Ecological assessment of Cantabrian landscapes

A study of soil and vegetation quality at two Biscayan locations

MSc Oreina Orrantia Albizu

PhD Thesis - 2016

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Universidad del País Vasco
Euskal Herriko Unibertsitatea

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A Antonio,
por tu apoyo incondicional

Unai nire semeari,
zuk emandako maitasuna nire indarra izan da

Mayiri,
zenbat musu eman gabe

Si saber no es un derecho,
seguro será un izquierdo

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ABBREVIATION LIST

English	*Spanish*		
B	B	Biological value	CI indicator
BD		Bulk density	Chapter 5
BES	BSE	Biodiversity and ecosystem services	
BP	PF	Deciduous plantation	VU type
CC		Canopy cover	Chapter 5
CI	IC	Conservation interest index	
CR	RC	Carbon retention	CI indicator
DF	BD	Degraded forest	VU type
E	E	Coeficient of ecosystem needs	CI indicator
EP	PE	*Eucalyptus* plantation	VU type
ES	SE	Ecosystem services	
F	F	Floristic-phytocoenotic value	CI indicator
FC		Field capacity for water retention	Chapter 5
FO		Climatophilous broadleaved deciduous/evergreen forest	VU type
FW		Field water content	Chapter 5
GC		Ground cover	Chapter 5
H	H	Protection of hydrological resources	CI indicator
HD	DH	Habitat Directive	
HT	BZ	Scrub vegetation	VU type
I	I	Initial indexo f conservation interest (after Loidi 1997)	
MD	PA	Meadows and pastures	VU type
MF	BM	Mature forest	VU type
N	N	Naturality	CI indicator
P	P	Resilience	CI indicator
PES	PSE/PSA	Payment for environmental services	
PNV	VPN	Potential natural vegetation	
PP	PP	Conifer plantation	VU type
R	R	Rarity	CI indicator
RA	ZR	Rural area	VU type
RF	BR	Hygrophilous forest	VU type
S	S	Soil protection	CI indicator
SCI		Sites of Community Importance	
SOM		Soil organic matter	Chapter 5
SQF		Soil Quality Factor	CI indicator
T	A	Threat	CI indicator
VU	UV	Vegetation unit	

.

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PREFACE

Our main goal has been to assess the ecological value of Cantabrian landscapes of the Biscay province, both of the vegetation and of the soil.

To achieve this target the thesis has been organized in six chapters. The first chapter (Introduction) gives an overall idea of the fundamentals of the thesis. The second chapter is a proposal and description of a Conservation Interest Index (CI) as a tool for ecological assessment of the territory based on phytosociology. For that purpose we have defined an index that would measure biotic, abiotic and anthropic factors and have proposed it as a management tool for Natura 2000 network. The third chapter is an ecological assessment of the vegetation found at a protected area –a case study-, where we have classified the vegetation of the basin onto seven main vegetation units, have applied CI index at every vegetation patch of ten quadrats, and have proposed a conversion of the achieved ecological value onto an economic value as part of a payment for environmental services scheme (PES).

At our next step (Chapter 4) we have developed an insight analysis onto the Biological value (B), the section of the CI Index that was related to vegetation, to define a local quality maximum and to observe how anthropic pressure and topographic variables describe this vegetation unit.

Initially we had defined a soil quality factor (SQF, Chapter 2) composed by Carbon Retention (CR), Soil Protection (S) and protection of hydrological resources (H) based on observational field experience. In Chapter 5 we have studied several parameters of the top soil of six vegetation units at an extreme climatic condition (after a severe drought) in order to identify the effect of anthropic pressure and land management upon top soil conditions and threat imposed by cultural management.

There is a description of the scientific context, background, interest, objectives and study area of every chapter from 2 to 5.

Finally, we briefly go through a general discussion and gather the main conclusions of this thesis in Chapter 6. Last chapters (7-8) show main scientific contributions of this thesis and general informative maps and vegetation relevés.

SUMMARY

In this study we have undertaken the ecological assessment of semi-natural and artificial vegetation types encountered at two sites of the Biscayan territory (North Atlantic Spain). We have used an index based on phytosociological premises, examining the landscape according to a categorization into vegetation units. This framework has been extended to soil analysis with the purpose of establishing the connections among vegetation and biological quality of top-soil, including as well resistance to drought and temperature changes. Our starting point assumed that ecological quality would covariate with anthropic pressures gradually transforming landscapes.

To achieve this ecological assessment we work with a composite index (Conservation Interest, CI) formed by three index sets: vegetation (B), soil (SQF) and territorial ecosystem needs (E). The vegetation index is called "Biological value" and is based on a phytosociological description of the territory, where vegetation is analysed from a landscape level and classified onto broader "vegetation units": grasslands, scrubs, forests, coniferous, *Eucalyptus* and broadleaved plantations and rural and urban areas. The definitions of B and E are based upon the experience of the botanist of the Department of Plant Biology and Ecology of the University of the Basque Country. The soil quality factor (SQF) had an initial description based on field observations.

Initially, we have proposed the use of CI as a management tool in protected sites and performed an approach to its use in economic schemes such as payment for environmental services (PES), acknowledging the need of a tool based upon ecological functionality of the territory for such economic valuations. Later we have analysed in detail "Biological value" index performance in ten quadrats (250 ha) at Golako basin and in all forests (110 ha) present at Alonsotegi municipality that draw a picture of actual anthropic pressure effects upon vegetation: forestry impact on landscape homogenisation and low general biological values (<50% except for forests), while enhances forest fragmentation processes, and reduces forest patch sizes, while livestock decreases forest intrinsic value. Forest low distribution numbers show a high risk factor (<6% and 9% real to potential cover ratio, at Golako and Alonsotegi respectively), with conservation policies not resulting in real protection as only inaccessibility or non-productivity preserves forests. After relating B index and forest fragment size we observe a minimum patch size of five hectares to preserve forest ecological functions.

Afterwards we analyse Alonsotegi top soils under different land uses and after a period of maximum drought and describe a relationship between the percentage of field water and field capacity for holding water, the percentage of water content and organic matter in soils and porosity and organic matter, and an inverse relationship between percentage of field water content and bulk density and bulk density and organic matter. Presence of organic matter in the top soil reduces its bulk density and increases porosity which allows more water presence, reducing desiccation effects at drought conditions. *Eucalyptus* plantation was the driest and hottest unit, with high metabolic rates and greatest bulk density despite its medium values of organic matter content. Ranking values achieved by vegetation units sustain the idea that actual forestry practices decrease soil capacity for water retention, soil water and organic matter content and therefore reduce soil quality. At last, *Eucaliptus* plantations' high temperature and metabolic rates have an effect on climate change mitigation policies.

Our results on landscape quality after soil and vegetation analysis are in accordance with other studies at regional and international level. The originality of this research is that the same tool is used among all present vegetation units which allow a practical comparative tool that would allow future management proposals in order to achieve an improvement of the ecological value of a territory based on good quality vegetation and soil after land use improvement.

RESUMEN

En este estudio desarrollamos una evaluación de los tipos de vegetación semi-natural y artificial presentes en dos lugares del territorio de Bizkaia (España noratlántica). Utilizamos un índice basado en presimas fitosociológicas y examinamos el paisaje siguiendo una categorización en unidades de vegetación. Este marco se extiende al análisis del suelo con el objetivo de establecer conexiones entre vegetación y calidad del suelo, incluyendo resistencia a la sequía y a cambios de temperatura. Asumimos como punto de partida que la calidad ecológica covariaría con presiones antrópicas que gradualmente modifican el paisaje.

Para alcanzar esta valoración ecológica trabajamos con un índice compuesto (Interés de Conservación, CI) formado por tres índices: vegetación (B), suelo (SQF) y necesidades territoriales ecosistémicas (E). El índice de vegetación, llamado “valor Biológico”, se basa en una descripción fitosociológica del territorio, donde la vegetación es analizada desde un nivel de paisaje y clasificada en “unidades de vegetación” más amplias: pastos, matorrales, bosques, plantaciones de coníferas, de eucalipto y de frondosas, y áreas rurales y urbanas. Las definiciones de B y E se basan en la experiencia de los botánicos del Departamento de Biología Vegetal y de Ecología de la Universidad del País Vasco. El factor calidad del suelo (SQF) parte de una primera definición basada en observaciones de campo.

Proponemos el uso de CI como una herramienta de gestión de lugares protegidos y hacemos un acercamiento a su uso en esquemas de pago por servicios ambientales (PSA), reconociendo la necesidad de una herramienta basada en la funcionalidad del territorio para dichas evaluaciones económicas. Más tarde analizamos en detalle los resultados de la aplicación de B en 10 estaciones (250 ha) de la cuenca del Golako y en todos los bosques (110 ha) de Alonsotegi, que dibujan los efectos de la presión antrópica sobre la vegetación: la industria forestal homogeniza el paisaje y reduce sus valores biológicos (<50% excepto para bosques), así como fragmenta los bosques, reduciendo su tamaño, mientras que la ganadería disminuye el valor intrínseco del bosque. La escasez de bosques muestra un factor de riesgo elevado (cociente cobertura real-potencial <6 y 9%, para Golako y Alonsotegi respectivamente), mostrando que las políticas de conservación no suponen una protección real ya que sólo la inaccesibilidad o improductividad conservan los bosques. La relación entre índice B y tamaño de fragmento de bosque muestra un tamaño mínimo de 5ha para mantener sus funciones ecológicas.

En Alonsotegi, el análisis del suelo relacionado a sus distintos usos y tras un periodo de máxima sequía permite describir relaciones entre el porcentaje de capacidad de retención y contenido de agua, el porcentaje de contenido de agua y materia orgánica, porosidad y materia orgánica; y relaciones inversas entre porcentaje de contenido de agua y densidad aparente, y entre densidad aparente y materia orgánica. La presencia de materia orgánica en el suelo reduce su densidad aparente, aumentando su porosidad lo que permite mayor presencia de agua, reduciendo la desecación en condiciones de sequía. Sin embargo, la plantación de *Eucalyptus* era la más seca, caliente, con altas tasas metabólicas y mayor densidad aparente a pesar de tener valores medios de materia orgánica. La jerarquización de las unidades de vegetación destaca las actuales prácticas forestales disminuyen la capacidad del suelo para retener agua y del contenido de agua y materia orgánica, reduciendo la calidad del suelo. Finalmente, la elevada temperatura y actividad metabólica del eucaliptal tiene implicaciones en las políticas de mitigación del cambio climático.

Nuestros resultados de calidad del paisaje a partir de vegetación y suelo siguen la línea de otros estudios a nivel regional e internacional. La originalidad de esta investigación es que la misma herramienta se utiliza en todas las unidades de vegetación existentes permitiendo una práctica herramienta comparativa para ser usada en futuras propuestas de gestión cuyo objetivo sea la mejora del valor ecológico de un territorio basada en una buena calidad de la vegetación y del suelo a partir de una mejora del uso del territorio.

1 INTRODUCTION

1.1 El contexto

1.1.1 Algo más que una declaración de intenciones. Think globally, act locally

La biodiversidad se encuentra fuertemente amenazada y son principalmente amenazas de origen antrópico las que están generando esta situación de desequilibrio y cambio del sistema: fragmentación y pérdida de hábitat, proliferación de especies exóticas invasoras, cambio climático. Lo anecdótico es que el ser humano, como parte de la riqueza biológica de este mundo, se amenaza a sí mismo y pone en riesgo su propia existencia, porque lo que está en riesgo es nuestra presencia en la Tierra y en las condiciones actuales. La biodiversidad como tal seguirá existiendo, aunque sea otra.

Es desde la convicción de que está en nuestras manos hacer algo para reducir nuestro impacto ecológico, que quise evidenciar la función ecológica y "social" de nuestro entorno natural frente a lo artificial, estudiando su estado de salud y dando argumentos sólidos para fomentar, a partir de ese conocimiento, un giro hacia una sostenibilidad real del territorio vasco.

Este trabajo se basa en un indicador (I) de interés de conservación utilizado para el estudio fitosociológico del medio por el Departamento de Biología Vegetal y Ecología de la Universidad del País Vasco (UPV/EHU) desde 1994. Aspiro a que esta investigación aporte una mejora y validación del índice como herramienta de trabajo en la gestión territorial.

1.1.2 La Teoría General de Sistemas

En esta investigación se desarrolla un análisis desde diversas áreas del conocimiento (ecología de la vegetación, economía, paisaje, etc), y dentro de cada área se dibujan nuevas subáreas. Son unidades que suman un todo, un sistema complejo por sus relaciones intrínsecas, bióticas y abióticas, y sus implicaciones futuras, y cómo éstas van a condicionar la vida, también la humana, en un futuro no muy lejano.

Debido a esta interdisciplinariedad y complejidad subyacente, en este capítulo hacemos un acercamiento ontológico a la investigación, describiendo cada una de sus partes y las relaciones que existen entre ellas, para facilitar una percepción holística de lo que aquí planteamos y, por lo tanto, tener una compresión sistémica.

Jan Smuts, creador del "holismo" (Holism and Evolution, 1926) defendía que el universo y sus partes constituyentes generan unidades ("unidades integradas") que tienden hacia un todo, de complicación creciente. En dichas unidades participan factores abióticos y factores bióticos, incluido el ser humano. Las unidades globales no pueden ser reducidas a la suma de sus elementos constituyentes puesto que están integradas, interconectadas, haciendo que el conjunto sea más que la suma de sus partes. M. de Bolòs (1992a) enumera una serie de características de dichas unidades integradas: nunca son la suma de sus partes; internamente son relativamente homogéneas, y a su vez contrastan con los demás. A menor escala, mayor homogenización interna y diferenciación entre ellas, lo que permite desarrollar sistemas de clasificación; son discretas, están delimitadas; presentan dinámica propia en procesos de intercambio y transformación de materia y energía; presentan una estructura relacionada con su funcionamiento; y poseen su propio desarrollo, que les lleva a experimentar cambios en su estructura.

Mediante esta concepción holística de la biología se llega al desarrollo de una nueva esfera científica denominada Teoría general de sistemas, TGS o enfoque sistémico, fundada por L. von Bertalanffy en 1945 (de Bolòs 1992b). Se trata de una metateoría capaz de abordar niveles muy diferentes de realidad, analizando la composición y dinámica de sistemas complejos en un intento de generalizarlos, de sistematizarlos. Así, buscamos unas unidades complejas, integradas y jerarquizadas, que permitan analizar y sintetizar la información que se extrae de la superficie de la tierra, respetando distintos niveles de organización, desde una perspectiva holística entre las ciencias del paisaje y de la ecología, y que aseguren ser portadoras de la mayor información posible y permitan el desarrollo de una herramienta integradora y relativamente sencilla de uso, dentro de su complejidad.

Concretamente, la fitosociología se adapta a la TGS al entender las comunidades vegetales como sistemas abiertos, en flujo continuo de materia, energía e información, que tienden a evolucionar hacia una mayor complejidad (Loidi 2001).

1.1.3 Escuelas europeas vs. anglosajonas

Existe una importante diferencia a la hora de entender la ecología a nivel de comunidad entre las escuelas europeas y la anglosajona que tiene grandes implicaciones en la selección de la unidad de estudio.

La escuela europea sigue los trabajos de Braun-Blanquet (1979) sobre el estudio descriptivo de las comunidades vegetales. Posteriormente, la fitosociología evoluciona a nivel nacional con los trabajos de Rivas-Martínez (2011) que desarrollan la fitosociología integrada (o dinámico-catenal) en la que se tienen en cuenta las comunidades vegetales y su relación con el medio.

La escuela anglosajona sigue dos corrientes muy distanciadas entre sí (apud. Terradas 2001): los trabajos de Clements, que entendía la comunidad como una especie de superorganismo cuyas especies miembro están fuertemente unidas entre sí, y que podrían de alguna manera relacionarse con el concepto Braun-blanquetista de la comunidad (Loidi 2001); y los trabajos de Gleason que describen un concepto individualista de comunidad: la relación entre especies coexistentes son el resultado de requerimientos y tolerancias similares, por lo que ponen en duda la existencia de límites entre comunidades y por lo tanto la posibilidad de ser clasificada.

Si bien en la escuela europea se acepta la comunidad vegetal como unidad de estudio, en la escuela anglosajona gleasoniana la unidad de estudio es la especie ya que no se entiende que la comunidad, como unidad propiamente dicha, exista ni pueda ser sistematizada. Consideramos que esta diferencia conceptual posiblemente ha originado que los trabajos que se realizan por ambas escuelas en cuanto a indicadores de biodiversidad estén basados unos en el concepto de "riqueza específica" y otros en la "fitosociología integrada". No es nuestro objetivo analizar cual de las dos líneas de trabajo es científicamente más acertada.

En esta investigación seguimos los trabajos de la escuela europea, concretamente de la sinfitosociología de la Península Ibérica (España y Portugal) explicada más adelante (apartado 1.2.1). Nuestra elección se basa en un aspecto técnico: el volumen de estudios fitosociológicos y el importante desarrollo que tiene la escuela sigmatista a nivel europeo la convierten en una herramienta interesante y práctica para la valoración de la biodiversidad local, nacional (e.g. Loidi 2001) y europea (e.g. Arsénio 2011, Mori et al. 2013, Mucina 1997 & 2013, Peet & Roberts 2013).

Entre los autores que defienden que la conservación de la biodiversidad debe basarse en enfoques sobre los ecosistemas en lugar de en especies podemos citar a Franklin (1993). Éste argumenta varias razones: a nivel de ecosistemas se abarca un número mayor de especies correspondientes a los organismos más pequeños; la matriz del paisaje tiene un rol crítico en el mantenimiento de la biodiversidad y viceversa, la biodiversidad tiene un papel fundamental en la productividad de las tierras agrarias; así como el número de comunidades existentes es menor y más manejable que el de especies.

Además, Loidi (1994, 2001, 2004) cita otros importantes argumentos a favor de enfoques basados en comunidades vegetales: la Unión Europea ha adoptado la sistemática fitosociológica para su aplicación en el estudio de los hábitat europeos; el estudio fitosociológico describe la vegetación desde la perspectiva biológica, integrando ecología y fitodiversidad; es un buen soporte para estudios funcionales del medio; la vegetación (la fitodiversidad) agrupa a los productores primarios del medio terrestre, y deviene en su estructura y biomasa; es uno de los grupos taxonómicos mejor descritos y es fácil de inventariar y mapear.

En su contra se argumenta que, si bien se requiere menos información para abarcar un mayor número de hábitat, los límites de las comunidades pueden ser ambiguos lo que en teoría puede originar problemas en la localización y delimitación concreta de territorios a proteger (Ewald 2003). Sin embargo, en la práctica esto no sucede gracias al consenso establecido sobre la metodología de trabajo entre los expertos fitosociólogos que analizan el territorio (Loidi 2004).

