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Ecological landscape assessment in a silvicultural system in the Urdaibai Reserve (Basque Country, Spain)

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Abstract. Forestry industry has transformed deciduous Cantabrian colline landscape from very diverse ecosystems into exotic monospecific *Pinus* spp. or *Eucalyptus* spp. tree plantations. Our aim was to determine the biological quality present at a forested and protected river basin based on vascular plant communities' field examination and cartographic and aerial information analysis. We have transformed vegetation maps into biological quality maps, readily interpreted in terms of conservation state for land management. We have tested the index along an anthropized but protected area in the Atlantic Iberian Peninsula (Urdaibai Biosphere Reserve –and Natura 2000 site, Basque Country) individually assessing 158 vegetation fragments included in ten quadrats of 25 ha each. A comparison of land use distribution between exotic coniferous plantations and native forests showed a ratio ~11:1, and *Quercus robur* native forests have been fragmented and reduced to small patches, mostly below one ha (73.7% of fragments). The ratio real to potential cover revealed occupation below 8% of potential territory, confined to altitudes and slopes over 200 m asl and 30% respectively. Mean biological value of the basin (38.4% of maximum) correlated to conifer plantation surface and native forest emerged as the only vegetation unit attaining index values above 50%. A quantitative approach to determine whether local lowland oak forest could be considered at favourable conservation status involved studying co-variation between index values and fragment size by means of asymptotic models that would provide a maximum expected biological value associated to a minimum required surface (72.9% for ≥2.5ha). We have obtained the highest index values (77.1%) for forest patches ≥5.0 ha, although fragments over that threshold accounted for barely 2.9% of the basin. Oak forests are far from showing a favourable conservation status, revealing that actual protection policies provide little shelter to native forest where silvicultural policies rule the landscape.
Keywords: applied phytosociology; Atlantic region; favourable conservation status; biological value index; landscape assessment; *Quercus robur* woodlands.

Evaluación ecológica del paisaje en un sistema silvicultural de la Reserva de la Biosfera de Urdaibai (Euskadi, España)

Resumen. La industria forestal ha transformado el paisaje caducifolio del piso colino formado por ecosistemas muy diversos en plantaciones monoespecíficas de árboles exóticos de los géneros *Pinus* spp. o *Eucalyptus* spp. Nuestro objetivo ha sido determinar la calidad biológica presente en una cuenca forestal antropizada y protegida, en la Península Ibérica Atlántica (Reserva de la Biosfera de Urdaibai, sitio Natura 2000, País Vasco) basada en el análisis de las comunidades vegetales y el análisis de información cartográfica y aérea. Hemos transformado los mapas de vegetación en mapas de calidad biológica, que pueden ser rápidamente interpretados en términos de estado de conservación en aras de una gestión territorial. Hemos testado el índice a través de 158 fragmentos de vegetación incluidos en diez cuadrantes de 25 hectáreas cada uno. La comparación de la distribución del uso entre plantaciones de coníferas exóticas y bosques nativos autóctonos mostró una proporción de 11:1, los bosques nativos de *Quercus robur* se encuentran en un estado fragmentado y reducido a parches pequeños donde los robledales de Quercus robur han sido fragmentados y reducidos a teselas de pequeño tamaño, en su mayoría por debajo de 1 ha (73.7% de los fragmentos). La relación de la de cobertura real a potencial reveló una ocupación por debajo del 8% del territorio potencial, confinado a altitudes de 200 m y pendientes de más del 30%. El valor biológico medio de la cuenca (38.4% del máximo) correlación con la superficie de plantación de coníferas, mientras que el bosque nativo emergió como la única unidad de vegetación capaz de alcanzar valores de índice por encima del 50%. Un acercamiento cuantitativo para determinar bajas los robledales locales podrían considerarse en un estado de conservación favorable involucró el estudio de la covariación entre los valores del índice y del tamaño por medio de modelos asintóticos que proporcionarían un valor biológico máximo esperado asociado a una superficie mínima requerida (72.9% para ≥2.5ha). Hemos obtenido los valores de índice más altos (77.1%) para teselas de robledal ≥5.0 ha, a pesar de que los fragmentos de la tesela por encima de ese umbral representaron apenas el 2.9% de la cuenca. Los robledales están lejos de mostrar un estado de conservación favorable, lo que revela que las actuales políticas de protección brindan escaso refugio a los bosques nativos, donde las políticas de silvicultura gobiernan el paisaje.
Palabras clave: Fitosociología aplicada; Región Atlántica; estatus de conservación favorable; índice de valor biológico; estudio del paisaje; bosques de *Quercus robur*.

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Introduction

European timber production relies on old-growth or secondary forests management rather than plantations (San-Miguel-Ayanz *et al.*, 2011). In contrast with this conservative trend, present and recent past forestry practises at the Spanish Atlantic landscape are characterized by the substitution of native deciduous woodlands at the *colline belt* (lowlands below 600 m asl) by monocultures of exotic, basically coniferous and *Eucalyptus*, species. This transformation of lowland landscape affects mainly vicariant *Q. robur* forests, widely different from *Q. robur* habitats encountered elsewhere in Europe (Sainz Ollero *et al.*, 2010). Northern areas of the Iberian Peninsula represent the southern distribution boundary of European oak forests, where strong Mediterranean influence enriches biodiversity and confers to regional oak forests a higher degree of heterogeneity at intra- and inter-habitat level (Sainz Ollero *et al.*, 2010). Despite the ecological significance, European conservation policies fail to protect this complexity of habitats and leaves Spanish mixed *Q. robur* oak forest ecosystems out of the Habitat Directive (Rodà *et al.*, 2009). In this respect, woodland habitats found in Eastern Europe represent internationally protected biodiversity hot spots and, as acknowledged by Miklín and Čížek (2014), their situation is being compromised by timbering, the magnitude of the loss being mostly unknown, and perhaps unperceived. Given that *Q. robur* oak woodlands are main habitat of regional colline belt (e.g. Loidi *et al.*, 1997) and key for supporting local biodiversity (Atauri *et al.*, 2004), this exclusion renders the territory vulnerable to non conservative forestry management (e.g. Merino *et al.*, 2004; Schmitz *et al.*, 1998). In this context, providing quantitative assessment of regional biological value of the landscape would represent a base line for future conservation policies.

The design of survey procedures to conduct monitoring programs of ecosystem quality in quantitative terms remains an open subject (Louette *et al.*, 2015). Indeed, there are many nature conservation studies which measure community characteristics as a proxy for individual species and ecological processes (e.g. Ammer & Utschick, 1982; Bastian & Bernhardt, 1993; Bastian, 1996; Hernando *et al.*, 2010; Milder *et al.*, 2008; Penas *et al.*, 2005) as an alternative to measurement of species diversity. In our case, we have resorted to phytosociology, where plant communities and their relationships with the environment is taken into consideration (Rivas-Martínez, 2007). Criteria to measure biological value based on phytosociology have been employed for agricultural or agro-environmental schemes (Géhu & Géhu-Frank, 1981; Asensi, 1990; Herrera *et al.*, 2001; Lomba *et al.*, 2004; Loidi, 2008; Taffetani & Rismondo, 2009; Panitsa *et al.*, 2011; Peet & Roberts, 2013), or at forested landscapes in the Iberian Peninsula (Hernando *et al.*, 2010; Zapata & Robledano, 2014) or Central Europe (Bastian, 1996; Deixler, 1982, 1988). In fact, a large proportion of the European biodiversity is currently surveyed using the phytosociological approach (Mucina, 2013; Douda, 2010) and provides the grounds for the definition of habitats of European interest included in the Habitats Directive (HD) 94/93/ECC (Rodwell *et al.*, 2002).

