0.56	0.24	0.812

SE = Standard Error. Significant at *p < 0.1, **p < 0.05, ***p < 0.01.

Figure Caption

Fig. 1 Location of the study area and percentage cover of natural forest and forest plantations. Natural Forest includes mixed oak forest (8.21% of the total 2,217 km^2 surface), Cantabrian green oak forest (2.18%) and beech forest (1.74%). Forest plantations include conifer (38.63%) and eucalyptus (3.87%) plantations. Broad-leaved plantations (3.56%) and riparian forests (0.76%) were excluded from the analysis due to a lack of plant richness data in the region for these forest systems.

Figure



3°0'0"W
N
W
E
S
GOLF OF BISCAY
43°30'0"N
43°20'0"N
43°10'0"N
43°0'0"N
42°50'0"N
CANTABRIA
ARABA
Natural forest (12.89%)
Forest plantations (46.08%)
Non-forest ecosystems (41.03%)
1:500.000

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