1.1.4 Niveles de organización del paisaje

Existe una graduación en los niveles de estudio del paisaje que se materializa en distintas disciplinas con un objeto de estudio a diferente escala, desde el nivel básico al más complejo (entre paréntesis su unidad de análisis): Taxonomía, estudia la flora (especie); Fitosociología, estudia la comunidad vegetal (asociación); Fitosociología dinámica o Sinfitosociología, estudia la tesela (serie); Fitotopografía, estudia la catena (geoserie); Biogeografía, estudia el territorio (célula de paisaje).

Los sistemas de clasificación vegetal a nivel florístico son más precisos que los existentes a nivel ecológico-fisionómico, sin embargo, estos últimos son más adecuados para el estudio de vegetación a grandes escalas debido a que pueden ser utilizados en zonas donde la flora es escasamente conocida pero con condiciones ecológicas semejantes a nivel intercontinental. Es decir, el paralelismo entre las condiciones ecológicas y su fisionomía permite prescindir del estudio de la composición florística, si bien siempre es posible la “utilización de sistemas mixtos con categorías fisionómico-ecológicas a grandes niveles y unidades florísticas en las categorías de más detalle” (Peinado et al. 2008).

Así, entendemos que para asentar las bases de esta herramienta debemos comenzar el estudio del territorio desde dos niveles: su flora y la comunidad vegetal que la mantiene; y desde aquí, ir subiendo los distintos niveles de análisis del paisaje. Por lo tanto, y teniendo en cuenta que la gran complejidad del medio natural aumenta sus posibilidades de clasificación y sistematización, consideramos de utilidad analizar el interés de conservación de las áreas naturales basándose en el estudio de la calidad de las comunidades vegetales y de su relación con el medio mediante el análisis de la relación suelo-planta y la respuesta del suelo a diferentes usos de la cubierta vegetal.

1.1.5 La herramienta: valoración de la biodiversidad y de sus funciones

El autor R. Margalef (1974) define **diversidad biológica** (intraespecífica, interespecífica y de los ecosistemas) como “el lenguaje utilizado por la naturaleza en cada momento y en cada lugar, de acuerdo con las condiciones locales” (apud Izco 2005); y define el ecosistema como un nivel de organización, no como una unidad concreta, al margen del espacio y del tiempo.

El equilibrio ecológico en el intercambio de materia y energía del sistema es básico para permitir la vida del ser humano. Sin embargo, es difícil saber dónde está el límite de biodiversidad necesaria para mantener este sistema en funcionamiento. Además, J. Loidi (2004) habla de prudencia a la hora de valorar las especies presentes en un área, además de su diversidad (entendida como número de especies) también se deben tener en cuenta otros aspectos relevantes de las diferentes especies presentes (endemismos, especies raras o relícticas).

El ecosistema, en su proceso de estructuración y organización, realiza una serie de funciones que generan a su vez bienes y servicios de los que se beneficia la sociedad actual (Costanza et al. 1997). Por ello, consideramos que en el proceso de evaluación de un ecosistema hay que tener en cuenta, además de su riqueza específica, la estructura y organización de esa comunidad.

Consideramos necesario diferenciar ambos conceptos, funciones y servicios, por las implicaciones que conlleva el proceso de mercantilización de servicios que se está dando en los últimos tiempos. Peterson et al. (2010) disocian claramente el binomio función-servicio: cuando se habla de funciones del ecosistema se refiere al sistema ecológico, la biota y los factores abióticos que contribuyen a dichas funciones; mientras que los servicios pertenecen al sistema económico y social y son los que ayudan a mantener una óptima calidad de vida de los seres humanos.

Analizando la definición dada por de Groot y col. (2002) observamos que la mercantilización y humanización de la biodiversidad llega hasta el sistema ecológico mezclando de nuevo ambos conceptos: “se entienden las **funciones** de los ecosistemas como la **capacidad de los procesos y componentes naturales para proveer de bienes y servicios que satisfagan las necesidades humanas**, directa o indirectamente; y los **servicios del ecosistema son aquellos beneficios que la gente obtiene de los ecosistemas”**.

Nuestros trabajos iniciales en la creación de un índice (Orrantia 2004; Loidi et al. 2007, Orrantia et al. 2008) se dirigieron a la valoración de los servicios realizados por las diferentes unidades de vegetación estudiadas, centrándonos en dos servicios para los que comenzaba a despuntar un mercado: carbono, agua. También trabajamos con el valor de la función del suelo como regulador de procesos pero sin ahondar en esa necesaria separación entre funciones y servicios.

Según Peterson y colegas (2010), el marco creado en torno a la mercantilización de los servicios del ecosistema es el mismo que opera en los ámbitos legal, político o financiero. Es decir, aquel que busca beneficios directos y a corto plazo (un producto) para el ser humano pero que no tiene en cuenta la mano de obra. Por ello, la mercantilización de las funciones del ecosistema como servicios para la humanidad puede ser perjudicial para la biodiversidad porque crea una distancia entre el ser humano y el sistema productor, el ecosistema, y el trabajador del ecosistema desaparece. Además, los servicios están sujetos a la existencia de un mercado y si éste desaparece, desaparece también la necesidad de mantener el servicio (Chan et al. 2007).

Aunque existen diferentes clasificaciones de las funciones ecológicas, básicamente éstas pueden ser de regulación, de refugio y de producción, mientras que la de información (culturales) sería un servicio. Entre las diversas funciones del sistema, las de regulación y de refugio tienen una importancia crucial para la estabilidad del sistema ecológico. Además, las funciones de los ecosistemas tienen tres tipos de valoración: ecológica, social y económica, si bien las valoraciones ecológicas y sociales no suelen ser transformadas en un valor monetario.

Existen otros autores que también han trabajado sobre esta separación en tres tipos de valoración de las funciones y servicios, ecológica, social y económica, y que destacan la importancia de la calidad del ecosistema en la generación de funciones y de servicios. Entre ellos, de Groot y colegas (2002) afirman que la importancia de un ecosistema (llamada “ecological value”) viene determinada por la integridad de su capacidad de regular y dar refugio, así como por parámetros ecológicos como complejidad, diversidad y rareza.

A nuestro entender, es crucial proteger el sistema (las funciones) que genera los servicios. Protegiendo nuestro ambiente nos aseguramos la disponibilidad de distintos servicios que sean de interés ecológico, social y económico ahora y en el futuro. Por lo tanto, nuestros esfuerzos se centran actualmente en la evaluación de las funciones que generan dichos servicios. Esta evolución en nuestra manera de entender el índice aquí desarrollado (CI) se observa a lo largo de los capítulos de esta tesis debido a que tenemos trabajos ya publicados previos al nuevo paradigma, establecido a lo largo de 2013. En el capítulo 5 se sientan las bases del análisis de la calidad del suelo en base a su capacidad de desarrollar procesos y funciones, y no servicios.

Finalmente, aunque en el capítulo 2 consideramos que la herramienta que aquí se desarrolla proporciona una valoración ecológica que **puede ser de utilidad en una posterior transformación en un valor económico** (mercantilización de los servicios), al centrarnos en las funciones del ecosistema no desarrollamos más allá esta línea de trabajo.

1.1.6 Una visión crítica de la economía ecológica

Para poder defender debidamente nuestra decisión de evaluar mediante esta herramienta únicamente las funciones relacionadas con la ecología del sistema (de regulación y de refugio) en base a la calidad de sus procesos, estructura y funciones hacemos a continuación un breve acercamiento a la valoración de los servicios de los ecosistemas actual.

Hay numerosa bibliografía sobre la valoración de los servicios. Algunos de estos trabajos son únicamente valoraciones ecológicas funcionales que pueden ser utilizadas para ponderar decisiones de gestión territorial (algunos ejemplos son los realizados en la Península Ibérica por Arsénio 2011; Gómez-Mercado et al. 2007; Loidi et al. 1992; Meaza and Cuesta 2010; Monteiro-Henriques 2010; Orrantia et al. 2009; Sesma and Loidi, 1993). Sin embargo, buena parte de los estudios disponibles desarrollan análisis costo-beneficio (e.g. Azqueta 1994, 1996), disponibilidad a pagar (Costanza et al, 1997), o más concretamente en valoraciones contingentes (Chiabai et al. 2011; Godoy et al, 2000; Richmond et al, 2007; Rolfe et al, 2000; Portela et al, 2008; entre otros). En ambos casos la información ecológica es utilizada para caracterizar la condición o el cambio ecológico de aquellos sistemas que están siendo evaluados. Posteriormente se utilizan los métodos económicos citados que permiten obtener una valoración económica de los servicios generados (Pascual & Perrings 2007; Scherr et al. 2006; Wilson et al. 2004; Wunder 2005, 2007).

La integración de las fases ecológica y económica, especialmente en la comprensión de los aspectos ecológicos para definir los parámetros del indicador económico, determinará en buena medida los resultados de la evaluación (Schultz et al. 2012). Por ello, Medeiros and Torezan (2013) consideran primordial que dichos ejercicios de valoración económica estén asesorados por expertos en diferentes ámbitos de la ecología; sin embargo dichos autores observan que un problema añadido es que el ejercicio suele estar dirigido al usuario potencial o real de ese territorio, con el **riesgo de arrastrar en todo el proceso de cálculo la falta de caracterización funcional ecológica de la unidad que se está analizando**. Es crucial que el encuestado tenga información suficiente para entender la importancia ecológica de ciertas especies o procesos. La premisa de poseer un conocimiento ecológico apropiado tanto del economista como del encuestado no siempre sucede (Schultz et al. 2012) lo que provoca que raramente se primen las entidades bióticas y abióticas que generan los servicios, lo que a su vez resulta en que los mercados no lleguen a proteger a las funciones de los ecosistemas ni la biodiversidad (Peterson et al. 2010). Además, falta un protocolo replicable común para la transferencia de valoraciones económicas de un área a otra (meta-análisis y transferencia de beneficio) (Navrud & Ready, 2007; Troy & Wilson 2006) y para el uso de tarifas de descuento[1] apropiadas (Chiabai et al, 2012).

[1] El "problema del descuento" hace referencia a que en el análisis económico del valor de los servicios se debe aplicar un factor de descuento para considerar el bienestar de las generaciones venideras por el servicio que hoy se protege, es decir, descontar al valor presente el beneficio que se producirá a futuro.

Aunque el colectivo científico asume que hay una problemática importante, inherente a los métodos de valoración utilizados, los cuales presentan una dosis importante de subjetividad, subyace la idea de que, a medida que se desarrollen más valoraciones, los datos obtenidos del análisis de los servicios ecosistémicos irán incrementando en valor económico, aunque deben ser considerados como estimas con cierto grado de infravaloración (Sardá et al. 2007). Sin embargo, a nuestro parecer, todos estos aspectos mencionados generan una gran dosis de incertidumbre y escepticismo relacionados con la aplicación de la valoración de no-mercado, basada en mercados hipotéticos que pueden sobrestimar o subestimar el valor del servicio.

1.1.7 "Servicios funcionales" del suelo

Si analizamos con detenimiento las caracterización de de Groot y colegas (2002) de las funciones de regulación y de refugio, así como de los servicios derivados de éstas, realizadas por las áreas naturales observamos que los parámetros que aportan información básica están relacionados con la cobertura vegetal (Biological value, del índice CI), el recurso hídrico (H), la capacidad del suelo como estabilizador de procesos (S) y la capacidad de retención de carbono (C) (Tb. 1.1). Observamos que existe un solapamiento entre varios de los agentes involucrados (H, S y C) y de los conceptos función-servicio (Apdo. 1.1.5) y que la información sobre estas tres entidades se obtiene principalmente estudiando el suelo.

La localización de las plantas en la interfase aire-suelo genera una necesidad de recursos aéreos (luz y CO2) y edáficos (agua y nutrientes) que condiciona su organización, tanto a nivel de planta como de comunidad: la temperatura, la luz y el agua son las principales constricciones ambientales que van a determinar los balances de energía y nutrientes de las plantas (Terradas 2001). Así, los dos ambientes, comunidad vegetal y suelo, están interrelacionados por entradas y salidas de materia y energía: la fitodiversidad afecta a los procesos y organismos del suelo y la diversidad de los organismos del suelo afectan a la producción primaria y la fitodiversidad (Wardle and Van der Putten 2004). Por lo tanto, para entender cómo la biodiversidad afecta al funcionamiento del ecosistema es necesario un análisis de las interacciones existentes "above ground-bellow ground".

Siguiendo el concepto de calidad del suelo revisado por Schoenholtz y colegas (2000) las propiedades físicas, químicas y biológicas y ciertos procesos específicos son utilizados para inferir la capacidad del suelo para desarrollar funciones de manera efectiva. Los atributos del sistema suelo están funcionalmente interrelacionados y lo caracterizan en un rango de valores dependiente del uso y gestión al que haya estado sometido, lo que permite que dichos atributos puedan ser utilizados para cuantificar y estandarizar la calidad del suelo (Larson y Pierce 1994). En definitiva, el factor calidad del suelo (SQF) se considera medible y depende del ecosistema y del manejo recibido a lo largo del tiempo (Larson y Pierce 1994).

Se ha seleccionado la parte superficial del suelo como unidad de estudio, debido a que se trata de un sistema esencial en el ciclo de nutrientes y con una gran influencia en otros procesos del ecosistema: estado hídrico del suelo, transferencia de energía y germinación y establecimiento de la vegetación, entre otros (Faccelli & Pickett 1991; Sayer 2006; Smith 2004). Este sistema se desarrolla en el capítulo 5 de la presente tesis.

Por último, entendemos que el suelo, al igual que la vegetación, es dinámico y lo único que es constante es el cambio. Nada permanece estable ni es homogéneo. Cuando interpretamos los resultados en base a máximos teóricos alcanzables en el desarrollo del suelo y de la vegetación nos estamos refiriendo a una evolución a futuro desde el conocimiento y las condiciones mesológicas actuales, asumiendo, desde la complejidad de un sistema abierto y heterogéneo, la incapacidad de interpretar el futuro y, por lo tanto, aceptando las limitaciones que nos imponen. Así pues, consideramos más oportuno hablar de la unidad de bosques como "máximos alcanzados".

	Funciones	Procesos y componentes del ecosistema	Servicios	Definido por	Ud. medida	Indice
A	**Reguladoras**	**Mantenimiento de procesos ecológicos esenciales y sistemas que mantienen vida**				
1	Regulación gaseosa	Papel de los ecosistemas en ciclos biogeoquímicos	1.1. Protección frente a rayos UV por O3 (prevención de enfermedades)	Actividad geológica y Ciclos geoquímicos del suelo	MOS	B
			1.2. Mantenimiento de la calidad (buena) del aire			Rc
			1.3. Influencia en el clima (ver función 2)			B
2	Regulación del clima	Influencia en la cobertura del suelo y procesos biológicos en el clima	2.1. Mantenimiento de un clima favorable (temp., precipitación, etc) para la habitabilidad humana, el cultivo, la salud, etc.	Actividad geológica y Ciclos geoquímicos del suelo. Balance del Carbono orgánico	COS	Rc – S
3	Prevención de catástrofes	Influencia de la estructura del ecosistema en casos de trombas de agua	3.1. Prevención de tormentas (ej. por arrecifes)	Hidrofobicidad	UV/MOS	S
			3.2. Prevención de inundaciones (ej. por bosques y humedales)	capacidad del suelo para retener agua	VWC	H
4	Regulación hídrica	Papel de la cobertura del suelo en la regulación de la escorrentía y en la descarga de ríos	4.1 Drenaje e irrigación natural	capacidad del suelo para retener agua	VWC	H
			4.2 Medios para el transporte	No se considera en este estudio		-
5	Abastecimiento de agua	Filtrado, retención y almacenamiento de agua dulce (ej. en acuíferos)	Abastecimiento de agua para su consumo (ej. agua potable, para riego o uso industrial)	capacidad del suelo para retener agua	VWC	H – S
6	Retención del suelo	Papel de la red de raíces de la vegetación y de su biota en la retención del suelo	6.1. Mantenimiento de la tierra arable		MOS	S
			6.2. Prevención del daño por erosión o salinización	Cobertura vegetal	UV	B – S
7	Formación del suelo	Disgregación de rocas y acumulación de materia orgánica	7.1. Mantenimiento de la productividad en tierras arables	Materia orgánica del top soil	MOS	Rc – S
			7.2. Mantenimiento de la productividad natural de los suelos	MOS y pH	MOS y pH	Rc – S
8	Regulación de nutrientes	Papel de la biota en el almacenamiento y reciclaje de nutrientes	Mantenimiento de suelos saludables y ecosistemas productivos	MOS	MOS y pH	Rc – S
9	Tratamiento de residuos	Papel de la vegetación y de la biota en la retirada o ruptura de nutrientes y compuestos xénicos	9.1. Control de la contaminación/ detoxificación	MOS	MOS	Rc – S
			9.2. Filtrado de partículas (polvo)	Cobertura vegetal	UV	B – S
			9.3. Reducción de la contaminación acústica			B
10	Polinización	Papel de la biota en el movimiento de los gametos de la flora	10.1. Polinización de especies silvestres	Diversidad		B
			10.2. Polinización de cultivos	Cobertura vegetal		B
11	Control biológico	Control de la población mediante relaciones trófico-dinámicas	11.1. Control de plagas			B
			11.2. Reducción del herbivorismo (daño a cultivos)			B

Tabla 1.1. Funciones y servicios del ecosistema (adaptado de de Groot et al. 2002) y su relación con los parámetros de estudio.

1.1.8 Clasificaciones de la vegetación

> *"To conduct or publish ecological research without reference to the type of community the work was conducted in is very much like depositing a specimen in a museum without providing a label"* (Peet and Roberts 2013)

Como ya hemos explicado, para estudiar la biodiversidad y las funciones del suelo hemos analizado las comunidades vegetales y su relación con el medio: el estado de conservación de la fitodiversidad, o valor biológico (B), así como diversos parámetros obtenidos del suelo (SQF). Así, obtenemos un índice agregado de varios indicadores entre los que están SQF y B.

El índice Interés ce Conservación (I) fue creado por J. Loidi (Loidi 1994) utilizando la clasificación sintaxonómica desarrollada por Braun Blanquet (1979) y actualizada por Rivas-Martínez y coautores (2011). Dicha herramienta estaba basada en el análisis de unidades (asociaciones o comunidades de plantas) que son fácilmente cartografiadas. Cada sintaxón mapeado estaba asociado a un valor que cuantificaba diferentes parámetros que definían su valor biológico (B) y su necesidad ecosistémica (E).