A tool for measuring the degree of ecosystem conservation was initially developed by Loidi (1994) as a conservation interest index that was based upon vegetation units as observational units defined after syntaxa. The use of habitat types as vegetation units that gather several phytosociological syntaxa has been previously used at landscape classification (e.g. Bölöni *et al.*, 2007; Deixler, 1982; Milder *et al.*, 2008; Penas *et al.*, 2005) and the method recommended for landscape development planning and nature conservation management for excessively fragmented landscapes (Bölöni *et al.*, 2007). In this sense, Loidi's conservation interest index summarized phytosociological criteria applied originally by Seibert (1980) and Géhu & Géhu-Frank (1981) and it has been used in studies in Greece (Dimopoulos *et al.*, 1998; Boteva *et al.*, 2004), Atlantic and Mediterranean Spain (García-Baquero & Valle, 1998, Gómez-Mercado *et al.*, 2007; Loidi *et al.*, 2007; Meaza & Cadiñanos, 2000; Orrantia, 2004; Orrantia *et al.*, 2008; Sesma & Loidi, 1993) and Portugal (Lomba *et al.*, 2004).

In this study we have employed a simplified version of the initial biological quality index, relying exclusively on the parameters defining Biological value. We have tested it inside a lowland Biosphere Reserve and Natura2000 site, a river basin located at the interface between the coastal fringe and the mountain range in Atlantic North Spain (Bizkaia province). Our working hypothesis has been that assessing a protected territory under presumably moderate anthropic pressures, we could define a local biological quality maximum to compare with areas with different degrees of degradation. The main goal has been the definition of a threshold for a functional forest surface associated to maximum local conservation status. For this purpose, we have analysed the topographic distribution of vegetation, characterizing the main vegetation units. Then, we have assessed the overall biological value throughout a phytosociological index. The vegetation types were compared with topographic predictors and maps of potential vegetation. We have also studied the index resolution as a useful quantitative tool for the evaluation of the conservation status of woodlands as the main potential habitat.

Methods

We have evaluated the biological quality of those main vegetation units found at a territory applying a method based on the inspection of floristic composition of vegetation patches and referring the vegetation encountered to a habitat type and related it to phytosociological classes or alliances. We have followed available phytosociological description for the Iberian Peninsula (Loidi *et al.*, 1997; Rivas-Martínez, 2007; Rivas-Martínez *et al.*, 2011). Field data, vegetation and topographic maps and field and aerial photographs have been used to assess ecological factors such as fragment size, elevation, inclination or slope gradient (hereafter slope) and slope direction (hereafter aspect). The topographic context of the survey was not included in the index but has been used to explain the index variability related to landscape factors.

Study area

The field study took place at the Golako River (3462 ha), a narrow and long basin (a funnel form between 1.7 and 6.0 km width x 10.5 km long), located in Bizkaia province, Basque Country, Spain (between 43º12'–43º28' N and 2º33'–2º46' W). Golako river course (15 km) is part of Natura 2000 European Network (code SAC-ES2130006) and the whole catchment is included in UNESCO Urdaibai Biosphere Reserve, protected since 1984. Its biogeographic location is within the Eurosiberian region, at the eastern sector of the Cantabrian-Atlantic subprovince. Slope average is 38%, and elevation 1-776 m asl, with an average of 225 m. Annual average temperature is above 13ºC and annual precipitation average ranges between 1500 and 1700 mm, with soft rain all year long, maximum intensities occurring during May and July (AEMET). Local climatophilous forests are acidophilous and mesophytic pedunculate oak (*Q. robur*) forests related to low altitude (0-500 m asl), moderate slope (mean 15%) and high minimum temperatures of the coldest month (mean 9.6ºC; Roces-Díaz *et al*., 2014). The whole area is formed by Cretaceous materials, mostly sedimentary such as marl, flysch, sandstone and limestone, with some intrusions of volcanic rocks of submarine Cretaceous eruptions.

Biological value index

Biological value (B) is estimated on the basis of five descriptors: Naturalness (N), Resilience (P), Threat (T), Floristic value (F) and Rarity (R).

$$B = N + P + T + F + R \quad (1)$$

According to Loidi (1994, 2008), Naturalness (N) should be understood as the degree of human influence in terms of distance to climax (see Machado, 2004 for a thorough review). Resilience (P) is the capability of a vegetation type to recover itself after disturbance by nature or humanly induced causes. Threat (T) is related to various factors associated to human socioeconomic circumstances of a given territory. Floristic value (F) is the specific diversity of the formation or phytosociological diversity, and includes the vegetation structural diversity, the particular relationships between organisms and the content of endemic flora or syntax. Rarity (R) is the average distance between the spaces in which a species or vegetation type occurs within a phytogeographical context. Each parameter scales from 0.0 to 10.0 resulting in a biological quality (B) index ranging between 0.0 (no vegetation) and 50. With the exception of Rarity, whose value depends on distances between syntaxa, every descriptor was accorded a maximum theoretical value in order to reduce arbitrary valuation, and vegetation description was done at phytosociological alliance or class level (Table 1). It is out of the scope of this contribution to depict the index and the assessment methodology (for a detailed description see Loidi 1994; Loidi *et al*., 2007; Orrantia *et al*., 2008) although we would further briefly clarify several facets related to fieldwork.

Vegetation units

We identified the vegetation units (VU) of the area adopting the main typology from the Vegetation Map of the Autonomous Community of the Basque Country (see websites) and adapted it to phytosociological typology described by Loidi *et al*. (1997) and Rivas-Martínez *et al*. (2011). Table 1 shows ten different vegetation units which accounted for the variety of ecosystems present at the catchment: hygrophilous forest (RF), climatophilous broadleaved deciduous forests (mature –MF– and degraded –DF–), heathlands (HT), meadows (MD) and coniferous (PP), eucalypt (EP) and deciduous (BP) plantations, rural areas (RA) and no vegetation (NV). Each vegetation unit was defined and described its general abiotic factors, general appearance and structure, characteristic species of the habitat and cited phytosociological classes or alliances belonging to it (in concordance with Böloni *et al*., 2007). The homogeneity of the vegetation units encountered simplified description and standardisation processes.

Semi-natural oak wood (*Q. robur*) patches encountered in the plots were given special interest and after inspection we identified mesophytic oak forests (*Polysticho setiferi-Fraxinetum excelsioris* climatophilous association, EUNIS class G1.A1) and acidophilous oak forests (*Hyperico pulchri-Quercetum roboris* climatophilous association, EUNIS class G1.86). Later, one best-preserved forest fragment was labelled as mature forest (MF), in order to have an approach to real basin's maximum obtained from field work and to test it against theoretical predictions. At last, analysis of GIS data led us to consider EUNIS classes G1.A1, G1.86 and G5.61 (Table 1) under the term of degraded forest (DF). In the text we will name mesophytic or acidophilous oak forests referring only to above mentioned associations and EUNIS classes related to *Quercus robur* L. (pedunculate oak). A ratio between real vegetation and potential natural vegetation (PNV) was used in order to have an estimate of risk. Ten samples below 0.04 ha were inspected, disregarded as being considered a forest and were included within the VU they were associated to (especially to RA) and therefore slightly incrementing the biological value of these patches. Two of these samples have been included in the model (forest biological value vs. patch size) as a sample in order to have a minimum.

Fieldwork procedures

The catchment's altitudinal distribution gathers 46.20% of the territory between 100 and 250 m asl, with a maximum at 150-170 m asl. We followed this altitudinal gradient and used a spatially explicit sampling design to obtain ten quadrats as research plots (500 x 500 m) of 25.0 ha each located along a mountain stream with its river forest. Survey methods and procedures applied in this work were conditioned by the fact that every vegetation unit appearing within the study area should be represented at the selected plots. This conception, required to make results extensive to a wider territory, introduced an initial bias in the sampling pattern. The sum of all plots represented 7.5% of the total basin.