Concretamente, valor biológico (B) se basa en la descripción de las características sintaxonómicas de la vegetación y utiliza una nomenclatura compleja que responde a la **presencia de comunidades vegetales concretas y su relación con el medio** y donde la unidad básica es la **asociación**.

Ecólogos, técnicos y gestores del territorio suelen utilizar, sin embargo, diferentes clasificaciones ecológicas a nivel de **hábitat**, cuya unidades básicas pueden ser las **unidades de vegetación, de paisaje** o los **usos del suelo**. Así mismo, la información cartográfica sobre vegetación está disponible en diversos sistemas de clasificación. El uso de diferentes escalas, unidades y objetivos de cada clasificación hace que no siempre queden claras las equivalencias entre unos y otros sistemas.

Actualmente, si bien depende del público objetivo, parece haber una tendencia a nivel europeo hacia el uso de la sintaxonomía y/o del sistema de clasificación de hábitat EUNIS, de la EEA; además, la información de las áreas protegidas por la Red Natura 2000 sigue la clasificación de la Directiva de Hábitat (DH).

La relación entre estos sistemas no es sencilla al basarse en diferentes conceptos y trabajar a diferentes escalas, aunque existen estudios que hacen un acercamiento entre dichos sistemas. A estas correlaciones se las conoce como "pasarelas" (crosswalks) y para Euskadi se han encontrado entre los sistemas EUNIS-DH y DH-Fitosociología (IKT 2010, MIH-CAPV 2009). Nosotros trabajamos a nivel de unidades de vegetación (prados y pastizales, brezales, helechales y argomales, bosques, y plantaciones de coníferas, de eucaliptos y de frondosas, así como zonas rurales y urbanas), que agrupan diferentes asociaciones fitosociológicas presentes en el área de estudio.

1.1.9 Una pequeña aclaración sobre nuestra filosofía de trabajo

Esta investigación está fundada en la fitosociología, ciencia que defiende que las plantas se asocian para formar comunidades adaptadas a las condiciones climáticas y mesológicas de su entorno, y que dicha asociación va evolucionando, pasando por diferentes etapas de sustitución, hasta llegar a una etapa clímax, representada principalmente por un bosque como entidad ecológica más madura.

Algunos científicos (e.g. Terradas 2001) apuntan a que detrás de esta ciencia podría haber cierta postura fundamentalista al entender que el bosque es la máxima expresión ecológica y que todo lo demás son ecosistemas artificiales degradados "por nuestra culpa", quedando un mensaje oculto que sugiere que toda perturbación es intrínsecamente perversa.

La lectura de esta crítica ha sido enriquecedora debido a que, hasta no conocerla, no había sido consciente de que ese mensaje podría estar subyacente en este trabajo. Y sin embargo, nos parece adecuado el acercamiento fitosociológico para conocer el medio natural actual y su potencialidad futura para alcanzar el objetivo de esta tesis. Entendemos la crítica y consideramos que la ciencia fitosociológica se ha desarrollado mucho para evitar fomentar el mensaje oculto y son numerosos los ejemplos: diagramas no lineales ni cerrados de sucesión ecológica, aceptación del cambio y de la falta de equilibrio perpetuo, etc.

Conocer las debilidades nos ha permitido desarrollar una fortaleza de esta investigación y potenciar de esta manera el papel de los "ecosistemas imperfectos".

1.2 Antecedentes y estado del arte

1.2.1 Fitosociología: qué es y por qué es importante conocer las comunidades vegetales; por qué permite hablar de biodiversidad y de funciones del ecosistema

Como ya hemos explicado en esta introducción (apdo. 1.1.8), esta tesis basa su trabajo en un índice (I) que inicialmente valoraba únicamente el interés de conservación de ciertas clases de vegetación (sintaxonomía) presentes en el País Vasco (Loidi 1994). A partir de aquel trabajo ideamos una metodología en la que, además del valor biológico de la vegetación se tenían en cuenta ciertas funciones de los ecosistemas en los que el agente principal es el suelo, y que son básicos para el mantenimiento de la biodiversidad (Orrantia 2004) y que integran el nuevo índice de interés de conservación (CI).

La clasificación sintaxonómica antes mencionada es una herramienta de la fitosociología, que es a su vez una de las ciencias básicas de la geobotánica (también denominada fitogeografía). Utilizando la definición de Rivas-Martínez (2007), la fitosociología es la parte de la geobotánica que estudia las comunidades vegetales (fitocenosis), sus relaciones con el medio, los procesos temporales que las modifican y sus funciones. Este autor entiende la fitosociología como un modelo abstracto, basado en **inventarios de vegetación**, realizados en condiciones mesológicas homogéneas en un lugar y tiempo dados, en el seno de una comunidad vegetal particular, correspondiente a una determinada etapa de la sucesión estructuralmente estable. En esta misma línea, Van der Maarel (2005) propone la siguiente definición para fitocenosis: "*a piece of vegetation in a uniform environment with a relatively uniform floristic composition and structure that is distinct from the surrounding vegetation*".

La fitosociología asume que la escala temporal de las condiciones mesológicas del medio es tan grande en comparación con la brevedad de la vida de las plantas, que se pueden entender constantes. De esta manera, se puede considerar que los cambios que tienen lugar en las comunidades vegetales en una escala de tiempo breve se deben al "dinamismo" de la propia comunidad (Loidi et al. 2011). El conjunto de mecanismos que conforman el dinamismo impulsan a su vez la **sucesión**, entendida por dichos autores como "*el fenómeno de cambio o evolución en las comunidades vegetales que ocupan un determinado lugar a lo largo del tiempo*".

La historia de la competencia entre las distintas poblaciones de especies concurrentes se visualiza como un ciclo, una sucesión, de diferentes fenómenos (instalación, expansión, apogeo, estabilización, declive y extinción no sincrónica) que se puede sintetizar como diferentes etapas sucesionales con una composición florística (constancia) y fisonomía (dominancia) características, un reemplazo completo de unas comunidades por otras, en un mismo lugar y hasta alcanzar un estado final maduro. Esta **etapa clímax** permanecerá estable mientras no cambien las condiciones mesológicas. Al estudio del reemplazo –sucesión- de unas comunidades por otras se le conoce como **sindinámica**. Hay sistemas florísticos basados en la constancia, en la dominancia o en ambos. En los primeros importa cualquier cambio en la composición y se utiliza en territorios fragmentados y con fuertes procesos dinámicos generalmente de origen antrópico; mientras que en los segundos únicamente se estudian los elementos dominantes, especialmente en fitocenosis (comunidades vegetales) bien conservadas.

En la fitosociología clásica cualquiera de sus rangos jerárquicos son **sintaxones** y su unidad fundamental la **asociación**. Dicha unidad queda definida en el Congreso Internacional de Bruselas de 1919 como una "agrupación vegetal de una composición florística determinada, que presenta una fisionomía uniforme y que crece en condiciones estacionales igualmente uniformes", de tal manera que la composición florística de una asociación es reflejo de unas condiciones ambientales concretas. Por este motivo la **clasificación de las comunidades vegetales es considerada como una clasificación indirecta de los hábitat**, y se acepta que la homogeneidad florística implica homogeneidad ecológica y fisionómica (Peinado et al. 2008).

Posterior a la fitosociología clásica de Braun-Blanquet, que estudia las características intrínsecas de las fitocenosis, se ha desarrollado la **fitosociología dinámico catenal** (integrada o paisajista), encargada de estudiar las características externas a la propia comunidad y el modo en cómo se relaciona con otras comunidades: estudia la zonación de las series de vegetación a lo largo de un gradiente ecológico específico.

En la fitosociología dinámica las unidades son las **series y permaseries**; y en la fitosociología catenal lo son las **geoseries y geopermaseries**. Ambas expresan la biodiversidad, estructura y sucesión del paisaje vegetal de los ecosistemas terrestres, naturales, seminaturales y antrópicos. En España esta ciencia está arraigada y desarrollada por numerosos autores.

1.3 Área de Estudio

El estudio se realiza principalmente en dos zonas de la vertiente atlántica del País Vasco: La cuenca del Golako y un municipio de la cuenca del Kadagua, Alonsotegi. Las descripciones detalladas de cada lugar se realizan en los capítulos correspondientes.

La investigación realizada en la cuenca del Golako (desarrollada en los capítulos 2-4) es la continuación de una tesis de master, un estudio piloto realizado en 2003-2004 para optar a la titulación de *Magister Scientiae* en Áreas Costeras (Universidad de Costa Rica 2002-2004). Este trabajo realizado en diez estaciones de la cuenca seleccionadas *ex profeso* permite, entre otros aspectos, estudiar el funcionamiento del índice CI en un área bien conocida y analizar la evolución de la vegetación de la cuenca durante las últimas décadas (1999-2013). Este tipo de selección preferencial de las estaciones suele darse en aquellos ambientes antropizados en los que la vegetación natural y seminatural es escasa y está influenciada por el uso de la tierra (Peet and Roberts 2013).

El trabajo de estudio de suelo de las diferentes unidades de vegetación y en diferentes estados de conservación se han desarrollado en la cuenca del Kadagua a su paso por Alonsotegi (capítulo 5) lo que ha permitido caracterizar el suelo de cada unidad de vegetación y conocer la aplicabilidad de la herramienta a nivel local (municipal).

1.4 Interés de la investigación

Reconocer y poner en valor el importante papel que tiene la biodiversidad en el bienestar humano es básico para lograr su protección en un mundo globalizado y capitalista, consumidor y aniquilador de todo aquello que es supuestamente prescindible. A comienzos del siglo XXI un conjunto de entidades a nivel internacional inicia el programa de la Organización de Naciones Unidas para la Evaluación de los Ecosistemas del Milenio (EEM 2012). El objetivo principal era "evaluar las consecuencias de los cambios en los ecosistemas para el bienestar humano y asentar las bases científicas de las acciones necesarias para mejorar la conservación y el uso sostenible de los mismos, así como su contribución al bienestar humano".

La conclusión final de la EEM es que "*la actividad humana está ejerciendo una presión tal sobre las funciones naturales de la tierra que ya no puede darse por seguro que los ecosistemas del planeta vayan a sustentar a las generaciones futuras. Al mismo tiempo, la Evaluación muestra que, con las acciones apropiadas, es posible revertir la degradación de muchos servicios de los ecosistemas en los próximos 50 años, pero que los cambios requeridos en las políticas y en la práctica son sustanciales y no están en curso en la actualidad*" (EEM 2012).

Posteriormente, en el Acuerdo de París, dentro de la Convención Marco de Naciones Unidas sobre el Cambio Climático, se aprueba "entrar en acción" para, además de reducir emisiones de gases de efecto invernadero, retener el aumento de la temperatura global "bien por debajo de los 2ºC" aunque no indica actuaciones para lograr dicho objetivo.

La valoración ecológica de las funciones de los ecosistemas de un territorio debe ser considerada en la puesta en valor de políticas de gestión del mismo, que aboguen por la conservación y restauración de áreas naturales. Para ello se precisa una definición de las funciones que se van a tener en cuenta en la valoración y de la metodología de valoración.

Los riesgos de llevar a cabo una valoración de algo tan intangible como la biodiversidad y sus servicios y/o funciones basándonos en el estudio de la vegetación son reales: una simplificación muy elevada de la herramienta conllevaría a una homogeneización de los resultados (i.e. todas las praderas no tienen el mismo valor ecológico) y, por lo tanto podríamos favorecer una pérdida de biodiversidad. Por otro lado, herramientas complejas que dificulten la obtención de resultados (en tiempo y calidad) podrían significar el fin de la herramienta.

Se conocen grandes brechas de conocimiento a escala local y nacional, y se desconoce el estado de los servicios y el costo de su agotamiento a nivel de cuencas nacionales (EEM, 2012). Por ello, consideramos que **esta investigación posee un interés demostrativo al utilizar una herramienta adaptada a la realidad de la costa atlántica vasca, que proporciona la base para valorar y cuantificar ciertas funciones de los ecosistemas partiendo del conocimiento de la flora local** y atender a las necesidades de conocimiento puestas en evidencia por la EEM.

A nivel regional se han desarrollado trabajos de evaluación ecológica basándose en la fitosociología (Asensi 1990), o estudios de valoración de los servicios de los ecosistemas con una metodología que tiene en cuenta la biodiversidad, fijación de carbono, servicios de agua y de los ecosistemas a partir de análisis teóricos de bases de datos públicas con herramientas (GIS) de información geográfica (Onaindía et al. 2013); o la influencia de usos del territorio sobre los recursos hídricos (Garmendia et al. 2011). Existen además trabajos a nivel europeo que utilizan el indicador "Biological value" (B) desarrollado por Loidi (1994) (ver apartado 4.4.2) y la caracterización del suelo ha sido contrastada con estudios internacionales (apartado 5.4) que servirían para validar la reproducibilidad del presente trabajo.

Conservation Interest Index (CI) es una herramienta de análisis territorial que se vale de un sistema mixto de clasificación de la vegetación con criterios ecológicos, con categorías fisionómicas o ecológicas en los niveles superiores (hábitat EUNIS) y unidades florísticas (sintaxonómicas) en las categorías de más detalle. El **uso de la fitosociología como herramienta para valorar los servicios de los ecosistemas** de la Península Ibérica, su **correlación con el sistema de clasificación de los hábitats EUNIS**, utilizados y auspiciados

por la Agencia europea de Medio Ambiente (EEA), son algunos de los aspectos innovadores de este proyecto.
Otra característica innovadora es el **ejercicio de valoración ecológica** en sí, de los que existen pocos casos a nivel del territorio español, y la utilización de una herramienta con base científica sólida que permita ponderar el valor de cada propiedad en base a su calidad ecológica.

La **caracterización del suelo y su relación con las unidades de vegetación** en el desarrollo de las funciones del suelo de regulación hídrica y de fijación de carbono (contenido real de agua y de materia orgánica por unidad de vegetación), así como la **necesidad de protección territorial de ciertos hábitat**, avalados por normativa de local a europea y por conocimiento científico, completan el conjunto de indicadores que se analizan en CI.

Por último, el Panel Intergubernamental de Expertos sobre el Cambio Climático (PICC) concluía que una de las contribuciones de la EEM es que "*la evaluación sobre los servicios de los ecosistemas y sus vínculos con el bienestar humano y las necesidades de desarrollo es único. Examinando el ambiente a través del marco de los servicios de los ecosistemas facilita identificar cómo los cambios en los ecosistemas influyen sobre el bienestar humano, y proporcionar información que los responsables de tomar decisiones pueden sopesar junto con otras informaciones sociales y económicas*" (EEM 2012). De tal manera que la herramienta CI **facilitaría la toma de decisiones** de los actores sociales, políticos y técnicos implicados en la gestión territorial permitiendo que la biodiversidad juegue su papel en la liga de las grandes estrellas, a la par que el desarrollo económico, la salud humana o la equidad social.

1.5 Objetivos

La hipótesis de partida es que las presiones antrópicas transforman el territorio y determinan la calidad ecológica de la vegetación.

El objetivo final de esta investigación es hacer una evaluación ecológica en dos lugares de la provincia de Bizkaia (España), de su vegetación y de su suelo, y relacionarlo con los usos del territorio.

Como objetivo secundario son: estudiar la calidad de la vegetación y del suelo por medio de una serie de parámetros previamente seleccionados, que permitan validar un índice de interés de conservación, CI, como herramienta para la evaluación de la funcionalidad ecológica de los ecosistemas atlánticos.

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2 PROPOSAL AND DESCRIPTION OF CONSERVATION INTEREST INDEX AS A TOOL FOR ECOLOGICAL ASSESSMENT OF THE TERRITORY

Paper 1: Vegetation Science and the implementation of the Habitat Directive in Spain: up-to-now experiences and further development to provide tools for management

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Vegetation Science and the implementation of the Habitat Directive in Spain: up-to-now experiences and further development to provide tools for management

Abstract

One decade and a half after being proclaimed, the Habitat Directive has been largely implemented in most of the EU member states under various approaches and with different degrees of intensity. The high contribution to European biodiversity provided by the Spanish territories, along with extensive mountainous areas with low population densities and the engagement in safeguarding biological and ecological patrimony exhibited by a large part of the society and its governments have led to the design of a vast Natura-2000 network in Spain. At present, it includes 23.6% of the national territories which represent 24.7% of total EU network and the proportion of Annex I habitats types incorporated to protected areas embody 30.22% when referred to the total existing in the country. Under these circumstances, naturalistic evaluation appears as an important task for vegetation scientists and some criteria and scales are commented. In this sense, undertaking the development of Payment for Environmental Services (PES) schemes, where landowners collaborating to environmental welfare will be rewarded with money, becomes a viable contrivance to political managers.

Resumen

Década y media después de ser aprobada, la Directiva de Hábitat ha sido frecuentemente desarrollada en la mayoría de los Estados Miembros de la UE bajo distintos acercamientos y con diferentes grados de intensidad. La elevada contribución de los territorios españoles a la biodiversidad europea, junto con sus extensas áreas montañosas con bajas densidades de población y el compromiso adquirido para la salvaguarda del patrimonio biológico y ecológico mostrado por gran parte de la sociedad y de sus gobiernos, ha llevado al diseño de una extensa red Natura-2000 en España. En el presente incluye el 23.6% de los territorios nacionales que representan el 24.7% del total de la red de UE, y la proporción de tipos de habitat del Anexo 1 incorporados a las áreas protegidas agrupan el 30.22% del total existente en el país. Bajo estas circunstancias, la valoración naturalística se presenta como una labor importante a hacer por científicos de la vegetación, y algunos criterios y escalas son comentadas. En este sentido, llevar a cabo el desarrollo de esquemas de pago por servicios ambientales, donde propietarios de terrenos que contribuyen al bienestar ambiental son recompensados con dinero, se convierte en una herramienta viable para los gestores políticos.

2.1 Context: Applying the Habitats Directive in Spain

As it was explained in a previous work (Loidi, 1999) the Habitats Directive (94/93/ECC) was largely conceived within a phytosociological framing, which resulted in a description of habitats based mostly upon vegetation types. This implied using vegetation types as defined in phytosociology as the basic units for the habitats inventory which, tacitly, have required global cartography at 1:50,000 scale of the whole country (Rivas-Martinez et al., 1994). Advantages obtained from having done a complete survey of habitats in every national territory of the EU are multiple:

- A realistic idea about actual extension of a given type of habitat at the moment the survey is performed.
- Accurate location of places and areas covered by the different habitat types.
- Evaluation of the proportion of each habitat type submitted to protection when implementing the Natura-2000 network, identifying the empty areas and those locations in which new protected areas need to be proposed.

In this sense, concerning Spain, the Natura-2000 network includes 1381 Sites of Community Importance (SCI) in 2007. A total surface of 11 911 211 ha is covered, which situates Spain as the main contributor to European Natura-2000 network, this extension representing 24.7% of the 48 263 859 ha of EU countryside linked to the network: ~ ¼ of EU Natura-2000 network resides in Spain. This means that 23.6% of the national territory has been incorporated to this protection scheme, Spain becoming the second country of the EU in such terms only exceeded by Slovenia with 31.4%. (http://ec.europa.eu/environment/nature).

Once a complete inventory of habitat types has been performed, essential information can be extracted since it becomes possible to estimate the proportion of total existing resources of each habitat type ascribed to the N-2000 network (Tb. 2.1).

Table 2.1. Table showing the existing surfaces (in hectares) of several habitat types compared with the amount of them included in the N–2000 network in Spain. Light blue indicates coastal habitats, dark blue humid and aquatic habitats, yellow scrub and scrubland habitat, light green high mountain habitat, red forests and lilac Canary Islands habitat (Courtesy of Elena Bermejo, TRAGSA).

Code	Habitat type	Total area for Spain	N-2000 Network ES	%
1120*	*Posidonia* beds (*Posidonion oceanicae*)	3.06604	1.30713	42.63
1240	Vegetated sea cliffs of the Mediterranean coast with endemic *Limonium* ssp.	19.11484	6.72984	35.1
2130*	Fixed coastal dunes with herbaceous vegetation (“grey dunes”)	35.76322	16.82405	47.7
4040*	Dry Atlantic coastal heaths with *Erica vagans*	56.34819	22.76593	40.4
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* – type vegetation	74.69709	230.29355	32.44
3250	Constantly flowing Mediterranean rivers with *Glaucium flavum*	69.8293	23.0827	33.05
1520*	Iberian gypsum vegetation (*Gypsophiletalia*)	2119.765	646.8167	30.51
4030	European dry heaths	18214.83813	5636.77197	30.95
5330	Termo-Mediterranean and pre-desert scrub	13868.97	3565.025	25.7
5120	Mountain *Cytisus purgans* formations	2771.1947	1156.81516	41.74
6160	Oro-Iberian *Festuca indigesta* grasslands	735.73267	354.72324	48.21
6230*	Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas in Continental Europe)	1134.564	452.1137	39.67

9120	Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the scrub layer (*Quercion robori-petraeae* or *Ilici-Fagenion*)	3176.39723	1343.35601	42.29
9340	*Quercus ilex* and *Quercus rotundifolia* forests	19866.25777	5633.33399	28.35
9520	*Abies pinsapo* forests	21.84651	10.89202	49.86
9360*	Macaronesian laurel forests (*Laurus, Ocotea*)	58.21709	28.51737	48.97
9370*	Palm groves of *Phoenix*	8.86577	3.13908	35.4
9550	Canarian endemic pine forests	604.3287	300.1388	49.66
-	All types	183755.1	55536.91	30.22

Several habitat classes are included and comparisons are made between its total coverage for Spain and the surface under protection by Natura-2000 network. Habitats have been classified into five categories: coastal, aquatic and humid, scrubs, high mountain forests and Canarian (Macaronesian). Percentages show that protected areas remain over 25% approaching 50% for some habitats. High scores are obtained for the Canarian, mountains and coastal habitats, whilst lower values are found for the scrubs. Forest ranks among the highest within the rare endemic types and lower in the commonest holm-oak formations.

In a broad sense, we can consider that results for the whole process (cartography, proposals of SCI, etc) have been adequate, some balance having been reached: a large share of all the habitat types in Annex I have been integrated (~30%) while distribution of protected areas are even in terms of habitat type. Summarizing, 23.6% of national territories belong to the network and, furthermore, about 30.22% of any given habitat type is subject to conservation in terms of Annex I (as well as many others not included in this list).

2.2 Naturalistic evaluation

An important service rendered by this large-scale habitat mapping of vegetation types is the possibility of being used as a basic document for a naturalistic evaluation. This is not a new idea (Lucas, 1973; Seibert, 1980; Loidi, 1994; Meaza & Cadiñanos, 2000) and using vegetation as the grounds for naturalistic or ecological evaluation, has been undertaken by different authors (Asensi, 1990; Kirby, 1986; Géhu & Géhu-Franck, 1980) though not strictly based on vegetation maps. Our purpose has been assessing the naturalistic value of vegetation units by means of a set of criteria described next (Loidi, 1994; Orrantia et al., 2008):

1. Naturalness. N

Tries to express the degree of human influence (hemerobie) on it. Comprises two aspects: (1) the damage or transformations caused by man in plant communities and (2) how these plant communities are the result of and dependent on human activity themselves. It is expressed in terms of distance from the climax or potential natural vegetation (PNV). The highest naturalness would correspond to PNV in an undisturbed situation.

0 Intensely urbanised areas, completely occupied by buildings, roads, etc. Practically no plants.

1 Peri-urban areas, surroundings of areas submitted to intense urban activities, with plant communities strongly dependent upon influence of man (high disturbance); cultivated fields. (*Polygono-Poetea annuae, Artemisietea vulgaris (pp), Galio-Urticetea, Ruderali-Secalietea (pp), Plantaginetalia, Parietarietalia*).

2 Parks, gardens, abandoned crop-fields. Pioneer therophytic vegetation. (*Onopordenea, Pegano-Salsoletea, Taeniathero-Aegilipion, Tuberarietea*).

3 Tree plantations of exotic species for timber production.

4 Grazed grasslands and meadows. *Arrhenatheretalia, Poetea bulbosae, Festuco-Brometea* (pp)

5 Natural scrub and grasslands of secondary origin. *Rosmarinetea, Festuco-Ononidetea, Cisto-Lavanduletea, Calluno-Ulicetea, Festuco- Brometea* (pp), *Sedo-Scleranthetea, Lygeo- Stipetea*.

6 Scrub-mantle and fringe vegetation. *Prunetalia spinosae, Cytisetea scopario- striati, Pistacio- Rhamnetalia alaterni* (pp).

7 Cleared natural woodlands due to grazing and forested meadows (dehesas). Mixed woodlands of authoctonous and exotic trees. Combined explotation of grazing and wood extraction.
8 Young natural woodland (initial stage) mixed with mantle and other seral communities linked to the forest system such as those of *Galio-Alliaretalia, Epilobietea angustifolii, Betulo-Adenostyletea* (pp). Severe forest explotation or recent abandonment.
9 PNV and permanent vegetation submited to light exploitation. The units involved are approximately the same as in the next level.
10 Mature non exploited forest. Rock crevices and screes. Undisturbed coastal dune communities Salt marshes. High mountain climatic meadows and scrubs. Peat-bogs.
Querco-Fagetea (pp. max), *Quercetea ilicis* (pp. Max), *Pino-Juniperetea, Vaccinio- Piceetea, Nerio- Tamaricetea, Asplenietea trichomanis, Thlaspietea rotundifolii, Ammophiletea, Spartinetea, Arthrocnemetea, Salicornietea, Crithmo- Limonietea, Juncetea trifidi, Elyno-Seslerietea, Salicetea herbaceae, Oxycocco- Sphagnetea, Scheuchzerio- Caricetea nigrae, Littorelletea, Potametea, Molinietalia* (pp).

2. Resilience. P

The capability of a vegetation type to recover itself after destruction (disturbance) by natural or humanly induced causes. An inverse scale is proposed as the less replaceable plant communities are evidently more demanding of protection.

0 No vegetation.
1 Pioneer annual communities and weeds.
Polygono-Poetea annuae, Ruderali- Secalietea, Hellianthemetea annuae.
2 Nitrophilous perennial vegetation.
Artemisietea vulgaris, Plantaginetalia majoris.
3 Scrub vegetation.
Rosmarinetea, Calluno- Ulicetea, Cisto- Lavanduletea, Pegano- Salsoletea.
4 Perennial grasslands and meadows.
Festuco- Brometea, Molinio- Arrenatheretea, Nardetea, Lygeo- Stipetea, Festuco- Ononidetea.
5 Azonal permanent vegetation: salt marshes, coastal dunes and cliffs, swamps, fens, riverain vegetation, etc.
Arthrocnemetea, Juncetea maritimi, Ammophiletea, Potametea, Phragmitetea, Littorelletea.
6 Mantle and edges.
Prunetalia spinosae, Cytisetea scopario- striati, Pistacio- Rhamnetalia alaterni (pp).
7 Natural forests of temperate and not too dry areas.
Querco- Fagetea (pp), Querceta ilicis (pp), Nerio- Tamaricetea.
8 Xeric-mediterranean climatic vegetation. Rock crevices and screes. Peat-bogs (if peat is partially removed).
Quercetalia ilicis (pp), Pistacio Rhamnetalia alaterni (pp), Juniperion thuriferae, Asplenietea trichomanis, Thlaspietea rotundifolii, Crithmo- Limonietea, Oxycocco- Sphagnetea, Scheuchzerio- Caricetea nigrae.
9 High mountain vegetation.
Vaccinio- Piceetea, Pino- Juniperetea, Juncetea trifidi, Elynetalia, Salicetea herbaceae.
10 Relict vegetation; no possibility of recovery by natural means after destruction. Exceptional localities, mainly belonging to 7 to 9 categories, which develop under climatically unfavourable conditions and have the character of a refuge due to topography or other circumstances. At least some of the plants have a reduced reproductive ability and the destruction of the community implies its complete or partial disappearance.

3. Threat. T

This parameter depends on several factors which difficult its evaluation, and which are dependent on the human socioeconomic circumstances of each country or territory. This scale is adapted to the Iberian Peninsula in the present times.

0 No vegetation.
1 Rock crevices and other inaccessible mountain sites.
Crithmo- Limonietea, Asplenietea trichomanis, Elyno- Seslerietea, Juncetea trifidi, Salicetea herbaceae.
2 Seral scrub.
Cisto- Lavanduletea, Rosmarinetea, Festuco- Ononidetea, Calluno- Ulicetea.
3 Natural grasslands.
Festuco- Brometea, Lygeo- Stipetea, Sedo- Scleranthetea.

4 Edges and mantles.
Prunetalia spinosae, Cytisetea scopario- striati, Pistacio- Rhamnetalia alaterni (pp).
5 Grazed meadows and grasslands (retreat of ranching activity).
Arrhenatheretalia, Poetalia bulbosae.
6 Oligotrophic mountain forests.
Ilici- Fagenion, Quercenion pyrenaicae, Vaccinio- Piceetea, Pino- Juniperetea (pp), etc.
7 Forested meadows (dehesas).
8 Lowland and foothill forests.
Carpinion, Quercetalia ilicis, Quercetalia pubescentis.
9 Salt marshes, riverine vegetation, wet places.
Arthrocnemetea, Salicornietea, Juncetea maritimi, Salicetalia purpureae, Populion albae, Potametea, Phragmitetea (pp), etc.
10 Coastal dunes, accesible mires (peat exploitation).
Ammophiletea, Scheuchzerio- Caricetea nigrae (pp), *Oxycocco- Sphagnetea* (pp).

4. Floristic- phytocoenotic value. F

The intrinsic biological value of a formation (vegetation type) is given by the different species which constitute it, the relationships between them and the structure, more or less complex that, as a frame work, contains them.

The proposal for mapped units is:

a. The floristic value: specific diversity.
b. The phytosociological value: phytosociologic diversity (richness of associated or included syntaxa in the appropriate unit if there is more than one).
c. Vegetation structural complexity.
d. The particular relationships between organisms (individuals and populations).
e. The phytogeographical character: content of endemic or territorially characteristic flora and syntaxa.

0 No vegetation.
1 Nitrophilous vegetation, common flora, simple structure.
Poligono Poetea annuae, Artemisietea vulgaris s.l., Ruderali- secalietea.
2 Scrub vegetation.
Rosmarinetea, Calluno- Ulicetea, Festuco- Ononidetea, Cisto- Lavanduletea, Pegano- Salsoletea.
3 Grasslands and meadows. Helophytic and aquatic vegetation.
Phragmitetea, Potametea, Molinietalia, Arrhenatheretalia, Festuco- Brometea, Poetea bulbosae, Lygeo- Stipetea.
4 Littoral and inland saline vegetation
Arthrocnemetea, Spartinetea, Salicornietea, Juncetea maritimi, Crithmo- Limonietea.
5 Rock crevices and screes, coastal dune vegetation.
Asplenietea trichomanis, Tlaspietea rotundifolii, Ammophiletea.
6 Oligotrophic deciduous forests and Mediterranean woodlands, mantles and edges.
Quercetalia roboris, Quercetalia ilicis, Prunetalia spinosae, Cytisetea scopario- striati.
7 Eutrophic species-rich deciduous forests.
Fagion, Quercetalia pubescentis.
8 Orotemperate and oromediterranean climatic vegetation, high mountain forest and scrub vegetation. *Nardus* meadows.
Vaccinio- Piceetea, Pino- Juniperetea, Nardetea.
9 Criorotemperate and crioromediterranean grasslands and associated communities. Peat-bogs and mountain rivulets and ponds. Chionophylous (snow-bed) plant-communities.
Juncetea trifidi, Elyno- Seslerietea, Scheuchzerio- Caricetea nigrae, Oxycocco- Sphagnetea, Montio- Cardaminetea, Salicetea herbaceae.
10 Mesophytic and wet forests of thermic areas with a rich flora which contains rare or relictic plants and associated communities of *Galio- Alliarietalia, Trifolio- Geranienea, Montio- Cardaminetea, Adenostyletalia*, etc. Forested meadows (dehesas). *Populetalia albae, Alno- Padion, Carpinion.*

5. Rarity. R

Rarity of a given plant is considered within a phytogeographical context, that is, that it appears in few or few little places, and so it is necessary to have the country phytogeographically studied and the territorial units defined and mapped. The average distance between the spaces in which a species or vegetation type occurs is used.

0	500 m or less
1	500 to 700 m
2	700 to 1000 m
3	1000 to 1500m
4	1500 to 2500 m
5	2500 to 3500 m
6	3500 to 5000 m
7	5000 to 10000 m
8	10 to 20 Km
9	20 to 40 Km
10	40 Km or more

6. Coefficient of territorial need for ecosystem protection. E

This parameter tries to emphasise ecosystems with a variable value but situated in densely populated, and thus ecologically degraded, areas. This parameter is measured by means of human population density calculate in Inhabitants/ Km^2 for administrative provinces.

0.5	From 1 to 4
0.7	4 to 19
0.9	20 to 39
1.1	40 to 59
1.3	60 to 79
1.5	80 to 99
1.7	100 to 129
1.9	130 to 199
2.1	200 to 299
2.3	300 to 599
2.5	600 or more

7. Carbon Retention. CR

Different vegetation units' role in carbon retention is assessed, by means of the amount of biomass. In the case of forests, it is taken into account the maturity degree (carbon sink).

1	Herbaceous communities. What it is produced is rapidly transformed into CO_2 by farm animals. (grazed grasslands).
1.2	Timber production in meadows. Fruit trees (orchard).
1.4	Natural scrub, short term timber production (15 y).
1.6	Medium term timber production (35-40 y) or degraded or juvenile forests.
2	Natural mature forest or long term timber production (80-100 y).

8. Soil Protection. S

Plant community's role on soil protection is assessed: (root system substances retention capability, soil enrichment or genesis).

0.4	Rural areas. Recently harvested area. No vegetation cover left.
0.6	Timber plantations using severe treatment (machinery, chemicals) on steep slope.
0.8	Timber plantations using severe treatment (machinery, chemicals) on moderate slope.
0.9	Seral scrubs.
1	Grasslands and meadows.
1.8	Degraded woodlands, juvenile woodlands.
2	Broadleaf natural woodlands.

9. Protection of Hydrological Resources. H

Assesses the hydrological value of a basin and its capacity of regulation and water purification.

0.4	Rural areas. Wrong actions in timber harvesting activities (damage to river ecosystem).
0.5	Tree plantations using machinery and chemicals close to streams. Cattle-hut close to a stream.
0.8	Tree plantations using machinery and chemicals far apart from streams.
0.9	Vegetable garden and other crops.

1 Meadow, grasslands and scrub.
1.5 Natural forest and woodlands.
2 Riparian woodland.

2.3 Conservation Interest (CI)

The Conservation Interest (CI) becomes the final estimation which will be used by the land manager, attributing a numerical value to a particular area. Calculations involve determining the Biological Value (B), which is obtained by adding five parameters portraying biological properties of each of the mapped vegetation types plus the rarity:

$$B = N + P + T + F + R$$

Maximal score attained in terms of B by a given vegetation type or cartographic unit (VU) appearing within the mapped area would be 50. Additional descriptors such as E, CR, S and H are included as factors so that the final formulation of the Conservation Interest (CI) becomes:

$$CI = B \times E \times CR \times S \times H$$

And since maximum value of E x CR x S x H is 20, highest ecological evaluation in terms of CI would be 1000. At this point, to estimate total value of CI for a given (i) VU we would multiply CI_i by its surface of coverage (A_i) so that Total Conservation Interest of the unit (TCI_i) can be calculated as:

$$TCIi = CIi \times Ai$$

Finally, to solve global CI for an area (GI) in which various VUs are present, we should add up every TCI_i, and then:

$$GI = \sum TCIi$$

By this procedure, we could reach total grades for the Conservation Interest of any area, providing a detailed knowledge of its plant communities as well as accurate vegetation maps are available.

2.4 Payment for Environmental Services

In order to guarantee social acceptance and, moreover, a desirable involvement of local rural population in nature conservation policies, financial resources have to be spent to avoid that charges and inconveniencies of protecting valuable habitats should become a burden to land owners. Several initiatives have been taken in various countries, as in Costa Rica (Orrantia 2004; Saenz 2000) consisting in variable amounts of money being paid to land owners on the grounds of environmental services offered by vegetation or ecosystems appearing in their properties. Such policies are developed under the concept of Payment for Environmental Services (PES), a tool which can be used by Administration to encourage rural population to preserve and improve the quality and extension of valuable ecosystems within their lands.

It becomes evident that an assessment method of either environmental or naturalistic quality of any territory is needed, and we propose the hitherto explained Conservation Interest (CI). From the numerical values on o to 1000 scale obtained for a particular landscape, we can deduce the economic reward for the landowner. Monitoring evolution of environmental services provided along time could be performed by regularly repeated evaluations (i.e. every 2 years).