Table 1. Vegetation types encountered at Golako plots. Phytosociological description of vegetation units and crosswalk between them and EUNIS habitat classification. Several syntaxa present at the basin within heaths, meadows and plantations are not represented in plots.

VU	Vegetation Unit	Syntaxa	EUNIS code	EUNIS description
MF/DF	Mature/ Deg. forest	*Polysticho setiferi-Fraxinetum excelsioris* (*Pulmonario longifoliae-Quercion roboris*)	G1.A1	Atlantic mesophytic *Quercus robur* oak woodland
DF	Degraded forest	*Hyperico pulchri-Quercetum roboris* (*Quercion pyrenaicae*)	G1.86	Acidophilous *Quercus robur* oak woodland
		∅	G5.61	Juvenile broad leaved native woodland
RF	Riparian forest	*Hyperico androsaemi-Alnetum glutinosae* (*Alnion incanae*)	G1.21(Z)	Ash/alder alluvial forests (*Alnus glutinosa*)
HT	Heathland	*Teucrio pyrenaici-Genistetum occidentalis* (*Genistion occidentalis*)	F7.44(Y)	Endemic oro-Mediterranean heaths with gorse
MD	Meadow, pasture	*Lino biennis-Cynosuretum cristati* (*Cynosurion cristati*)	E2.11	Unbroken pastures
		Arrhenatheretum elatioris (*Arrhenatherion elatioris*)	E2.21	Atlantic lowland hay meadows
PP	Coniferous plant.	∅	G3.F(L)/ G3.F(M)/ G3.F(P)	*Pinus sylvestris*/ *Pinus pinaster*/ *Pinus radiata*
			G3.F(S)/ G3.F(T)/ G3.F(Y)	*Larix* sp./ *Chamaecyparis lawsoniana*/ Other conifers
			G5.74	Early-stage coniferous plantations
			G5.82	Recently felled areas, formerly coniferous trees
EP	Eucalipt plantt.	∅	G2.81	Broadleaved evergreen trees
			G5.73	Early-stage broadleaved evergreen plantations
			G5.81	Recently felled areas, formerly broadleaved evergreen trees
BP	Deciduous plant.	∅	G1.C(Y)	Other broadleaved deciduous plantations (*Q. rubra*)
RA	Rural area	∅	E5.6/ H5.6/ I1.2/ I2.2/	Anthropogenic vegetation, orchads and artificial grasslands
			J1/ J2/ J4.1	Towns and vegetation related to roads
			FB.4	Vineyards
			G1.D(X)	Fruit and nut tree orchards
NV	No vegetation	∅	J4.2	Road networks

Once all vegetation units were identified, we detected every vegetation patch within a given plot in aerial photographs and quantified their surface area. The steepness of the area required intensive fieldwork in order to identify the various patches of different vegetation types appearing on each plot. Each patch was identified by a code, which described the plot (e.g. P3), the vegetation unit (e.g. RF) and the number of the patch within that plot. The code "P3RF02" corresponds with the patch number 02 of the vegetation unit Riparian Forest within the plot P3. A database of 350 digital photographs was built for further identification. Later, all tracts and patches were detected in aerial photographs and their surface area quantified. A file was created including real (EUNIS) and potential vegetation (Series vegetation map; Loidi *et al*., 2011) and topographic (LIDAR) maps as well as aerial information (see websites). When available, we consulted earlier and later topographic maps (2001 and 2011, scale 1:10 000) and former aerial information (1996, 1999) in order to trace evolution of land properties: i.e. recently harvested for timber with no or very little vegetation cover left. Afterwards, we revised again in the field and data were corrected where needed. The minimum mapping unit size for a patch was 0.04 ha.

We based field study on the inspection of the floristic composition found at the ten quadrats. Within the field we visited and assessed every patch and gave a value between 0 and 10 for each of the five parameters (N, P, T, F and R) for each patch considering biological and ecological characteristics gathered in the field. We analysed biological values attained for each patch and summed all patches within the plot. Since total plot's size was 25 ha, plot's B was the sum of (B*S)/25 for every patch within the plot, $B_{plot} = \Sigma^{n}_{i} (B_{i\ patch} * Size_{i\ patch} / 25)$. Results were structured according to group (vegetation units, EUNIS class and Syntaxa) in terms of patch cover (% or hectares) and biological value (unit less). For the later, a crosswalk between different habitat classification systems was developed, linking present vegetation units with a syntaxonomical class or alliance and with a EUNIS habitat class (after Loidi *et al*., 2011 and Rodwell *et al*., 2002; Table 1).

GIS and Statistical analyses

The first approach to computerized cartography was undergone by vector drawing (gvGIS). Then we used QuantumGIS program for the Digital Elevation Model (DEM) analysis. Table 2 summarizes elevation, slope and aspect cell values, and elevation and slope means and standard deviation (SD) values and aspect frequencies for each plot. In the comparison of patch surface and plot's topographic factors (slope, elevation) for every rural and forest patch within the plots (Figure 1) we used mean values obtained after 625 cells/plot as plot altitude/slope data and mean values for each VU as patch size data. Aspect data were reclassified according to exposure to cold weather (according to García *et al*., 2005): northern, 316-45º, eastern, 46-135º, southern, 136-225º, and western, 226-315º; then we calculated frequency observed at each plot for the four exposition of all vegetation units and of forest DEM cells.

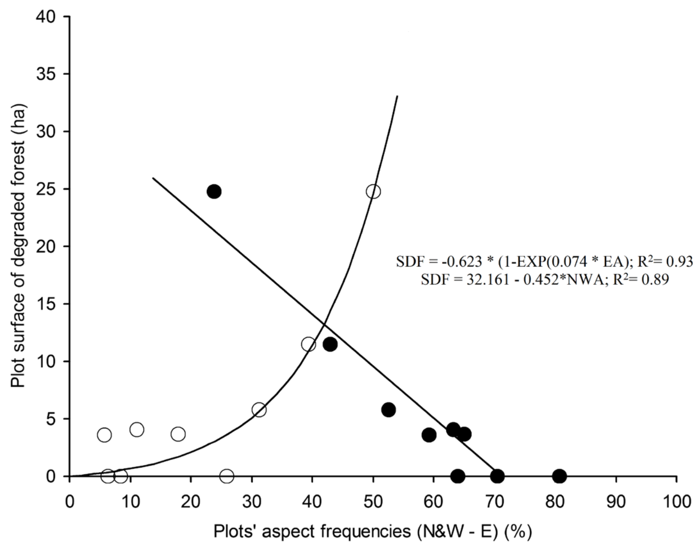

Figure 1. Aspect analysis: DEM aspect data reclassified into four quadrants related to exposure to cold weather: northern (316-45º), eastern (46-135º), southern (136-225º), western (226-315º) and each quadrant frequency for each plot obtained. Degraded Forest plot surface (%) vs. eastern (open circles) and northern & western (solid circles) aspect frequencies; Equations are shown.

Basin and plots topographic information (histograms and ANOVA) had been processed using R (altitude and slope means and SD; Table 2). We applied ANOVA (Tukey/Kramer) and ANCOVA tests to analyse differences in size for the different vegetation units in relation to topographic factors (altitude and slope). Degraded forests most frequent aspects within the plots (n) were studied after chi square test. Later, frequency analysis of the four expositions (%) was revised after ANOVA to find significant plot aspect frequencies related to patch size. We used statistical package STATVIEW 5.0 for Chi Square independence test and linear regression analysis. Non-linear regression procedures were performed with MYSTAT 12 version 12.02.00 for Windows (SYSTAT software, Inc.).