Transformation of ecological value in terms of CI units into monetary units can be achieved by the following equation (Orrantia et al. 2008):

$$PES = K \times GI/(1 + \text{Ln } At)$$

Where:
K: constant
GI: Accumulated CI value of the surveyed property (Σ TCIi x Ai)
Ai: Surface occupied by the i mapped unit VU (Σ Ai = At) in hectares
At: total surface of the property in hectares
PES: Indicator of the Payment for Environmental Services to the land owner

Hence, PES would be into direct proportion to the obtained CI values accumulated on GI and thus, also proportional to the occupied areas. So, the larger a property, the higher PES would be (large state effect). Consequently, and in order to moderate this "large state effect", GI appears corrected by natural logarithm of total extension of the property.

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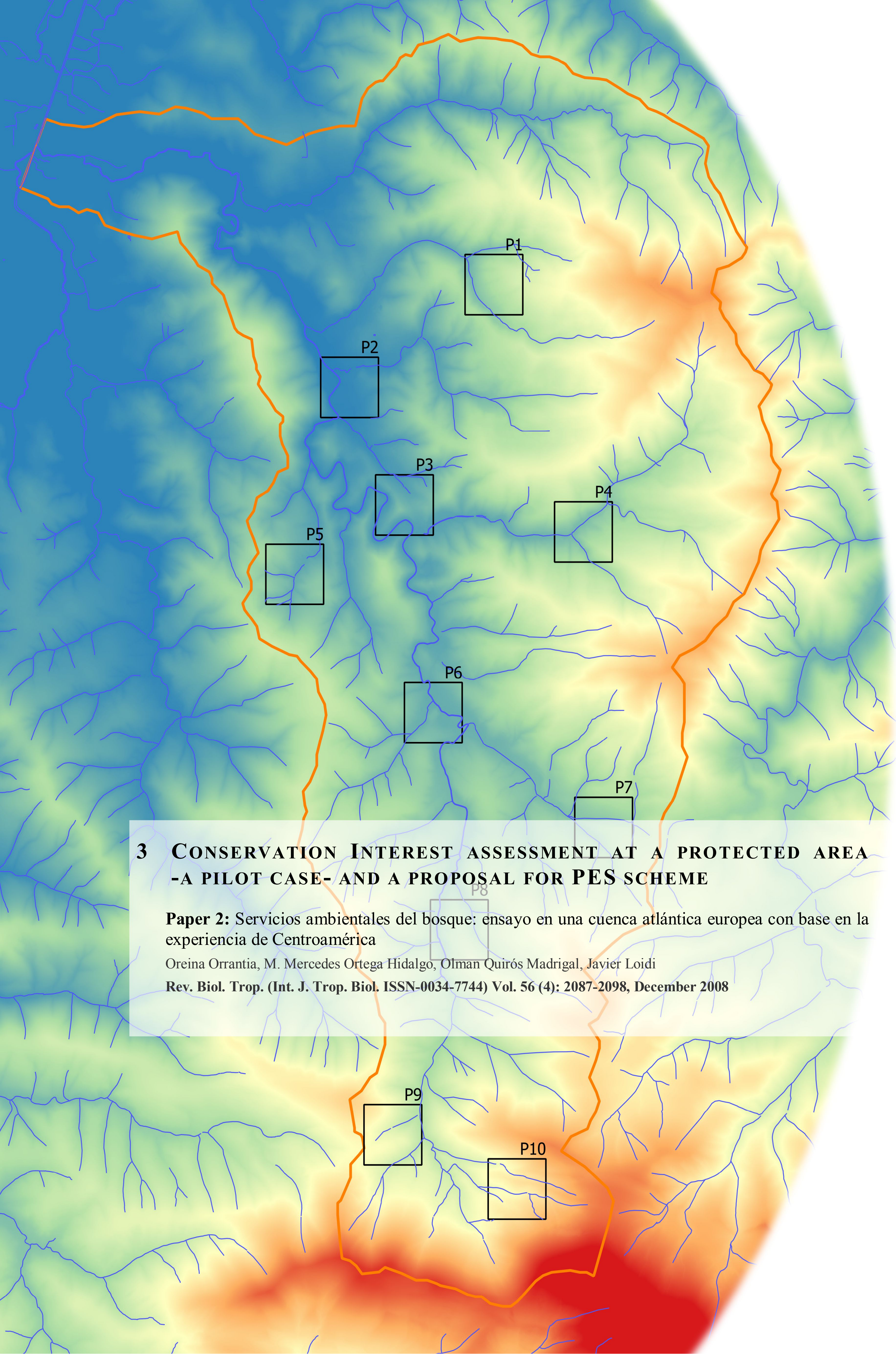

3 Conservation Interest assessment at a protected area -a pilot case- and a proposal for PES scheme

Paper 2: Servicios ambientales del bosque: ensayo en una cuenca atlántica europea con base en la experiencia de Centroamérica

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Servicios ***ambientales del bosque:*** *Un ensayo en una cuenca atlántica europea sustentada en la experiencia del medio tropical centroamericano*

Abstract

In this paper a Conservation Interest Index (CI) designed to numerically assess the naturalistic quality or value of a given terrestrial area has been applied along the Golako River Watershed (Biosphere Reserve, Basque Country, Spain). The area, although benefiting of some protection, is strongly influenced by human activities (forestry and cattle breeding). The CI is based on both available cartographic information about vegetation and fieldwork, the later needed to provide estimations for the various descriptors included in the index: in this way, a particular vegetation fragment receives a final score on a scale from 0 to 1 000. A set of 9 Vegetation Units have been defined to analyze actual vegetation profile and, a ten plot (500x500 m) uniformly distributed sampling design has been implemented. Landscape homogenization is high where main land use relies on timbering, contrasting with the more heterogeneous and fragmented profile related to rural activities. Above 150 m height forest appears dominant human occupation becoming patchy, whereas abruptness restraints farms to locations below 100 m. Concerning the index performance, gradual differences have been displayed by the forest, which appears as the only vegetation unit attaining values above 500 (50% in the index scale), mature forest ranking highest (860) followed closely by the riparian forest. We have developed a formula to translate environmental value into economic benefit to promote conservation work at the private property level, taking from the initial works undergone in Tropical ecosystems, where environmental services are rewarded irrespective of conservation state.

Resumen

En el presente trabajo se muestra la síntesis de un estudio piloto llevado a cabo en la reserva de la biosfera de Urdaibai (España atlántica), concretamente en la cuenca del río Golako, estudiándose 250 hectáreas durante 8 meses (2003). El objetivo ha sido, en primer lugar, definir un índice cuantitativo de conservación del territorio (IC), basado en la evaluación individual de 9 unidades de vegetación (UV) que sintetizan las características de la zona, para, a continuación, formular un método de compensación económica (PSA = euros) que permita la conservación de las áreas naturales de calidad que son propiedad privada. Dicho planteamiento se basa en la premisa de que el bosque natural, como todos los ecosistemas naturales, posee un valor social que puede ser cuantificado. Se trataría de valorar la contribución que las áreas naturales razonablemente bien conservadas prestan a la preservación de la calidad de vida de las poblaciones humanas. La herramienta de evaluación ambiental diseñada es de aplicación general, si bien su desarrollo en el contexto geográfico del País Vasco Atlántico, se articula en base a unas unidades de vegetación específicas del área geográfica, así como a una estructura del territorio particular. Los resultados del estudio indican que el 60% del territorio está representado por las plantaciones de *Pinus radiata* y que la superficie ocupada por el bosque natural en estados variables de conservación, está extraordinariamente fragmentada (82% por debajo de una hectárea). En este contexto, se desarrolla un concepto de Pago por Servicios Ambientales (PSA) propio, diseñado teniendo en cuenta las características específicas del territorio, fundándose en los estudios realizados de la experiencia de Costa Rica, de los planes estratégicos y jurídicos vascos, en el estudio del impacto de la actividad forestal y en las funciones del bosque natural como estabilizador de sistema. Los resultados de la iniciativa favorecerían la transformación de las áreas naturales, públicas o privadas, en un instrumento de utilidad pública al contribuir en la mejora de la calidad de vida de la población.

3.1 Introducción

El Pago por Servicios Ambientales (PSA) es una herramienta para promover la conservación de los recursos naturales de uso en todo el mundo (Vinicio 1998, FAO 2003, FONAFIFO 2003). Este esquema de financiación del mantenimiento de la cobertura arbórea se viene utilizando en Costa Rica desde 1997, donde la entrada de divisas debidas al ecoturismo supone un aporte importante a la economía. La estrategia de PSA nació como un mecanismo para frenar la deforestación y la degradación ambiental que venía sufriendo el país desde la década de los sesenta (Ortiz *et al.* 2003).

En Costa Rica, dicho esquema es utilizado para atender tres unidades de vegetación: las plantaciones, los bosques y los sistemas agroforestales, en los que se incluyen usos de la tierra para agricultura, ganadería y plantación forestal.

Los beneficios reconocidos de estas tres unidades son el papel que juegan en la protección del recurso hídrico, la conservación de la biodiversidad, la belleza escénica y la retención de carbono (mitigación de emisiones de gases de efecto invernadero). Así mismo, la financiación de este esquema se encuentra en el impuesto selectivo a hidrocarburos y combustibles, la asunción de costos ambientales en tarifas de servicios públicos, alianzas estratégicas entre FONAFIFO (Fondo Nacional de Financiamiento Forestal) y empresas privadas y el Fondo de Carbono Internacional (Certified Tradable Offsets, tramitados primeramente por la Oficina Costarricense de Implementación Conjunta). Su gestión es llevada a cabo por la oficina técnica Fondo Nacional de Financiamiento Forestal (FONAFIFO 2003).

El planteamiento realizado para aplicar esta herramienta en la Península Ibérica ha sido adaptar los conocimientos costarricenses a la situación y necesidades de la zona que, en el caso del área de estudio escogida (franja atlántica), se caracteriza por un paisaje montañoso, con abundantes núcleos de población dispersa que determinan en su conjunto elevadas densidades de población. En nuestros días, se hace evidente un aumento creciente de las áreas urbanizadas que es paralelo al deterioro de los espacios naturales, a la vez que crece el reconocimiento científico y social de los valores del bosque y el convencimiento de la necesidad de conservarlo por su contribución en el mantenimiento de la Sociedad del Bienestar. En este contexto, y siguiendo las recomendaciones de expertos (Meaza y Cadiñanos 2000), hemos estimado de utilidad abordar, en primer lugar, la evaluación del grado de calidad natural de los distintos territorios mediante criterios científicos, con un método repetible y que proporcione resultados numéricos, de modo que se pueda medir la contribución de las áreas naturales razonablemente bien conservadas a la preservación de la calidad de vida de las poblaciones humanas. Estas valoraciones representan el paso previo para otorgar primas monetarias cuyo objetivo final persigue la conservación del territorio natural.

Dicha actuación se enmarca en el ámbito legal en la Estrategia Ambiental vasca de Desarrollo Sostenible, EADS (2002-2020) (Gobierno Vasco 2002). El Programa Marco Ambiental (PMA) que desarrolla esta estrategia sigue las directrices de la "Estrategia de la Unión Europea para un desarrollo sostenible" y las cinco Metas Ambientales definidas en la EADS. En su primera fase (PMA 2000-2006) establece varios objetivos y compromisos a asumir que encajan con la línea seguida en este trabajo.

Entre los compromisos de la Meta 1 "*Garantizar un aire, agua y suelos limpios y saludables*", se citan: "*Mantener o aumentar la superficie forestal por los beneficios que de la misma se derivan tanto para la depuración del aire, régimen hidrológico de las aguas y control de la erosión*" y "*Aumentar la superficie con compromisos agroambientales hasta las 55 000 ha*".

Así mismo, entre los compromisos a largo plazo 2007-2020 de la Meta 3, se encuentran: "*(...) establecer un régimen normativo de primas compensatorias para bosques autóctonos sin rentabilidad económica directa o actividad económica en un plazo superior a los 100 años, en interés a su función social y ecológica*", "*Aumentar (...) la superficie de bosque*" y "*Alcanzar un aprovechamiento extensivo del suelo agrícola (...)*".

Para "*Limitar la influencia del cambio climático*", Meta 3 de la Estrategia, el PMA fija como objetivo "*Aumentar los sumideros de carbono*", concretándolo en una "*Promoción de usos imperecederos de la madera*".
Las metas anteriormente propuestas recogen, en lo esencial, la valoración de las funciones que el bosque natural presta a las sociedades humanas (ver Campbell y Doeg 1989, Maridet *et al.* 1996, Edeso *et al.* 1999, Elosegi *et al.* 1995, Montori *et al.* 2001, Grieve 2003 a, Yeakley *et al.* 2003, Scherr *et al.* 2006) entre las cuales los especialistas destacan: Biodiversidad: genética, específica y de los hábitats; Edafogenética: génesis y mantenimiento de la calidad y profundidad de los suelos; Mitigación de la erosión; Regulación del régimen hídrico: atenuación de las avenidas; Depuración de aguas en casos de contaminación orgánica; y Reservorio de carbono.

Por consiguiente, la herramienta de valoración utilizada en este trabajo, ha abordado la cuantificación de estas funciones en términos de un índice global de conservación (IC) que determinaría el grado de calidad ambiental de un área geográfica determinada. Así mismo, el trabajo formula una primera aproximación a la conversión del índice de calidad ambiental en primas monetarias, adaptado a una estructura de propiedad del suelo privada, basada en el pequeño propietario.

3.2 Materiales y Métodos

El trabajo se localiza en la Reserva de la Biosfera de Urdaibai (Golfo de Vizcaya, Norte de España, UTM 30TWP2887 a 30TWP3198), concretamente en la cuenca hidrográfica del río Golako. Se eligieron 10 estaciones de estudio de 500x500 m (25 ha/Estación) distribuidas uniformemente a lo largo de la cuenca del Golako, con la finalidad de conseguir una muestra equilibrada de los ecosistemas existentes (Loidi 2005), llamados unidades de vegetación (UV) utilizando, así mismo, información fitosociológica (Loidi *et al.* 1997, Rivas-Martínez *et al.* 2001) y mapas de vegetación potencial (Gobierno Vasco 1990).

Cada estación se situó junto a dicho arroyo, al objeto de dotar de un nexo de unión al conjunto de las estaciones. Las zonas escogidas no estaban canalizadas, presentaban bordes naturales y un acceso relativamente cómodo desde el valle, a través de pistas forestales, carreteras o senderos. Las estaciones se seleccionaron de manera que se abarcara toda la cuenca y sus diversos ecosistemas. Se dispersaron las estaciones evitando una distribución aleatoria por cuanto se quería recoger la totalidad de situaciones en los diferentes ámbitos de la cuenca. Por ello, hubo estaciones tanto en la vega como a media ladera, y tanto cercanas a núcleos rurales como alejadas de éstos.

Se procedió a recorrer a pie las 250 hectáreas que suman las superficies de todas las parcelas de muestreo, reconociendo en el lugar las diferentes UV y manchas de cada unidad existentes. Tras una primera aproximación se procedió a trabajar en mapas informáticos topográficos, de vegetación y ortofotos de diferentes años, así como con una base de 350 fotografías digitales tomadas durante el trabajo de campo. Esta aproximación permitió definir nueve unidades de vegetación (Tb. 3.1) presentes en el conjunto de las estaciones y utilizarlas para concretar la vegetación de las manchas existentes en cada estación. El estudio de campo se realizó entre septiembre de 2003 y mayo de 2004 (Orrantia 2004).

Tabla 3.1. Unidades de vegetación presentes en el estudio y su código, cuenca del río Golako, España.
Table 3.1. Landscape Units present at the study site and its code, Golako river basin, Spain.

Unidad de Paisaje	UV	
Aliseda	BR	Bosque Ribereño
Robledal acidófilo	BM	Bosque Maduro
Robledal mesofítico/ neutrobasófilo (*Quercus robur, Q. petraea, Q. pubescens*)		
Hayedo (*Fagus sylvatica*)		
Abedular (*Betula celtiberica*)	BD	Bosque Degradado
Robledal en fase de regresión o juvenil		
Pradera, campiña, zona de pasto, lastonar	PA	Prado, Pastizal
Brezal Argomal	BZ	Brezal
Brezal calcícola		
Pinar (*Pinus* spp.)	PP	Plantación de Pino
Eucaliptal (*Eucalyptus* spp.)	PE	Plantación de Eucalipto
Frondosas (de hoja caduca)	PF	Plantación de frondosas
Zona agrícola y rural	ZR	Zona Rural

En paralelo, se desarrolló un índice denominado Interés de Conservación, en el que se tuvieron en cuenta parámetros definidos por las funciones descritas para el bosque natural (Loidi 1994):

$$\mathbf{IC = (N + P + A + F + R) \times RC \times S \times H \times E}$$

Así, la suma de valores de N + P + A + F + R denominada valor biológico (B) por Loidi (1994), se inscribe en una formulación mas amplia que incluye 4 factores que dimensionan la contribución de las unidades de vegetación en términos de retención de carbono, protección de suelo y calidad de agua y necesidad territorial

$$\mathbf{IC = B \times RC \times S \times H \times E}$$

El significado de los términos (parámetros), así como los criterios de valoración son los descritos a continuación de forma resumida y aparecen detallados en Loidi *et al*., (2007).

N = Naturalidad: 0-10. Entendido como el grado de influencia humana en UV; distancia a la *clímax*
P = Resiliencia: 0-10. Estima de la capacidad para recuperarse tras una perturbación
A = Amenaza: 0-10. En función de las circunstancias socioeconómicas.
F = Valor florístico-fitocenótico: 0-10. Mide el valor biológico intrínseco: biodiversidad *s.l.,* estructura, etc.
R = Rareza: 0-10. Representa la distancia media entre los lugares donde aparece.
RC = Retención de Carbono: 0-2. Valor de las Formaciones forestales en términos de depósito de carbono.
S = Protección del suelo: 0-2. Coeficiente de retención del suelo por parte de las raíces; edafogénesis.
H = Mantenimiento o mejora de la calidad del agua: 0-2. Capacidad de purificación, servicio hidrológico de la cuenca.
E = Coeficiente de necesidades territoriales para la protección del ecosistema: 0-2.5. Dependiente de la densidad de población (hab/km^2).

Así, el valor biológico máximo alcanzable (B) es de 50, el cual, corregido por los cuatro factores de mejora propuestos, permite un máximo teórico de 1 000 unidades.

3.3 Resultados

Las características generales del paisaje estudiado aparecen en la Fig. 3.1 que muestra la ocupación total de cada unidad de paisaje estudiada en el conjunto de las estaciones. Se observa una elevada presencia de la plantación de pino PP (150 ha de 250 ha estudiadas), seguida por un grupo menos importante: PA, BD y ZR, PE y a cierta distancia PF, BM, BZ y BR. Ello a pesar del sesgo evidente en la elección de las estaciones para conseguir que todas las UV estuvieran presentes en el estudio.

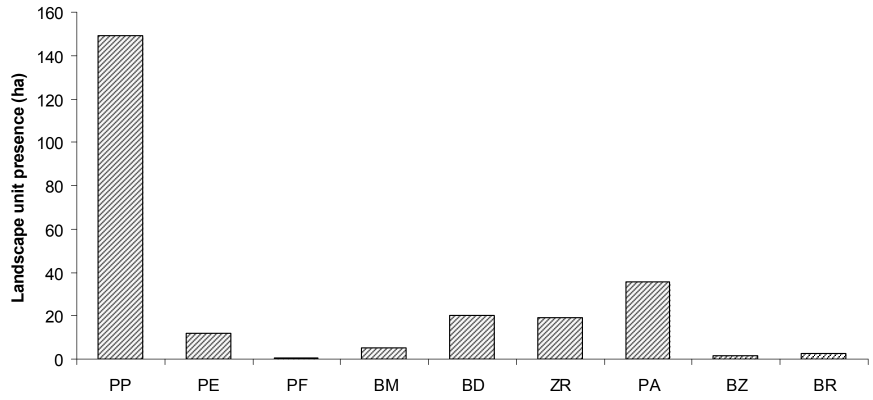

Fig. 3.1. Ocupación total de cada unidad de vegetación (UV) en el conjunto de las estaciones (ha / UV), cuenca del río Golako, España. PP, plantación de pino; PE, plantación de eucalipto; PF, plantación de frondosas; BD, bosque degradado; BM, bosque maduro; ZR, zona rural; PA, pastizales; BZ, brezal argomal; BR, bosque ribereño. Fuente: Orrantia 2004.

Fig. 3.1. Each vegetation unit (UV) surface extension within the total number of stations sampled (ha/UV), Golako river basin, Spain. PP, pine plantation; PE, *Eucalyptus* plantation; PF, broadleaved plantation; BD, degraded forest; BM, mature forest; ZR, rural area; PA, pasture; BZ, heather; BR, riparian forest. Source: Orrantia 2004.

Los valores del índice IC obtenidos (Fig. 3.2) muestran dos UV de elevado interés: BM y BR (bosque maduro y ribereño) con valores medios en torno a 800, seguidos por el bosque degrado (BD ~ 500). Un tercer grupo, de valores entre los 50 y 100, engloban a PF, PA y BZ. Por último, aparecen las unidades de PP, PE y ZR.

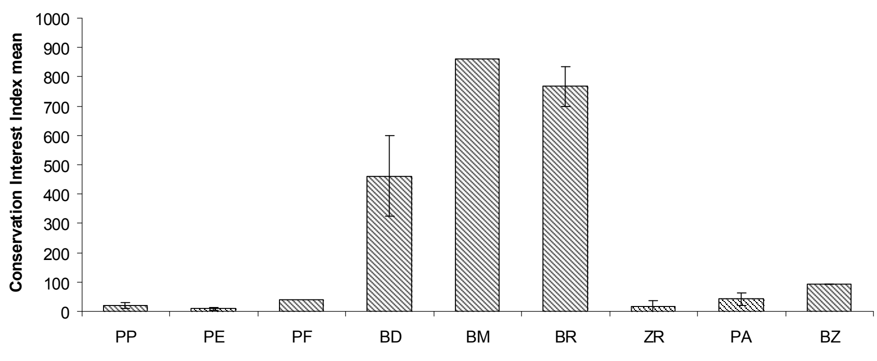

Fig. 3.2. Índice de Interés de Conservación (IC, media±SD) estudiado para cada unidad de vegetación (UV), Cuenca del río Golako, España. PP, plantación de pino; PE, plantación de eucalipto; PF, plantación de frondosas; BD, bosque degradado; BM, bosque maduro; ZR, zona rural; PA, pastizales; BZ, brezal argomal; BR, bosque ribereño. Fuente: Orrantia 2004.

Fig. 3.2. Conservation Interest Index (CI, mean±SD) for each vegetation unit (UV), Golako river basin, Spain. PP, pine plantation; PE, *Eucalyptus* plantation; PF, broadleaved plantation; BD, degraded forest; BM, mature forest; ZR, rural area; PA, pasture; BZ, heather; BR, riparian forest. Source: Orrantia 2004.

En la siguiente figura (Fig. 3.3) se muestra la fragmentación encontrada en cada estación y para cada unidad de paisaje: en general se observa una fragmentación del paisaje elevada. El caso más destacado es la UV Bosque Ribereño el cual, además de ocupar una superficie mínima (Fig. 3.1), se muestra sumamente segmentada, siendo muy amplio el fraccionamiento del bosque degradado (BD) con el 82% de las manchas estudiadas por debajo de 1 ha. En cuanto al bosque maduro, su rareza queda constatada por la presencia de una única muestra, el robledal de Arratzu, si bien de cinco hectáreas.

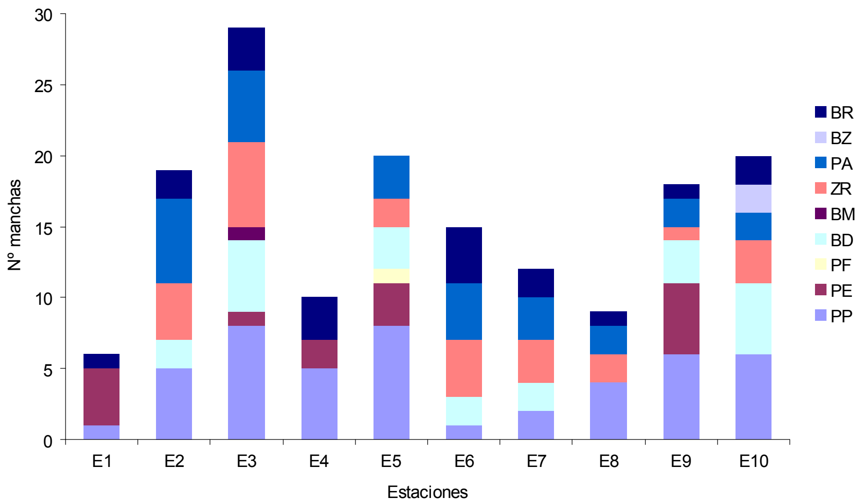

Fig. 3.3. Fragmentación existente por Unidad de Paisaje en cada estación (nº manchas / Estación), cuenca del río Golako, España. Fuente: Orrantia 2004. PP, plantación de pino; PE, plantación de eucalipto; PF, plantación de frondosas; BD, bosque degradado; BM, bosque maduro; ZR, zona rural; PA, pastizales; BZ, brezal argomal; BR, bosque ribereño.

Fig. 3.3. Number of patches per landscape unit present at each plot (no. patches / plot), Golako river basin, Spain. PP, pine plantation; PE, *Eucalyptus* plantation; PF, broadleaved plantation; BD, degraded forest; BM, mature forest; ZR, rural area; PA, pasture; BZ, heather; BR, riparian forest.

Así mismo, cabe destacar que se ha localizado una única parcela de PF en el área de estudio, cuando las especies caducifolias forman parte de la vegetación potencial del lugar. La utilización de especies perennes en la silvicultura causa un efecto negativo a la biodiversidad de la zona de estudio ya que las características de *Eucalyptus* sp. y *Pinus* sp. impiden el crecimiento de fauna y flora asociada a estas plantaciones. Por citar algunos casos: la falta de la ventana de luz que permitiría florecer a la flora autóctona, el desfase entre la floración (invernal en el caso del eucalipto) y la necesidad de alimento de aves reproductoras, la falta del estrato herbáceo y arbustivo, etc. consecuencias derivadas de la influencia de los aceites esenciales producidos por el eucalipto, por sus características anatómicas o por las técnicas de aprovechamiento forestal (Loidi 2005).

Estos resultados muestran que las UV cuya conservación y recuperación se considera prioritaria ocupan áreas reducidas, y en consecuencia, se ha propuesto que la fórmula de conversión de los valores de IC (calidad ecosistémica) obtenidos en primas monetarias (PSA) contemple un factor de corrección negativo para el efecto de la superficie. La ecuación se muestra a continuación:

$$PSA = K \times IC_{ac} / (1 + \ln S)$$

K: constante de ajuste

IC_{ac}: valor de IC acumulado de la propiedad en cuestión (IC x ha)

S: superficie en hectáreas

PSA: Pago por Servicios Ambientales a propietario rural

Para comprender el funcionamiento de la fórmula se realiza una simulación, en la que se toman valores de manchas obtenidos en el trabajo y se interpretan como si dichas manchas fueran propiedades. Se seleccionan 10 de diferentes tamaños, que se muestran en la Tabla 3.2.

Tabla 3.2. Simulación de funcionamiento de la conversión propuesta.
Table 3.2. Simulation of the proposed convertion.

Propietarios	Superficie (ha)	IC_{ac}	1 + ln S	IC_{ac} /(1+ ln S)
1	0.6	18	0.49	36.73
2	1.8	214	1.59	134.59
3	2.2	118	1.79	65.92
4	9.6	741	3.26	227.30
5	16.9	4 013	3.83	1 047.78
6	25.5	10 614	4.24	2 503.30
7	132.4	1518	5.89	257.72
8	320.1	17 500	6.77	2 584.93
9	681.2	25 142	7.52	3 343.35
10	2 614.5	641 718	8.87	72 347.01

Los valores obtenidos para S, el valor de IC acumulado (IC_{ac}) y la división (IC_{ac}/ (1 + Ln S)) se han trasladado a la siguiente figura (Fig. 4a) en la que se observa que, aunque el valor de IC prima las grandes extensiones de terreno con una calidad ecosistémica notable, su conversión en PSA corrige y evita que exista una relación directa entre superficie y percepción de compensación económica.

Con ello, lo que se pretende es crear una política de "primas compensatorias" para pequeños propietarios, alcanzando un objetivo doble: mantener la población rural en el campo y aumentar el número de hectáreas con bosque natural.

Las figuras siguientes (Fig 3.4b y 3.4c) muestran el funcionamiento para propiedades de una superficie entre media hectárea y diez. En el primer caso, superficies menores de una hectárea, el valor obtenido de la ecuación dobla el valor de la calidad ecosistémica, potenciando de esta manera la protección de pequeñas superficies que podrían funcionar como reservorio de hábitats para futuras actuaciones.

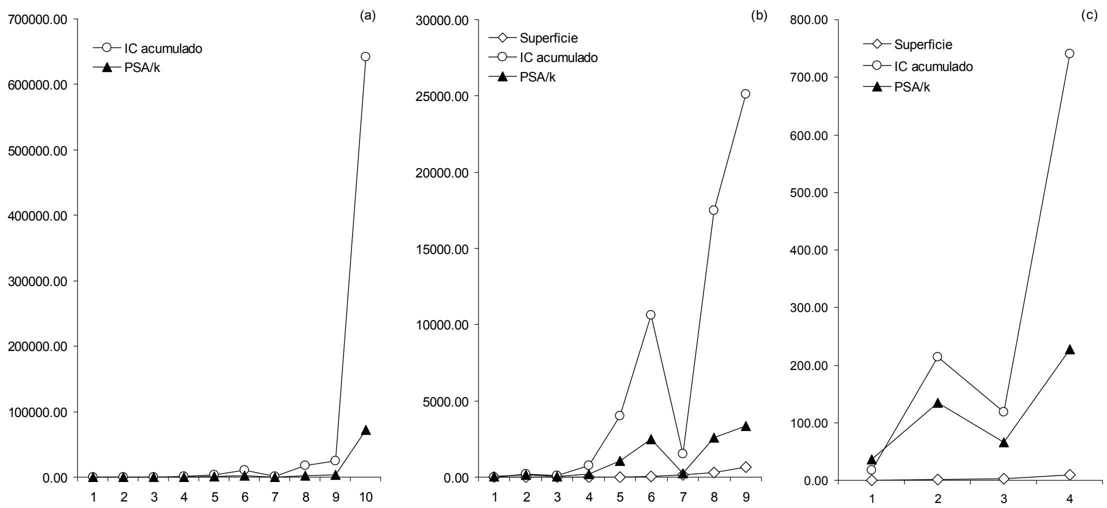

Fig. 3.4. Simulación del funcionamiento de la conversión propuesta. (4a) Resultados para las propiedades ficticias 1 a 10. (4b) Resultados logrados para las propiedades 1 a 9. (4c) Resultados logrados para las propiedades 1 a 4.

Fig. 3.4. Simulated functioning of the proposed conversion. (4a) Results for the fictitious land properties 1 to 10. (4b) Results obtained for 1 to 9. (4c) Results obtained for properties 1 to 4.

3.4 Discusión

Desde esta investigación se recomienda utilizar el PSA como instrumento para favorecer la conservación de los hábitats y de las especies naturales. Tal y como apuntan los estudios consultados (FAO 2003, Grieve 2003a, Pagiola *et al*. 2004, Scherr *et al.* 2006), el uso de un índice que evalúe la calidad ecosistémica de un área permitirá ofrecer una recompensa económica en base al estado de naturalidad de la propiedad, así como hacer un seguimiento para controlar que el "servicio" por el cual se está pagando esté llevándose a cabo. Proteger la biodiversidad y la riqueza ecológica de nuestro entorno aporta beneficios cuantitativos al ser humano y, por ello, el propietario cuyos terrenos tienen cierta calidad ecosistémica debe ser económicamente premiado e incentivado.

Las cifras calculadas de IC muestran que las unidades de vegetación que obtienen valores elevados realizan una función importante en el mantenimiento de la calidad ecosistémica de la cuenca, que deben ser interpretados en términos de beneficios (servicios ambientales) sobre los asentamientos humanos, no sólo del territorio en cuestión (cuenca del Golako), sino sobre una zona geográfica más amplia: la Reserva de la Biosfera de Urdaibai y su entorno geográfico.

Desde una perspectiva de conservación, la función que cumplen las áreas agrícolas y las manchas boscosas a ellas asociadas está siendo reconocida dentro de políticas de financiacion de esquemas agroambientales (AES). Áreas sujetas a dicho esquema podrían ver aumentada su capacidad para hacer frente al cambio climático, a la fragmentación del hábitat y al aumento de la presencia de especies exóticas invasoras (Donald y Evans 2006), así como actuar de reservorio de semillas, refugio de especies de interés para la polinización de los cultivos (Öckinger y Smith 2007), conservación de flora y fauna nativa, reducción de la erosión y de la contaminación difusa por pesticidas y potenciación del control de pestes por especies depredadoras naturales (Olson y Wäckers 2007). En este marco, los resultados derivados de nuestro estudio en una cuenca atlántica europea, caracterizada por la coexistencia de prácticas agrícolas tradicionales con un cierto grado de naturalidad paisajística y de la que forma parte el bosque (en distintos estados de conservación, i.e. valores de IC) mostrarían versatilidad en relación a su implementación en políticas de conservación en el contexto de los sistemas agrícolas mesoamericanos (Harvey *et al*. 2008).

El conjunto de trabajos realizados bajo la filosofía de AES sugieren que los valores otorgados en el presente estudio a las unidades PA y ZR deberán de incrementarse si se observan cambios con respecto a los servicios ambientales prestados, siguiendo así las directrices marcadas por las actuales políticas de conservación del territorio.

Así mismo, constatamos la necesidad de seguir desarrollando el índice para primar aquellas unidades de vegetación para las que se están observando ciertas necesidades de protección desde estamentos de la Unión Europea, tal es el caso de los brezales, además de los ya citados pastos. Así como estudiar el parámetro de Suelo del índice teniendo en cuenta las limitaciones técnicas de la metodología aplicada y las tendencias actuales (FAO 2002).

Por otro lado, es evidente que ciertas unidades no colaboran en el aumento del servicio ambiental de la cuenca, y, en el caso de las plantaciones forestales, éstas son especialmente dañinas para con la biodiversidad, el suelo, la calidad del agua, especialmente si se utilizan técnicas agresivas de silvicultura. Por ello, se considera que se debe plantear el papel que las actuales subvenciones a la plantación de pino y de eucalipto están realizando, al haberse transformado en incentivos perversos que contradicen las actuales políticas a favor del desarrollo sostenible.

El Índice IC desarrollado se fundamenta en los beneficios reconocidos por el esquema costarricense: la protección del recurso hídrico está representado por H, la conservación de la biodiversidad es el valor biológico (B, suma de Naturalidad, Resiliencia, Amenaza, Valor Florístico-fitocenótico, Rareza), la belleza escénica evoluciona hacia el concepto del Coeficiente de necesidades territoriales (E) y la retención de carbono es RC. En IC aparece una valoración del suelo (S) no reconocida por el sistema costarricense. Las tres unidades de vegetación valoradas inicialmente (plantaciones, bosques y sistemas agrícolas) se desarrollan en las 9 UV del estudio: BR, BM, BD, PA, BZ, PP, PE, PF, ZR. Sin embargo, en el estudio se hace una valoración *in situ* de estos parámetros, aspecto que hasta ahora no era desarrollado en el esquema oficial de PSA de Costa Rica (Pagiola 2002).

Las estrategias y planes de conservación atienden a las diferentes necesidades sociales y ecológicas regionales y redundan por tanto en una disparidad en los intereses y objetivos planteados. En países de Centro y Sudamérica (Nicaragua, Costa Rica, Colombia) existen iniciativas privadas que desarrollan un pago por servicios ambientales por la conservación de la biodiversidad y secuestro de carbono en paisajes agrícolas en base al incremento de los servicios ofrecidos por el propietario (Pagiola *et al*. 2004). El índice del servicio ambiental desarrollado es igual a la suma de dos índices, el de biodiversidad y el de secuestro de carbono, los cuales varían dependiendo exclusivamente del uso de la tierra. Si bien existe una limitación de base científica en este planteamiento, facilita el uso de un índice por personal no cualificado. Análogamente, se han realizado trabajos en Nueva Gales del Sur (Australia) en los que los objetivos de secuestro de carbono, mitigación de la salinidad, mitigación de suelos sulfatados, promoción de la biodiversidad, retención de suelo y mejora de la calidad de agua se sitúan en el contexto de un nuevo mercado económico creado para promover el cambio de uso de la tierra en propiedades privadas (Grieve 2003 a y b, Montagu *et al.* 2003, Oliver y Parkes 2003).