Table 2. Number of patches and surface cover (bold type, %) and topographic values (mean±SD) for each vegetation unit at each of the ten plots, plots' total and whole Golako basin's (column Basin) data obtained after field work and GIS analysis of the Vegetation Map of the Autonomous Community of the Basque Country (see websites). Topographic units are Altitude (m asl), Slope gradient (%) and Aspect (direction, highest frecuency).

		Number of patches (N)/ surface (P, %)																							
	VU	N1	P1	N2	P2	N3	P3	N4	P4	N5	P5	N6	P6	N7	P7	N8	P8	N9	P9	N10	P10	10 Plots		Basin	
Vegetation unit																									
Coniferous plantation	PP	1	**(86.5)**	5	**(12.7)**	8	**(44)**	5	**(90.6)**	8	**(64)**	1	**(32.9)**	2	**(79.4)**	4	**(95.4)**	6	**(47.1)**	6	**(43.8)**	46	**(59.8)**	347	**(66.2)**
Eucalypt plantation	EP	4	**(11.7)**	.	.	1	**(2.6)**	2	**(8.2)**	3	**(11.5)**	.	.	.	.	.	.	5	**(13.2)**	.	.	15	**(4.7)**	72	**(5.5)**
Broadleaf Plantation	BP	.	.	.	.	.	.	.	.	1	**(2)**	.	.	.	.	.	.	.	.	.	.	1	**(0.2)**	66	**(1.4)**
Mature forest	MF	.	.	.	.	1	**(3.66)**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	**(2)**	72	**(5.3)**
Degraded forest	DF	.	.	2	**(3.7)**	3	**(20)**	.	.	3	**(11.5)**	2	**(4.5)**	2	**(3.6)**	.	.	2	**(20.3)**	4	**(33.9)**	18	**(8.1)**	98	**(2.91)**
Rural area	RA	.	.	4	**(27.8)**	6	**(15.8)**	.	.	2	**(5.2)**	4	**(13.8)**	3	**(4.8)**	2	**(2.8)**	1	**(1.8)**	3	**(4.9)**	25	**(7.7)**	195	**(2.43)**
Meadow, pasture	MD	.	.	6	**(51.8)**	5	**(9.8)**	.	.	3	**(4.6)**	4	**(47.8)**	3	**(10.9)**	2	**(1.7)**	2	**(10.9)**	2	**(4.8)**	27	**(14.2)**	169	**(12)**
Heather	HT	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	**(7)**	2	**(0.7)**	78	**(2.3)**
Riparian forest	RF	1	**(1.7)**	2	**(0.5)**	3	**(1.2)**	3	**(1.2)**	.	.	4	**(0.3)**	2	**(0.3)**	1	**(0.2)**	1	**(4.5)**	2	**(1.2)**	19	**(1.1)**	24	**(1.3)**
No vegetation	NV	.	**(0.1)**	.	**(3.4)**	.	**(3.1)**	.	.	.	**(1.1)**	.	**(0.8)**	.	**(1)**	.	.	.	**(2.2)**	.	**(4.4)**	.	**(1.3)**	.	**(0.57)**
Tot no. of patches/plot		6		19		27		10		20		15		12		9		17		19		154		1121	
Mean±SD																									
Altitude		191.9	39.9	47.3	11.9	93.2	16.9	174.4	30.9	127.0	21.3	117.1	11.0	179.4	20.2	186.5	25.0	301.0	46.2	389.2	35.9	180.7	99.3	224.7	128.3
Slope		43.2	16.0	16.8	16.8	33.1	20.3	45.2	19.3	30.1	13.8	19.1	13.1	29.1	13.0	40.1	16.7	47.7	17.0	47.1	18.1	35.2	19.7	37.9	19.0
Aspect		W 58.24		W 45.28		E 37.92		E 37.92		E 39.36		S 31.2		W 34.72		E 45.92		N 49.92		W 39.52					

Results

Characterization of the country

GIS analysis of vegetation unit distribution in the basin (Table 2) showed that only 23.8% of the area was covered by semi-natural units (in brackets catchment VU distribution in %): meadows (12.0%), heaths, ferns, gorses, brambles or native hedgerows (2.3%) and forests (9.5%). Main representative of native forests were *Quercus robur* forests (0.3% mesophytic and 5.0% acidophilous) followed by a group of highly degraded forest patches defined by EUNIS as juvenile broad leaved forests (2.9%), and *Alnus glutinosa* and *Fraxinus excelsior* alluvial forests (1.3%). Silviculture was the main land use (73.2%) consisting largely on a monoculture of introduced non-native evergreen coniferous species (mainly *Pinus radiata, P. sylvestris* and *P. pinaster*), some blue-gum eucalypt (mainly *Eucalyptus globulus* 5.5%), and other deciduous plantations (1.5%). Rural areas covered 2.4% of the basin and above 200 m asl semi-natural vegetation cover decreased to 16.4% along with an increment of coniferous plantation cover to 82.2%.

In contrast, potential natural vegetation map (see Websites) exhibited the following landscape distribution: 5.9% represented by ash/alder alluvial forests, 30.1% and 63.8% by Atlantic mesophytic and acidophilous oak forests respectively, and 0.1% corresponding to Atlantic acidophilous beech forests. Mesophytic forest would be expected primarily below 200 m asl (76.9%) occupying 48.3% of the lower basin, whereas acidophilous forests would appear basically above 200 m asl (70.2%) covering 86.0% of the higher basin. A comparison in terms of real to potential cover ratio yielded 0.9% for the mesophytic forest and 7.8% for the acidophilous wood, globally representing 5.6% of the potential cover.

The influence of the topographic profile upon major vegetation units in the area (Table 3) was highly significant for Degraded Forests that appear mainly at higher slopes (>40%) and altitudes (250-450 m asl) whereas significance for meadows was restricted to slope (found largely between 15-20%) and conifer plantations covariate with elevation increasing between 175 and 225 m asl while no effects were evident for rural areas (Tukey/Kramer).

Table 3. ANOVA analysis of patch surface (percentage of DF surface at plot, plots mean ± SE) in various vegetation units taking plot's elevation (m asl) and slope (%) as factors: Rural areas (RA), Meadows (MD), Degraded Forest (DF) and Conifer Plantations (PP). F-value, P-value and Tukey/Kramer (T/K) significance are given (NS= not significant).

		Cat 1	Cat 2	Cat 3	*F-value*	*P-value*	T/K
RA	Slope	20.80 ± 7.00	8.60 ± 3.60	3.167 ± 0.913	5.226	0.0596	NS
	Elevation	15.65 ± 4.66	3.80 ± 1.00	3.35 ± 1.55	2.732	0.1579	NS
DF	Slope	4.75 ± 1.05	6.40 ± 2.55	28.15 ± 3.35	22.596	0.0066	S(1-3)(2-3)
	Elevation	6.28 ± 1.80	3.60 ± 0.00	28.15 ± 3.35	23.582	0.0061	S(1-3)(2-3)
PP	Slope	22.80 ± 10.10	62.47 ± 10.25	72.06 ± 11.59	3.49	0.09	NS
	Elevation	38.40 ± 10.71	87.98 ± 3.39	43.90 ± 0.90	12.716	0.0047	S(1-2)(2-3)
MD	Slope	49.80 ± 2.00	8.43 ± 1.94	4.35 ± 2.40	90.25	<0.0001	S(1-2)(1-3)
	Elevation	28.50 ± 12.37	4.20 ± 3.39	7.85 ± 3.05	1.833	0.2392	NS
Categories		1	2	3			
Elevation	(m asl)	30-150	175-225	250-425			
Slope	(%)	15-20	25-35	>40			

Frequencies of appearance of every cardinal point in each plot were computed (DEM analysis) and taken as predictors of degraded forest cover dynamics. Later, plot surface was related by means of exponential and linear regression lines to plot aspect frequencies (Figure 1). Forest surface (%) raised exponentially associated to increased proportion of ground eastern orientated in every plot (R^2= 0.93) whereas an opposite linear trend described the negative influence of combined frequencies of northern and western aspects (R^2= 0.89).