En cualquier caso, subyace una unidad de base dentro de las distintas formulaciones de PSA en lo que respecta a la necesidad perentoria de diseñar políticas de conservación eficaces. Es por ello que consideramos que se deben favorecer estudios de intercalibrado entre los distintos índices que permitan el desarrollo sobre bases científicas de metodologías comunes, preferentemente sencillas y fácilmente trasladables a los diferentes actores y ecosistemas. Dichos métodos incluyen dos capítulos diferenciados: a) las herramientas científico-técnicas (diseño e implementación de los índices de valoración ecosistémica) y b) las herramientas de gestión (económica, administrativa y política del PSA). En este segundo apartado la experiencia pionera de Costa Rica proporciona elementos que permiten ahorrar etapas a países que se incorporan a prácticas de Conservacion del Territorio.

Con este trabajo queremos cointribuir al desarrollo de líneas de actuación (metodología para otorgar primas económicas) basadas en índices de interés de conservación ecosistémico de las propiedades, de aplicación interregional.

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4 BIOLOGICAL VALUE ASSESSMENT

I. Ecological landscape assessment in a silvicultural system; A biological quality index as a measure of conservation in a coastal Atlantic ecosystem

II. Complementary analysis. B index application at Alonsotegi municipality territory

III. Complementary topographic material

I. Ecological landscape assessment in a silvicultural system; A biological quality index as a measure of conservation in a coastal Atlantic ecosystem

Abstract

Forestry industry has transformed deciduous Cantabrian colline landscape from very diverse ecosystems into exotic monospecific *Pinus* sp. or *Eucalyptus* sp. tree plantations. Our aim was to determine the biological quality present at a forested and protected catchment based on vascular plant communities' field examination and cartographic and airborne 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 catchment in the Atlantic Iberian Peninsula (Urdaibai Biosphere Reserve –UNESCO/ Natura 2000 site-, Basque Country) individually assessing 158 vegetation fragments included in ten quadrats (25 ha each). A comparison of land use distribution between exotic coniferous plantations and native forests showed a ratio ~11:1, where *Quercus robur* oak forests have been fragmented and reduced to small patches, mostly below 1 ha (73.7% of fragments), whereas the ratio real to potential cover revealed occupation below 8% of potential territory, confined to altitudes and slopes over 200 m a.s.l. and 30%, respectively. Mean biological value of the basin (38.4% of maximum) correlated to conifer plantation surface and 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.

Resumen

La industria forestal ha transformado el paisaje colino, decíduo, cantábrico de un ecosistema diverso en plantaciones exóticas y monoespecíficas de *Pinus* sp. or *Eucalyptus* sp. Nuestro objetivo en este estudio era determinar la calidad biológica presente en una cuenca forestal protegida, basándonos en el examen de las comunidades de plantas vasculares y en análisis de información cartográfica y ortofotos. Hemos transformado mapas de vegetación en mapas de calidad biológica, que pueden ser rápidamente interpretadas en términos de estado de conservación en aras de una gestión territorial. Hemos testado el índice a lo largo de una cuenca antropizada, pero protegida, de la la Península Ibérica (Reserva de la Biosfera de Urdaibai – UNESCO – Natura 2000- de Euskadi) analizando los 158 fragmentos de vegetación encontrados en diez estaciones de muestreo (25 ha cada una). Una comparativa de la distribución de uso del suelo entre plantaciones de coníferas exóticas y bosques autóctonos mostró un ratio ~11:1, donde los robledales de *Quercus robur* han sido fragmentados y reducidos a teselas de pequeño tamaño, principalmente por debajo de una hectárea (73.7% de los fragmentos), mientras que el ratio vegetación real a potencial mostró una ocupación por debajo del 8% del territorio potencial, confinado a altitudes y pendientes por encima de 200 m s.n.m. y 30%, respectivamente. La media del valor biológico para la cuenca (38.4% del máximo) estaba correlacionada con la superficie de plantaciones de coníferas, mientra que el bosque aparecía como la única unidad de vegetación capaz de obtener valores del índice por encima del 50%. Un acercamiento cuantitativo para determinar si los robledales locales podrían considerarse en un estado de conservación favorable implicó estudiar la covariación entre los valores del índice y el tamaño de la tesela por medio de modelos asintóticos que proveerían un valor biológico máximo esperado asociado a una superficie mínima requerida (72.9% para 2.5ha). Hemos obtenido los mayores valores del índice (77.1%) para teselas de robledal ≥5.0 ha, a pesar de que fragmentos por encima de ese tamaño representan el 2.9% de la cuenca. Los robledales están lejos de tener un estado de conservación favorable, revelando que las actuales políticas de protección proveen de escaso refugio a los bosques nativos, donde las políticas de silvicultura gobiernan el paisaje.

4.1 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 between 0 and 600 m a.s.l.) by monocultures of exotic, basically coniferous and *Eucalyptus*, species. This transformation of lowland landscape affects mainly vicariant *Q. robur* oak 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, Lomba et al. 2004, 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 and 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 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 Gutiérrez 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 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. 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: i) analysed topographic distribution of vegetation and assessed overall biological value by means of a phytosociological Index after individual characterization of the main vegetation units; ii) confronted present woodland cover against both topographic predictors and maps of potential cover; and iii) ascertained index resolution as regards to quantitative evaluation of conservation status focusing on detailed evaluation of woodland as the main potential habitat.

4.2 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 airborne photographs have been used to asses 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.

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

(eq. 4.1) $$\mathbf{B = N + P + T + F + R}$$

According to Loidi (1994) 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) as the ability of a vegetation type to recover itself after disturbance by natural or humanly induced causes, Threat (T) as related to various factors associated to human socioeconomic circumstances of a given territory, Floristic value (F) as the specific diversity of the formation, phytosociological diversity, vegetation structural diversity, the particular relationships between organisms and the content of endemic flora or syntaxa and Rarity (R) as 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 quality index ranging between 0.0 (no vegetation) and 50.0. 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 (Tb. 4.1). 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 and Orrantia et al. 2008) although we would further briefly clarify several facets related to fieldwork.

4.2.1 Study area

The field study took place at the Golako River catchment (3 462 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).

TABLE 4.1. 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 (association and alliance level)	Syntaxa	EUNIS code	EUNIS description
MF/DF	Mature/ Degraded 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	Acidophylous 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 plantt.	∅	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

Golako river course (15 km) is part of Natura 2000 European Network (code SAC-ES2130006) and the whole catchment is included in the 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 goes from 1 to 776 m a.s.l., 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 2013). Local climatophilous forests are acidophilous and mesophytic pedunculate oak (*Q. robur*) forests related to low altitude (0-500 m a.s.l.), moderate slope (mean 15%) and high minimum temperatures of the coldest month (mean 9.6ºC) (Roces-Díaz et al. 2014).

4.2.2 Vegetation units

The first step was to identify the vegetation units (VU) of the area adopting the main typology from the Vegetation Map of the Autonomous Community of the Basque Country (Gobierno Vasco 1990) and adapting it to phytosociological typology described by Loidi et al. (1997) and Rivas-Martínez et al. (2011). Extensive trekking along the Golako watercourse and its surroundings led to define ten different vegetation units which accounted for the variety of ecosystems present at the catchment (Table 1): hygrophilous forest (RF), climatophilous broadleaved deciduous forests (mature –MF- and degraded –DF-), heathlands (HT), meadows (MD) and coniferous (PP), *Eucalyptus* (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 Bölöni et al. 2007). The homogeneity of the vegetation units encountered simplified description and standardisation processes.

4.2.3 Fieldwork procedures

The catchment's altitudinal distribution gathers 46.20% of the territory between 100 and 250 m a.s.l., with a maximum at 150-170 m a.s.l (Fig. 8.5). 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. The conducting thread was a middle mountain stream with its river forest which, although actually covering a very small area, was present at almost every plot. 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.

Once all vegetation units were identified, we mapped every vegetation patch within a given plot. 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 airborne photographs and their surface area quantified. A file was created including real (Gobierno Vasco 2009) and potential vegetation (Gobierno Vasco 2011, Loidi et al. 2011) and topographic (Gobierno Vasco 2008) maps as well as airborne information (Gobierno Vasco 2004). When available, we consulted earlier and later topographic maps (2001 and 2011, scale 1:10 000) and former airborne 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 undertook a restitution of the cartographic data: computerized information of initial fieldwork together with maps from the airborne records were revised again in the field, and cartographic facts were corrected where needed.

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. We considered biological and ecological characteristics gathered in the field and, after the computerized work, we revised and obtained a final biological index value for each patch at every plot and for every vegetation unit. As regards individual plot evaluation, intensive fieldwork gave a real index value for each patch. We analysed biological values attained for each patch and summed all patches within the plot. Since total plot's size was 25ha, 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) (Tb. 4.1).

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 (Tb. 4.1) 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.

4.2.4 GIS and Statistical analyses

The first approach to computerized cartography was undergone by vector drawing computer program and GIS program (gvSIG 2014). Later we used QuantumGIS program (QGIS 2015) for the Digital Elevation Model (DEM) analysis that would allow us to merge all topographic and vegetation information (S4.1-S4.3 and Annex 1, Fig. 8.1-8.7).

Catchment's and plots' elevation, slope and aspect values were GIS calculated after a Digital Elevation Model (DEM) of the Basque Country: we transformed an altitudinal map (IGN 2015) onto an elevation raster and derived slope and aspect information. In order to have topographic information of the whole basin and of the plots where B index was applied we worked in two different levels: i) we generated a regular squared grid that covered the whole basin (20*20 m/cell) and ii) we created a grid for every plot of 625 cells (25*25 cells/plot of 20*20 m/cell). Both grids were coincident with all topographic raster cells (20*20m). Then we merged the information of the three topographic raster layers and the actual and potential vegetation vectorial layers with the catchment's grid and the plots' grid to obtain elevation, slope and aspect cell values, and elevation and slope means and standard deviation (SD) values and aspect frequencies for each patch and plot (see Tb. 4.2 for plot values).

The topographic profile of the catchment (see supporting information S4.1.Fig. 1 and S4.2.Fig 2) was represented by elevation range (m a.s.l.) and slope (%) measured as the average for each vegetation unit (supporting information S4.3.Tb. 4.1). In the comparison of patch surface and plot's topographic factors (slope, elevation) for every rural and forest patch within the plots 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.

Basin and plots topographic information (histograms and ANOVA) had been processed using R (altitude and slope means and SD, Tb. 4.2). 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 (Copyright© SYSTAT software, Inc. 2007).

4.3 Results

4.3.1 Characterization of the country

GIS analysis of vegetation unit distribution in the basin (Tb. 4.2) 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* oak 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*) and some blue-gum eucalypt (principally *Eucalyptus globulus* 5.5%) and other deciduous plantations (1.5%). Rural areas covered 2.4% of the catchment, and above 200 m a.s.l. 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 (Gobierno Vasco 2011) exhibited the following landscape distribution: 5.9% represented by ash/alder alluvial forests of the series *Hyperico androsaemi-Alnetum glutinosae*, 30.1% and 63.8% by Atlantic mesophytic (*Polysticho setiferi-Fraxinetum excelsioris*) and acidophilous (*Hyperico pulchri-Quercetum roboris*) oak forests respectively, and 0.1% corresponding to Atlantic acidophilous beech forests (*Saxifrago hirsutae-Fagetum sylvaticae*). Mesophytic forest would be expected primarily below 200 m a.s.l. (76.9%) occupying 48.3% of the lower basin, whereas acidophilous forests would appear basically above 200 m a.s.l. (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.

TABLE 4.2. 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 data obtained after field work and GIS analysis. Forests at plot scale are mesophytic (MF) and acidophilous (DF, including degraded and juvenile) and at basin scale mesophytic and acidophilous are included in MF while DF is only for juvenile forests (EUNIS G5.61). Topographic units are altitude (m a.s.l.), slope gradient (%) and direction -aspect- (º, highest frecuency)

		Number of patches/ surface (%)																							
	VU	P1		P2		P3		P4		P5		P6		P7		P8		P9		P10		10Plot		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)**
Eucalipt 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		N 32.64		E 37.92		E 39.36		S 31.2		W 34.72		E 45.92		N 49.92		W 39.52					

The influence of the topographic profile upon major vegetation units in the area (rural areas, meadows, oak forests and conifer plantations) was mainly significant (Tb. 4.3). Meadows appeared mostly at lower slopes (15-20%), whereas conifer plantation plot cover covariated with elevation: between 175 and 225 m a.s.l. plantations increased significantly when compared with both lower and higher elevations (Tukey/Kramer). No effects were evident for rural areas, although there was a tendency (P-value 0.06) to appear mostly at lower slopes, and conversely, degraded forests were present at higher slopes (>40%) and altitudes (250-450 m a.s.l.). Degraded forest plot cells appeared at very significant numbers (X^2=572.0, degrees of freedom=3, P-value<0.0001) at Northern aspects.

Table 4.3. ANOVA analysis of patch surface (percentage of VU surface at plot, plots mean ± SE) in various vegetation units taking plot's elevation (m a.s.l.) 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	3.17 ± 0.91	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 a.s.l.)	30-150	175-225	250-425
Slope	(%)	15-20	25-35	>40

Opposite trends for rural areas and woodlands regarding slope and elevation are shown in Fig. 4.1a and Fig. 4.1b, along with the results of non-linear regression analysis fitting asymptotic functions of the type $y = a - b * e^{(cx)}$ and $y = a + b * e^{-(cx)}$, where parameter *a* stands for minimum asymptotic value for either slope or elevation. Equations explained from 77% to 88% of actual variation and asymptotic minimum was found for forests and for rural areas with reference to slope gradient values: 1.05 ha (ASE, asymptotic standard error = 1.10) for slopes below 30% in DF and, conversely, 1.47 ha (ASE = 2.72) over 30% for RA. Effects of mean elevation on its turn set a crossing point at ~150 m a.s.l., but patch size minima were set at 0.4 ha for DF and 0.56 ha for RA (asymptotic standard error = 7.10 and 0.50 respectively).

Frequencies of appearance of every cardinal point in each plot were computed (DEM analysis) and taken as predictors of degraded forest cover dynamics: forest surface (%) raised exponentially associated to increased proportion of ground eastern orientated in every plot, whereas the opposite trend in linear terms was found as regards the frequency of northern and western territories (Fig. 4.1c). Regression lines explained 93% of variability in relation to positive effect of eastern orientation and 89% for negative influence of combined northern and western aspects. In both cases P10 has been excluded from analysis.

4.3.2 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 mature forest patch present at P3 (43.0) followed by riparian forests with values that ranged between 39.0 (P3RF02/03) and 43.0 (P4RF02/03) and mean biological value of 40.5 (Fig. 4.2a). Patches P3RF02/03 were a narrow riparian strip (one tree wide) while the two other patches were part of a riparian strand that run out of the plot, surrounded by a garden, an orchard and a road in the first case and by coniferous plantations in the second one.

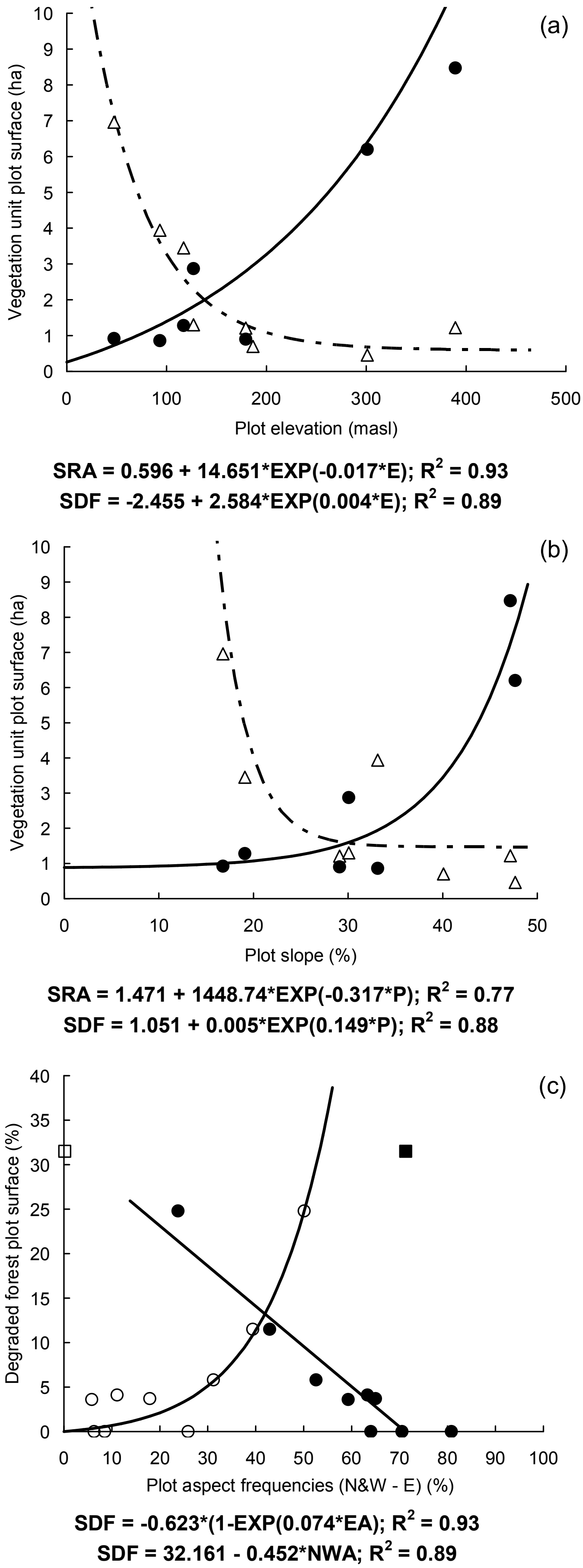

Figure 4.1. Comparative distribution of patch surface of rural areas and degraded forests with respect to plot's elevation (m a.s.l.), slope (%) and aspect (only forests, º). The size of every fragment that appeared at rural areas (SRA, triangle) and degraded forests (SDF, dot) was related to (a) altitude average (E) and (b) slope average (P) of the plot where it appeared. Plots altitude and slope mean values were obtained after DEM analysis of the whole plot (each plot was divided onto 625 cells of of 20*20 m/cell). For forest aspect analysis (c), we reclassified DEM aspect data into four quadrants related to exposure to cold weather: northern (316-45º), eastern (46-135º), southern (136-225º), western (226-315º) and obtained each quadrant frequency for each plot. Forest surface was related with eastern (white dot) and northern&western (black dot) aspects: highest aspect frequencies were either for increasing sizes at eastern aspects (EA) or decreasing sizes at northern&western aspects (NWA); data from plot 10 (square) is an outlier. Equations are shown

Detailed analyses of Degraded Forest biological value (Fig. 4.2b) 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 (two patches where B=8.0, and 25 patches with B=16.0 (mean B =15.1 ± 2.9). Tree cultures (conifers, *Eucalyptus* and deciduous) showed values lower than 9.5, along with rural areas where green gardens and orchards were included improving their evaluation.