Analysis of the contribution of descriptors to Biological value Index in the vegetation units

In order to analyse individual influence of the 5 additive descriptors in the final Biological value (B) of the various individual plots in the different vegetation units we have individually correlated every descriptor against the remaining. This procedure has been undertaken in every vegetation unit with the objective of discarding redundancy providing sample size (i.e. number patches per unit) allowed a robust analysis. Consequently, Broadleaf plantations and Mature Forest (1 single patch for each one) and Heath (two patches) have been excluded from the analysis. Sample size consisted in 25 points for DF, 19 for RF, 14 for EP, 62 for PP, 27 for MD and 25 for RA. No correlation was found (p>0.05) for any of the paired combinations of Naturalness (N), Resilience (P), Threat (T), Floristic value (F) and Rarity (R) in the cases of Degraded forest (DF), Riparian Forest (RF), Eucalypt plantations (EP) and Pine Plantations (PP). However, significant correlations have appeared for meadows ($p<0.001$) between N and P, T or F and between P and T or F, and between T & F and also for rural areas ($p<0.001$) between N and T and P and T. These results imply 8 positive correlations out of 60 combinations, basically regarding meadows. So, we have proceeded analysing Vegetation Units in terms of Biological value Index (B), focusing on the analysis of the forest and plantations.

Analysis of distribution and Biological value Index (B) of Vegetation units

As a general result, only forests (degraded, mature and riparian) presented biological quality values above 25 (50%). The maximum value was attained by a single mature forest patch present at P3 (43.0) followed by riparian forests with values that ranged between 39.0 and 43.0 and mean biological value of 40.5 (Figure 2). Detailed analyses of Degraded Forest biological value will be dealt with in next subsection "Biological value index in woodland landscape". The remaining units (heaths and meadows) showed values between 8.0 and 20.5. Meadows, despite a relatively higher distribution (14.2%), had low and very homogeneous biological values (mean B =15.1 ± 2.9). Tree cultures (conifers, eucalypt and deciduous) showed values lower than 9.5, along with rural areas where green gardens and orchards were included improving their evaluation.

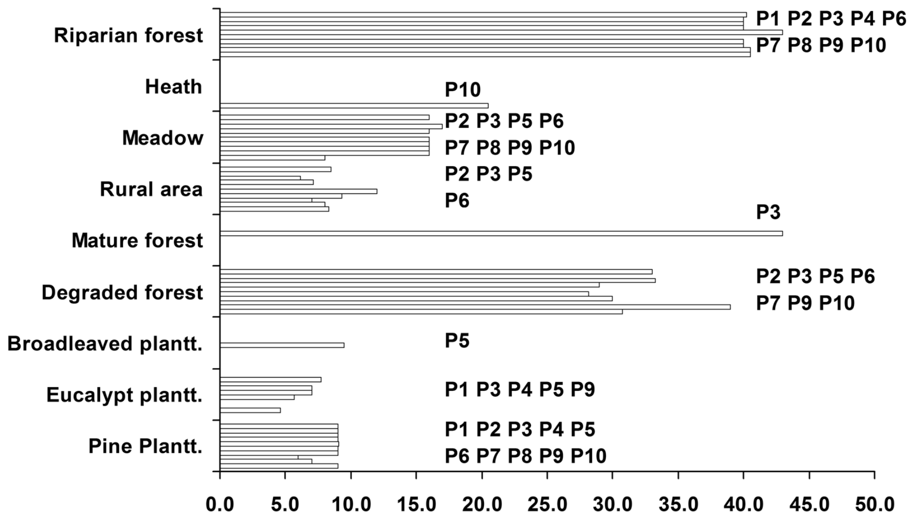

Figure 2. Bar plot of biological value index for each vegetation unit inspected at the Golako river basin.

Coniferous plantations appeared as the main factor explaining B mean plot values -B_{plot}- (Figure 3) and a negative correlation between B_{plot} and proportion of coniferous surface per plot (S_{PP} %) was found (ANOVA P-value = 0.003). A linear regression equation of B_{plot} vs. relative figures of coniferous surface per plot (S_{PP} %) showed that lower B_{plot} values were attained at increasing conifer plantation (p_{slope} = 0.0046). Estimations for the intercept were highly significant ($p_{intercept} < 0.0001$) predicting maximum mean B_{plot} value of 38.2% at coniferous cover of 0% (Figure 3a). Conversely, a positive correlation ($R^2 = 0.78$) appeared between B_{plot} values and total number of fragments per plot (Figure 3b).

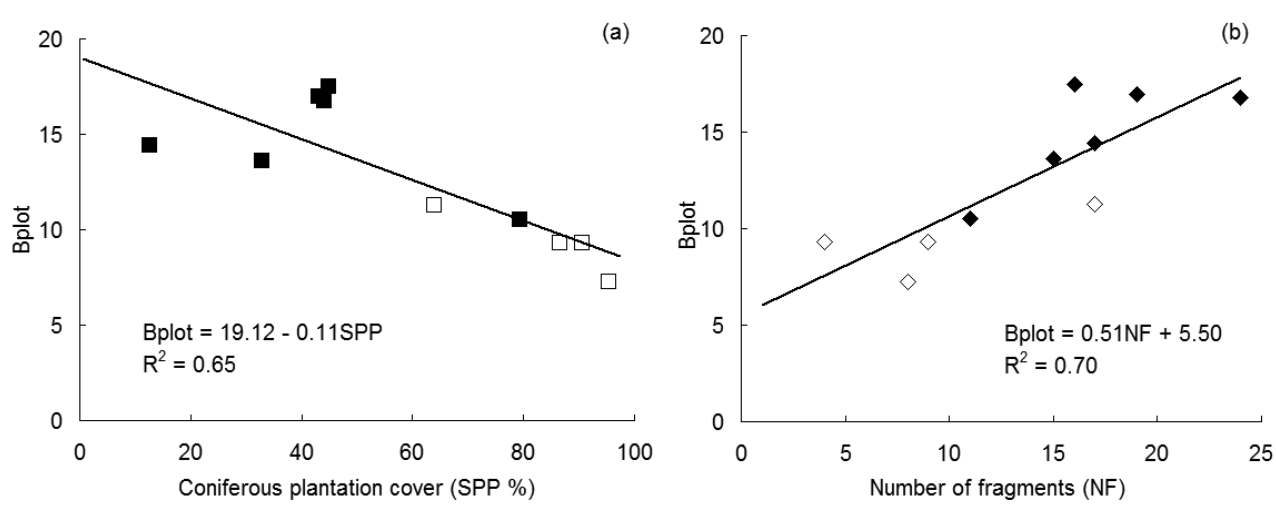

Figure 3. Linear regression analysis between mean biological value index attained per plot (Bplot) and (a) coniferous plantation cover (SPP%) or (b) number of fragments (NF, n). Open squares indicate absence and black ones presence of consolidated dwelling (more than 3 inhabited houses). Equations are shown.

Biological value index in woodland landscape

Gradual discrimination was registered only for forest patches. ANOVA analysis of percentual contribution of individual descriptors to B with surface as a covariate showed differences between descriptors to be highly significant, as well as the interaction of surface with the descriptors ($p<0.0001$ in both cases). Mean values were 12% for Rarity, 19% for Threat, 21.2 % both for Floristic value and Resilience and 26.6% for Naturalness. The degraded forest set (n=25) presented high B variability associated to different degrees of conservation that followed a continuum between 8 and 43.0 (including the mature forest single patch) standing for 16% to 86% rating as related to maximum B index (50). Forest patches within plots (n = 26, DF and MF) exhibited wide variability in terms of surface (from 0.04 to 6 ha) though 80.7% of those patches (n=21) had a size below 1.0 hectare accounting for 32.1% of oak forest total cover within the plots.

In an attempt to verify whether the patch extension had exerted any influence upon B evaluation, we initially examined the relationship between B index and patch size (DF surface, ha) for the degraded deciduous forest unit for those patches below one hectare. We obtained an asymptotic non-linear regression equation (eqn. 1) that provided an estimation of the maximum B attained (Figure 4a), where figures in brackets represent Wald 95% confidence interval:

(1) $$\text{Oak forest Biological value (below 1 ha)} = 31.56\ (\pm 3.37)\ (1\text{-}\exp^{(-16.44\ (\pm 9.87)\ \text{SDF})});\ R2_{\text{Mean corrected}} = 0.92\ \ n=21$$

Estimated value for saturation parameter (31.56) appeared significant (Asymptotic Standard Error = 0.79) and the model explained 92% of experimental variation. With upper cover been set at one hectare, minimum forest patch size required to reach maximum B was one hectare.

Since we had observed that similar size patches enclosed in different plots had in fact ranked different in terms of B, having those patches that had continuity outside it (larger real surface) attained higher biological values, we decided to analyse complete fragments instead of sections within the plot, including area outside the plot when necessary. Further, in order to be able to scale results to the whole basin we needed to increase resolution over 1 ha (only 5 fragments between 1 and 5.8 ha) so we extended our evaluation of B to a larger proportion of basin patches, underrepresented at plot scale (Figure 4b). This involved analysing 36 complete fragments (upper end 17 ha) and every fragment over 4.5 ha present in the basin was studied (n=8). As a consequence 56% of total catchment's forest surface was surveyed.

A set of seven points ranging from 0.7 to 9.5 ha appearing in Figure 4b exhibited a common B regardless of surface (Mean = 32.0; variation coefficient = 0.02): they represented areas formerly felled and fired for cattle (active nowadays) in a continuous secondary growth forest state and have been excluded from the analysis.

$$\text{Oak forest Biological value (plot)} = 36.43\ (\pm 2.29)\ (1\text{-}\exp\ (-6.97\ (\pm 2.43)\ \text{SDF})) \quad (2)$$

$$R^2_{\text{Mean corrected}} = 0.88,\ n=29$$

At catchment scale, asymptotic maximum increased related to inclusion of cover areas over one hectare, and maximum B value (36.4) was set > 2.5 ha. Variance explained by the model was 88.0% with higher level of significance of asymptotic maximum B (ASE= 1.12) and wider range of variance of the independent variable (from 0.03 to 17.2 ha). This result was linked to apparent minor differences in terms of B values within range 0-3 ha. As an alternative, we ranked dependent variable (B) in three categories - (a) below one hectare, (b) one to three hectares and (c) above five hectares - and performed Tukey/Kramer test (Table 4). Significant differences between fragment sizes categories (p= <0.0001) appeared.

Table 4. ANOVA and Tukey/Kramer results for the analysis of degraded forest biological index values (B index, mean ± SE) with forest patch size (S, mean ± SE). Patch size categories are similar to those in Table 3. (df, degrees of freedom; T/K, Tukey/Kramer).

	Cat a (<1 ha)	Cat b (1-3 ha)	Cat c (>5 ha)	F-value	P-value	T/K	n	df
B index	29.73 ± 0.91	33.44 ± 1.02	38.55 ± 1.15	19.91	<0.0001	a≠b≠c	(11,8,10)	2

All descriptors included in the index formula showed very significant effects upon B (Table 5), although resilience showed a slightly lower P-value (0.011). In fact, R^2 of every variable except resilience showed values over 0.6, while the later was 0.32. Intercepts for naturalness, resilience and threat had no significance, simplifying equation to y = bx.

Table 5. Linear regression equations of Biological index vs. individual descriptors. (a) intercept coefficient and (b) is slope. When the elevation is not significant the equation y = bx is shown.

	a	b	P-value	P-value(a)	R^2	F	b (a=0)	R^2	Equation
Naturalness	0.36	3.82	<0.0001	0.953	0.63	29.17	3.78	0.99	B= 3.78*N
Resilience	-3.00	5.23	0.0110	0.807	0.32	8.148	4.78	0.99	B= 4.78*P
Threat	7.52	4.00	<0.0001	0.055	0.72	44.04	5.23	0.99	B= 5.23*T
Floristic value	11.59	2.98	<0.0001	0.002	0.71	42.1			B= 11.59+ 2.98*F
Rarity	23.39	2.06	<0.0001	0.000	0.73	45.68			B= 23.39+ 2.06*R

Discussion

General profile of cover patterns of lowland vegetation and rural land uses

At Golako River basin (in the heart of Urdaibai Biosphere Reserve) wide extensions of plantations coexist with reduced distribution numbers of forests and other semi-natural vegetation units: 73,2% to 23.8% of basin's total cover, where oak forest accounts for 5.3%. Presence of native lowland oak forest is highly associated to height and abruptness. The influence of orientation requires some precisions: a) at the bottom of the gulf of Biscay, Atlantic winds flow in a 270º-360º arch, from west to north ~ 54.8% (Uriarte, 1985) and b) even at plot scale topographic profile is extremely heterogeneous and in spite of exhaustive inspection (625 points grid/plot) mean aspect calculation in terms of quadrats represents a simplification. From our results, mean eastern orientation favours increased forest cover whereas forest disappears where no eastern aspect is present within a given plot and/or added occurrence of northern and western orientations exceeds 70%. In fact, north to west arch predominates in the catchment and forest patches are found everywhere at northern cells since milder areas are devoted to silviculture. As a consequence, forest occupies favourable conditions (i.e. eastern aspect) only when they prevail. In this respect, García *et al*. (2005) refer southern preference in *Q. petraea* (altitudinal substitute for *Q. robur*) from a montane area of the Cantabrian range where ~27% of potential area is protected for this species.

In our study, forest existence appears linked to topographic constraints despite the fact that *Q. robur* potential niche at the Cantabrian sector is negatively related to altitude and slope (Roces-Díaz *et al*., 2014) but in agreement with general conditions for forests found in Europe (San-Miguel-Ayanz *et al.*, 2011) and for biodiversity in New Zealand where risk of biodiversity loss increases below 400 m asl (Walker *et al.*, 2008). In any case, inaccessibility provides very little protection: *Q. robur* forest potential cover of 99.4% appears as 0.4% below 200 m asl barely increasing to 5.9% above that altitude (far from potentiality of 87.9%). Similarly, Walker *et al*. (2008) showed that high elevation reserves contribute poorly to biodiversity protection, and proposed a protection baseline around 20% of original remaining habitat since below this cover area risk of biodiversity loss rises exponentially from 10% to 100%. According to this scheme both acidophilous and mesophytic oak forests would be well below their protection boundary, mesophytic oak forest being likely under extreme risk.

Index of Biological value: Biological quality of vegetation units

Landscape distribution into vegetation units has proved a flexible method to analyse and assess biological value and fieldwork has proved essential to assess index values after GIS analysis of vegetation maps. Along the catchment, plantations have qualified low (10 to 18% of maximum B) and semi-natural units such as heaths and meadows have scored similarly (30 to 40%). Although behaviour of descriptors seems somehow redundant in the case of meadows (semi-natural unit) appearing as primarily focused on analysing quality of forested areas. In fact, only forest in its various categories -riparian, degraded and mature- have exhibited values above 50% as well as variability associated to conservation state, with maxima for riparian (~82%) and mature (~86%) units (Figure 2). Our results compare well with mean B values for an Atlantic lowland inner basin separated by 25 km (surrounding Pagasarri Mountain): 8% for Coniferous Plantations, 40% for meadows, 45% for heaths and 67% for oak forest (Egurbide, 2007).

Published works in which biological values are computed in similar terms deal with geographical areas under Mediterranean influence allowing comparison of our results in strict terms: even if vegetation units provide means to compare conservation state of widely different terrestrial habitats, influence of land exploitation models outside regional scale may derive in results barely connected. We have reviewed in detail evaluations for analogous oak forest habitats (*Q. robur, Q. ilex, Q. pubescens, Q. rotundifolia, Q. suber*) undertaken in two territories under different regimes of protection, scaling B results to a 100 in order to obtain a clear contrast. Similar mean biological values have been obtained: 61.0% (± 7.4) in partially protected Guadiamar basin (6º10'50"E / 37º 16'10"N) in Southern Spain (Gómez-Mercado *et al*., 2007) and 61.7% (± 1.2) in a coastal Natura2000 Park in Crete Island (24 º16'00"E / 35º23'00"N) in Boteva *et al.* (2004). These values compare well with our own results of 64.0% (± 5.3) at Golako basin, and no clear influence of protection status has been perceived, rather the hitherto mentioned effects of inaccessibility (abruptness and altitude). In fact, unprotected Pagasarri woodland located at 1 km distance of city areas (~10^6 habitants) qualifies similarly. This lack of relation between plant or bird conservation value and protection state has also been reported for patches of *Pinus halepensis* close to a city in South-eastern Spain (Zapata & Robledano, 2014).

Regarding quality of semi-natural units such as Atlantic heaths (HT: *Erica* spp.) and meadows (MD) mean B values (%) in the surveyed area of Golako (B_{HT} = 41.0 ± 0.0; B_{MD} = 31.2 ± 2.5) compared well with those of Mediterranean locations, such as Guadiamar (B_{HT} = 27.8 ± 5.3; B_{MD} = 24.7 ± 3.7) and Crete (B_{HT} = 45.3 ± 0.5; no MD present), obtained from bibliographic sources (Gómez-Mercado *et al.*, 2007; Boteva *et al.*, 2004), respectively. Additional studies would be needed to calibrate biological index concerning vegetation syntaxa present in other geographical areas enhancing evaluation capacities of the index.

Discussion of B values in relation to silviculture and landscape homogeneity

Intensive exotic monoculture of evergreen species has an effect on both oak forest topographic distribution and patch size, and indirectly upon forest biological value (Figure 4), but also upon basin's overall biological value (Figure 3). We have obtained a negative correlation between relative area devoted to pine plantations (PP) and mean biological value (B) of plots (Figure 3a) setting a basin upper mean B index of 38.2% on 100% scale basis (elevation= 19.12; PP_{cover}= 0). In this respect, Santos *et al.* (2002) correlate land use to vertebrate species richness in a general survey of the Iberian Peninsula reporting common negative effect of agricultural land cover and of exotic forest on passerine birds, associated to increased habitat homogeneity. Additionally, for lowlands and mountains of the Cantabrian-Atlantic subprovince (Bizkaia and Gipuzkoa) Atauri and colleagues (2004) obtained increasing values of understory diversity (Shannon-Wiener) and richness (total number of species) and decreasing dominance (relationship between coverage of the most abundant species and total coverage of plot) in a gradient that follows our B values: from clear cut *Pinus radiata* plantations, through young plantations, to degraded forests and old plantations which they attributed to growing plantation age and management practises. Since at medium altitudes and slopes (~ 200 m and 20-30% respectively) conifer plantations are favoured, timber industry would be determining location and extension of natural and semi-natural vegetation units and thus, overall biological value of the landscape.

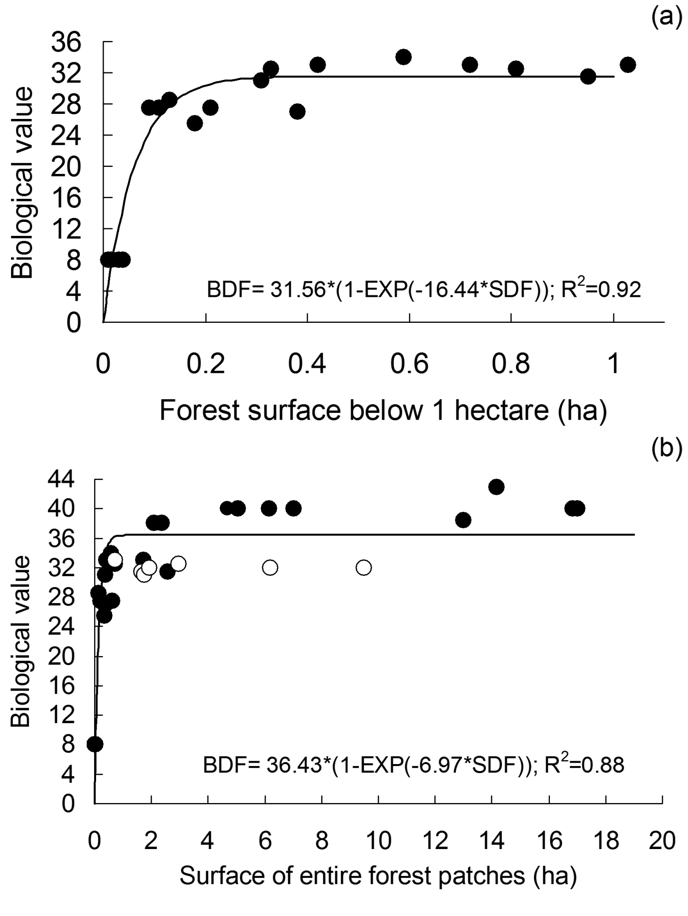

Figure 4. Frequency distribution of degraded deciduous forest patches in relation to surface. Asymptotic relationship between index of biological value for degraded deciduous forest (BDF = unitless) and patch size (SDF = ha) at catchment scale (n=29). Asymptotic equations obtained by non-linear regression analyses are shown.

Evaluation of remaining oak forest fragments: an attempt to define a favourable conservation status (FCS)

Although Golako basin is within a Natura 2000 site, *Q. robur* forests are not considered as natural habitats of community interest. Considerations above mentioned (see introduction) lead us to employ the concept of favourable conservation status as used for natural habitats of Community interest (HD 92/43/EEC). Thereafter, we will be using the descriptors included in the Directive (area, range, structure and function and future prospects) to analyze the status of *Q. robur* forest.

Area and range

Extreme reduction in forest potential area of distribution has been discussed elsewhere (see general profile). A wide range study of landscape evolution at Urdaibai Biosphere Reserve covering 50 years (1944-1994) shows homogenization associated to conifer monoculture, fragmentation increase and reduction of forest patch sizes, the later causing a clear reduction in plant biodiversity (Rescia et al. 1995), Our own involvement in the Golako catchment (from 1999) reveals little changes in land uses over the last 15 years and forest, meadows and heaths cover shows basically a stable trade-off with some precisions. A slight loss of meadows surface (~ 0.6%) is transferred to the vegetation unit termed Rural Areas that increase cover in 10%. This change discloses the increased relevance of housing as a competitor for territory even in protected areas, indicating that abandon of agricultural and cattle activities gives no opportunities to forest re-establishment.

Structure and function

Our index of biological value includes parameters to evaluate conservation state on real time (naturalness, floristic value and resilience) whereas others analyse future prospect (threat and rarity). Additionally, and although the specific study of fragmentation was not the object of this work, we found that, within 250 ha, semi-natural units (meadow, heath and degraded forest) where distributed in 454 patches, half of them below one hectare. This extreme fragmentation reduces B value of semi-natural units to 23.8% of maxima, and woodland lower biological index values to one half, with a mean value of 31.6 (63.2%). Occasional presence of narrow lines of riparian forest does not influence biological valuation (small size and homogeneous index rating), but pedunculate oak forest fragments do contribute to increased biological value of the landscape at upper levels of colline belt. On the contrary, presence of rural areas and plantations affect DF patch size and biological value in accordance with earlier results reported by Rescia *et al.* (1995). In this sense, Douda (2010) observed that landscape forests cover and distance to nearest settlement affected vegetation patterns reducing presence of valuable forest species.

Examination of remnant oak forest reveals that 80.7% of degraded forest patches were well below one hectare delimited by sharp boundaries (roads, parcels) and a lack of patches between 3 and 5 ha. We have chosen an asymptotic model of the type $y = a * (1-e^{-bx})$ to describe the relationship between values of B index and fragment size and applied it alternatively to samples below one hectare (0.1- 0.8 ha) and to all samples in this case with an upper limit of 17.2 ha (Figure 4a and b). Asymptotic maxima obtained would be representing maximum B attained by oak forest at Golako, providing as well a minimum patch size to attain it. In this respect, estimations below one hectare and for the complete basin have provided maxima representing 63.2% and 72.9% of B index respectively with associated minimum fragment area to attain maximum of 1.0 and 2.5 ha. This result would be indicating that both predictors are influenced by the size of the area inspected (25 ha vs. 3 460 ha). Influence of grain size in species richness predictions derived from higher habitat heterogeneity has also been reported in different studies of biodiversity patterns in Iberian Peninsula's fauna and flora, respectively (Santos Martins *et al.*, 2014; Kouba *et al.*, 2014).

A critical evaluation of asymptotic maximum was done as an instrument to predict minimum required surface. A favourable conservation status can be undertaken comparing our results with those of theoretical reference threshold values for spatial coherence (included in quality aspects involving structures and functions as well as typical species for a given habitat) for European dry heaths in Flanders set at 5 ha (Louette *et al.*, 2015). In fact, in spite of our aim to obtain a continuous scaling of biological value of forest to surface, our regression model has resented from absolute lack of patches at the basin in the range from 3 to 5 ha and a significant increase in B values appears in that interval: from 63.4% below 3 ha to 77.1%, precisely over 5 ha (Table 4). In any case, achieving maximum B value for the basin (well below best possible rating for *Q. robur* woodland =100%) would require patches of at least 5.0 ha scarcely present at the catchment: 9 patches > 5.0 ha with a maximum of 17.2 ha accounting for ~ 2.9% of entire basin.

Preserving ecological functions and processes of forest may well require a minimum 'functional surface' to, at least partially, avoid major constraints of human pressure. In this respect, in their study of bird conservation in *Quercus ilex* forests in central Spanish plateaux, Santos et al. (2002) found a strong correlation of total bird richness with patch size (explaining 75.3% of variance) considering 65% of patch size of holm oak (*Q. ilex*) was below two hectares, while nesting requirements for true forest birds was set at 100 ha (3.5% mean coverage). Similarly, Zapata & Robledano (2014) assessed forest biodiversity in *Pinus halepensis* in semiarid southeastern Spain and found abundance and richness of both flora and woodland bird fauna associated to increased patch size. In the Pannoian Basin, Csorba & Szabó (2012) considered 30-40 ha patches viable for softwood forests and the Environment Canada Ministry (Bryan & Henshaw, 2013), recommends minimum core forest value of 5 ha surrounded by 195 ha of edge forest (total 200 ha forest) and no less than 100 ha to be considered a forest. In contrast, the European Environmental Agency and the Convention of Biological Diversity (CBD) recognize FAO (Food and Agricultural Organization of United Nations) definitions of the minimum values for forest size (0.5-1 ha). From the present work, a woodland patch should be over one hectare to score 50% in terms of our index and above five hectares to reach about three fourths in terms of index quality and these results can be reasonably extended to Basque Atlantic lowland areas on the grounds of similar patterns of coverage and fragmentation. Our conclusions are hardly compatible with patch size requirements in terms of National Forest Inventories of different European countries with accepted values below 0.5 ha for Austria, Finland, France, Germany and Spain.

Summarizing, we have studied range, area, structure, function and oak forests future prospects at the Cantabrian colline belt and there is enough evidence to support the idea that they are not at a favourable conservation status. Although it is not a threatened species, from a population perspective *Q. robur* forests should be understood as building blocks for conservation planning (after Wood & Gross, 2008). Therefore, interest in pedunculate oak forest preservation relies in its ecological functions and processes, the benefits that humans obtain from them and their cultural values.

Overall analysis of biological index

Descriptors conditioning final biological values rank from 0 to 10 but potential maxima for given vegetation units depend on distance to climax: whereas woodland can attain maximum value (100%), meadow and heath upper score was set up at 50% and 60% respectively (Loidi, 1994). Besides, index results have shown a ranking on acidophilous *Q. robur* oak forest conservation state, but neither meadows, heaths, riparian or mesophytic forests have shown variability. In some cases it is a consequence of lack of data within plots (no presence of heath or mesophytic forest) or lack of variability on patches (riparian forests). Regarding meadows and heaths, B index provides only an average description of conservation state precluding further analysis.

Changes in land management over the last years (index was first defined 30 years ago) suggest a revision of present assumptions for several parameters such as threat and resilience: traditional land management is being abandoned and pastures and meadows intermittently substituted by plantations of exotic species or housing. Indeed, among the parameters defining the index, resilience is a poor predictor of values obtained by forest. In fact, resilience loss at Urdaibai Biosphere Reserve is due to drastic changes in land uses (Rescia *et al.*, 2010): landscape homogenization after transformation of timber industry has resulted in an increased ecological vulnerability.

Conclusions

As commonly observed at cultural landscapes in developed countries, occurrence of most semi-natural habitats, particularly forest, is restricted to inaccessible areas with lower human activity. The same is true for our area of study which despite being a protected territory, exhibits land uses fundamentally linked to timber production. Under this exploitation model, rural landscape has undergone homogenization and fragmentation processes rendering biological quality index of every vegetation unit to values below 50% with exception of forest. As a consequence, main biological value of the basin is low (38%).

Real to potential vegetation cover ratio appears as a useful tool for evaluating risk factors: *Q. robur* forests in the Reserve have diminished to less than 6% of potential coverage. Mesophytic oak forest is locally nearly extinct. (0.9% of potential cover) and acidophilous oak forests (7.8% of potential cover) are scarce and reduced to small fragments (80.7% patches are below one hectare) located at poorly accessible areas. Conservation policies imply no real protection.

We have defined asymptotic relationships between the index of biological value and patch surface as an instrument to estimate minimum fragment surface required to attain maximum B index values. A minimum forest patch size of five hectares appears desirable in order to preserve ecological functions and achieve a favourable conservation status. An asymptotic maximum for the basin is set at 72.9%, although such evaluation pertains to 2.9% of river basin.

Basin's most valuable vegetation unit is a regionally threatened plant community made of a common European plant species. *Q. robur* pedunculate oak forest is under extreme threat due to biodiversity loss, fragmentation and silvicultural land abuse. This mesophytic *Q. robur* forest can be included in Annex I type 9160 (Sub-Atlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli*) of the Habitat Directive, as has been done in the neighbouring territory of Navarra (Peralta *et al.*, 2013) and deserves a high conservation status specially the well conserved stands.

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