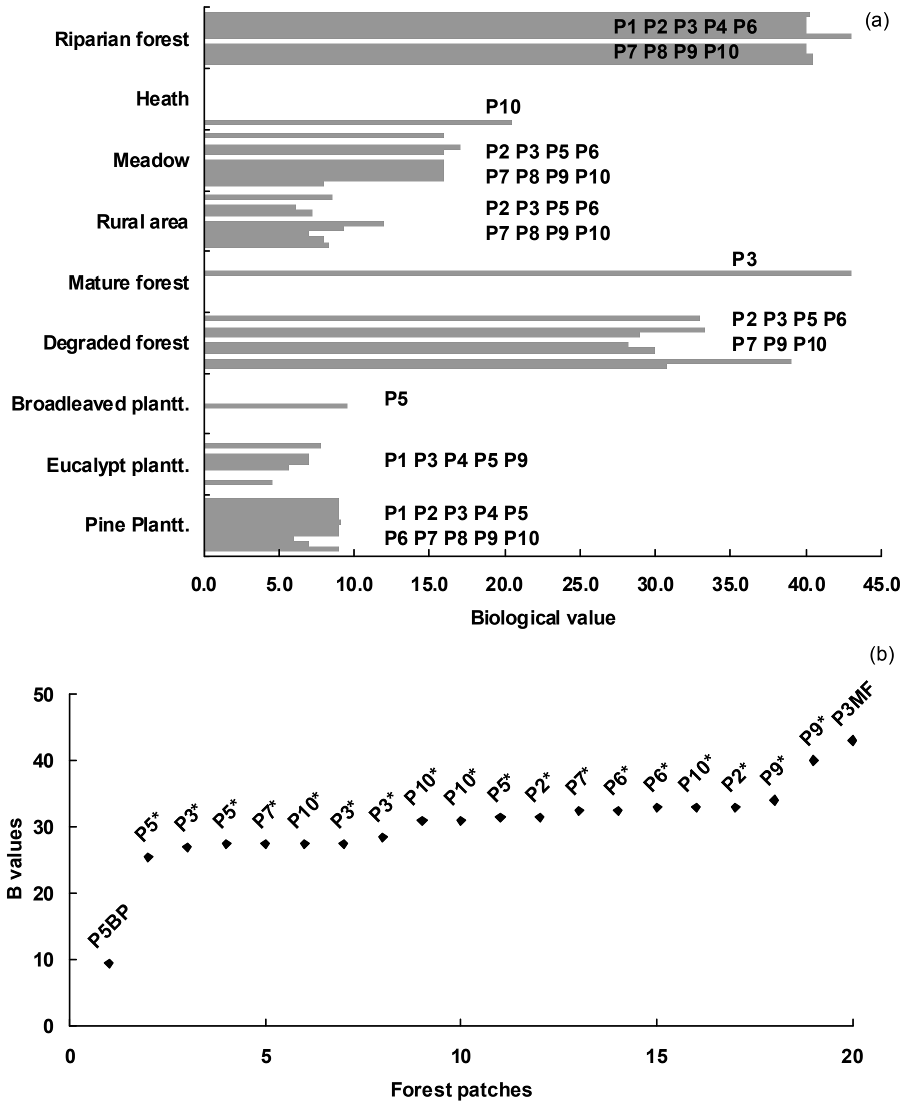

Figure 4.2. (a) Bar plot of biological value index for each vegetation unit inspected at the Golako river basin. b) Ranked distribution of forest B index. We surveyed ten quadrats (from P1 to P10, 25 ha/quadrat) and extracted index values (B, unitless) obtained at each plot for every fragment of deciduous forest (*), highlighting a maximum (mature forest, P3MF) and a minimum (broadleaf plantation, P5BP).

Coniferous plantations appeared as the main factor explaining B mean plot values -B_{plot}- (Fig. 4.3) 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-value$_{slope}$= 0.0046). Estimations for the intercept were highly significant (p-value$_{intercept}$< 0.0001) predicting maximum mean B_{plot} value of 38.2% at coniferous cover of 0% (Fig. 4.3a). Conversely a positive correlation (R^2 = 0.78) appeared between B_{plot} values and total number of fragments per plot (Fig. 4.3b). We undertook the analysis with actual plot figures (n =10) and added a baseline represented by a plot with a single fragment (n =11) with identical results (p-value$_{slope}$= 0.0011 and p-value$_{intercept}$= 0.0002): decreasing number of fragments related to coniferous plantation reduced mean B_{plot} value to a minimum of 6.21 for homogeneous plot (one fragment).

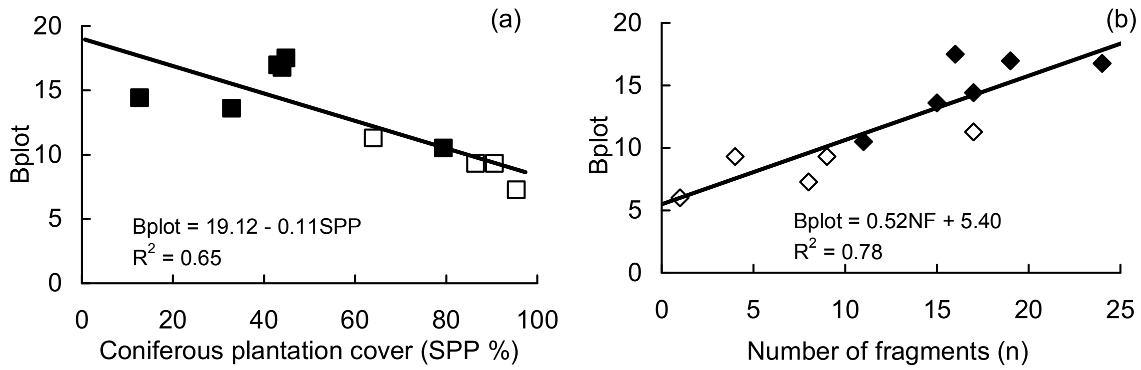

Figure 4.3. Linear regression analysis between mean biological value index attained per plot (Bplot) and (a) coniferous plantation cover (SPP%) or (b) number of fragments (NF). White figures indicate absence and black figures presence of consolidated dwelling (more than 3 inhabited houses). Equations are shown.

4.3.3 Biological value index in woodland landscape

Only degraded forests and rural areas had shown variability in terms of biological values for the various plots. Gradual discrimination was registered only for forest patches (Fig. 4.2a). The degraded forest set (n=18) presented high B variability associated to different degrees of conservation that followed a continuum between 25.5 and 40.0 standing for 50% to 80% rating as related to maximum B index (50). We found variability in biological value index for degraded forest patches including a plantation stand (P5BP01 = 9.5) and a mature forest patch (P3MF01 = 43.0) as extreme values (Fig. 4.2b). Forest patches within plots (n = 19, DF and MF) exhibited wide variability in terms of surface (from 0.1 to 6 ha) though 73.7% of those patches (n=14) had a size below 1.0 hectare accounting for 32.1% of oak forest total cover within the plots (Fig. 4.4a).

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 added seven samples below 0.04 ha, previously discarded (n=14+7). We obtained an asymptotic non-linear regression equation (eqn. 1) that provided an estimation of the maximum B attained (Fig. 4.4b), where figures in brackets represent Wald 95% confidence interval:

(eq. 4.1) **Oak forest Biological value (below 1 ha) = 31.56 (±3.37) (1-exp$^{\mathbf{(-16.44\ (\pm 9.87)\ SDF)}}$);**

$R^2_{\text{Mean corrected}} = 0.92$ n=21

Estimated value for saturation parameter (31.56) appeared significant (Asymptotic Standard Error = 0.79) and the model explained 91.5% of experimental variation. With upper cover been set at one hectare, minimum forest patch size required to reach maximum B was one hectare.

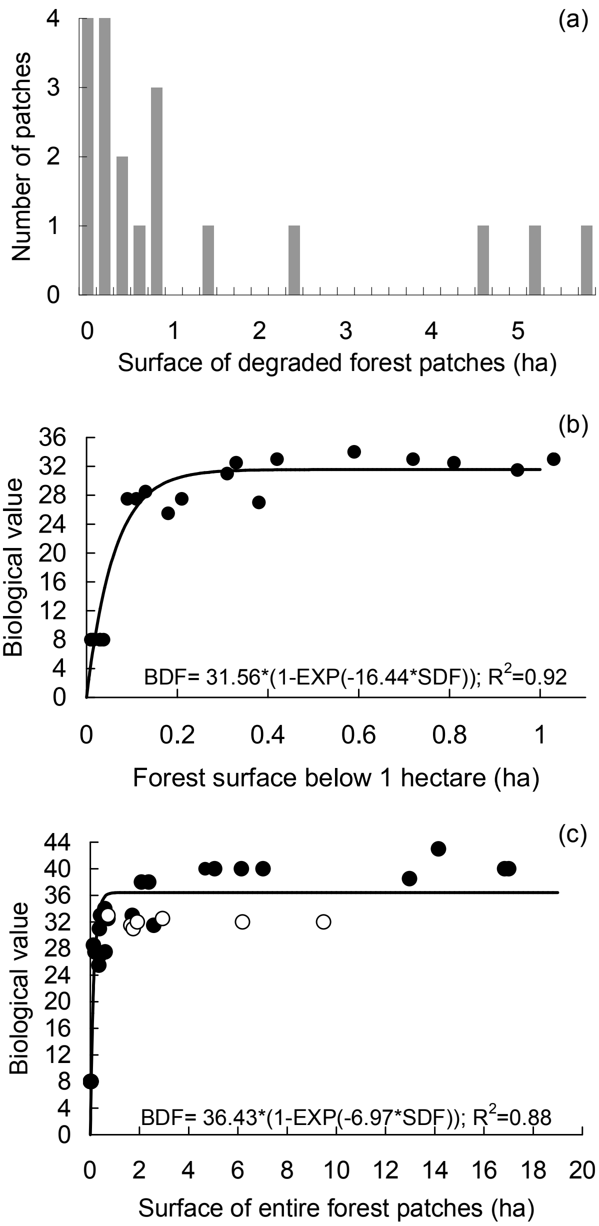

Figure 4.4. Frequency distribution of degraded deciduous forest patches in relation to surface. Asymptotic relationship between index of biological value for degraded deciduous forest (BDF = unitless) and patch size (SDF = ha) (b) below one hectare (n=21) and (c) at catchment scale (n=29). Asymptotic equations obtained by non-linear regression analyses are shown.

In order to be able to scale results to the whole basin we widened our survey of oak forest including in the study 29 forest fragments according to following criteria: a) since we had observed that those patches within the plot that had continuity outside it (larger real surface) attained higher biological values than those smaller patches completely enclosed in it, we analysed complete fragments including area outside the plot when necessary; b) to increase resolution over one hectare we included in this sample a large proportion of basin patches, underrepresented at plot scale (Fig. 4.4c) and which corresponded to 56% of total catchment's forest surface; c) we included seven values were DF < 0.4 ha (B=8) in an approach to theoretical zero. This modification involved analysing every fragment over 4.5 ha present in the basin (8 fragments) (eqn. 4.2). A set of seven points ranging from 0.7 to 9.5 ha appearing in Fig. 4.4c presented 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.

(eq. 4.2) **Oak forest Biological value (plot) = 36.43 (±2.29) (1-e $^{(-6.97\ (\pm 2.43)\ SDF)}$)**

$R^2_{\text{Mean corrected}} = 0.88$ 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 0.1 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 (Tb. 4.4). Significant differences between fragment sizes categories (p = <0.0001) appeared.

Table 4.4. 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 Tb. 4.3. (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 (Tb. 4.5), 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 4.5. A multiple regression analysis of all the parameters within the Biological index shows resilience as the worst adjusted. (a) is intercept coefficient and (b) is slope

	a	b	P-value	P-value (a)	R^2	F-statistic	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

4.4 Discussion

4.4.1 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%. Evidence for opposite trends in relation to topographic predictors (elevation and slope) as regards to human *vs*. forest occupation comes from plot analyses: presence of native lowland oak forest is highly associated to height and abruptness, in inverse correlation with human occupation (Fig.4.1). The shift-point derived from asymptotic models is set at an altitude ~150 m a.s.l. and a terrain slope ~30%: at slopes below 30% maximum forest surface is restricted to fragments of 1.1 ha and, conversely, human settlements above 30% are limited to 1.5 ha. 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 the later prevails. In this respect, Garcia 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 a.s.l. (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 a.s.l. 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.

4.4.2 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%). 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 (Fig. 4.2 b). Our results compare well with mean 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 / 35 º23'00"N) in Boteva et al. (2004). These values compare well with our own results of 67.6% (±4.9) 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) compare well with Mediterranean 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 data in Gómez-Mercado et al. (2007) and 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.

4.4.3 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 (Fig. 4.4), but also upon basin's overall biological value (Fig. 4.3). We have obtained a negative correlation between relative area devoted to pine plantations (PP) and mean biological value (B) of plots (Fig. 4.3a) setting a basin upper mean B index of 38.2% on 100% scale basis (elevation = 19.12, i.e. 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 also 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.

4.4.4 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.

FCS: 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 (see Annex 5.3) 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.

FCS: 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 73.7% of degraded forest patches were well below one hectare (Fig. 4.4a) 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 (Fig. 4.4b and Fig. 4.4c). 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 by Santos Martins et al. (2014) and Kouba et al. (2014) in different studies of biodiversity patterns in Iberian Peninsula's fauna and flora respectively.

A critical evaluation of asymptotic maximum as an instrument to predict minimum required surface to attain favourable conservation status can be undertaken comparing our results with 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 (Tb. 4.4). 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 and Robledano (2014) assessed forest biodiversity in *Pinus halepensis* in semiarid south-eastern Spain and found abundance and richness of both flora and woodland bird fauna associated to increased patch size. In the Pannoian Basin, Csorba and Szabó (2012) considered 30-40 ha patches viable for softwood forests and the Environment Canada Ministry (Environment Canada 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 2013) recognize FAO (FAO 2010) definitions of forest size minima values between 0.5 and 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 (see Annex 5.1). 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.

In sum, we have studied range, area, structure, function and oak forests future prospects at two sites of the Cantabrian colline belt and there is enough evidence that they are not at a favourable conservation status. Although it is not a threatened species, from a population perspective *Q. robur* oak forests should be understood as building blocks for conservation planning (after Wood & Gross, 2008) as interest in pedunculate oak forest preservation relies in its ecological functions and processes, the benefits that humans obtain from them and their cultural values. In this line, forest conservation importance, even of small fragments, relies also in the matrix they build (Bölöni et al. 2011; Fahrig 2001; Santos et al. 2002; Zapata and Robledano 2014) based on a large number of not necessarily the richest sites (Kouba et al. 2014), enabling migration, interactions and permeability of the landscape (Buček et al. 2012).

4.4.5 Overall analysis of the 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.

4.5 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 (73.7% 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. Presence of well conserved and similar *Q. robur* forest communities in Europe leave Spanish colline *Q. robur* forests out of the Habitat Directive. From our perspective, previous considerations provide grounds for the acknowledgement of these diverse phytosociological alliances located at the colline belt of the Cantabrian range as different plant communities to those found elsewhere in Europe in an attempt to sustain their future inclusion in Annex I of the Habitat Directive.

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II. Complementary analysis: B index application at Alonsotegi municipality territory

i. Preface and methodology

Until now (Chapters 2 and 3) we have analysed results obtained for CI index and B index at *Quercus robur* forest patches found at the study quadrats at Golako watershed. Next chapter (V) we undertake a topsoil analysis at Alonsotegi municipality that, although located at the same biogeographic region as Golako it shows a more heterogeneous landscape with other topographic characteristics (higher altitudes and greater slopes), with presence of several forest types and mainly non-protected territory.

In this last section of Chapter III we undergo a complementary performance of the B index assessment (Fig. 8.11), following the same methodology as in Golako basin for *Q. robur* oak forests, for the main forests types found at Alonsotegi, in an attempt to connect studies undertaken at Golako and Alonsotegi.

We have observed patch surface size and vegetation and obtained B index values for *Quercus robur* acidophilous forest (QR), *Fagus sylvatica* beech forest (FS) and Northwestern Iberian holm-oak *Quercus ilex* forest (QI). It has been included a last group recognized as “degraded forest” (DF, G5.61) which does not relate to the acidophilous forest described at Golako basin. Finally, *Quercus robur* forest patches at Golako were analyzed together, both acidophilous and mesophytic, while in Alonsotegi there were only acidophilous patches, as at those areas where mesophytic forest had potentiality to appear we only found *Pinus radiata* plantations.

ii. Results and Discussion

Surface distribution numbers for potential and real vegetation, topographic description (altitude, slope and aspect) and basic forest fragmentation data of Alonsotegi are discussed in next chapter (Tb. S%.1, 2 and 3 and Annex 2, Fig. 8.8-8.10). In general, forest mean patch size is smaller in Alonsotegi but also standard deviation values, as patch sizes in Alonsotegi are more homogeneous than at Golako while a few large size patches in Golako are increasing mean size values.

Forest patch size explained biological values for all forest types, both at Alonsotegi and at Golako, with R^2 above 48 except for *Quercus ilex* forests (Tb. 4.6) with an asymptotic relationship that followed the equation $B = a*(1-e^{(-b*S)})$ (Fig. 4.5). We have observed that *Q. robur* forest patches found at Golako showed greater biological values than those at Alonsotegi, related to greater mean sizes. Minimum fragment surface required to attain asymptotic B index values also differed among sites and forest types (S_{asym}, Tb. 4.6).

Table 4.6. Coefficients obtained for the asymptote ($B = a*(1-e^{(-b*S)})$) that explains the relationship between Biological value and forest patch surface, found at Alonsotegi and Golako (*). Patch size (S) shows mean±SD values (ha). Sasym shows S value for an increment of the asymptote bellow 0.0001%.

$B = a*(1-e^{(-b*S)})$	a	b	R^2	S	S_{asym}
QR+FS+QI	32.91	-2.61	0.48	2.42±2.95	1.0
Quercus robur	33.31	-2.37	0.50	1.88±2.56	5.0
Fagus sylvatica	32.88	-2.17	0.68	3.82±4.81	6.1
Quercus ilex	32.13	-3.88	0.11	2.19±2.72	3.6
Degraded (G5.61)	22.19	-5.10	0.52	1.64±1.12	2.7
*Q. robur**	36.43	-6.97	0.88	2.65±6.42	2.5
Q. robur below 1 ha*	31.56	-16.44	0.92	0.31±0.33	1.0

An analysis of covariance of the asymptotic biological value showed significant differences (p.value<0.0001) between forests and between sites, however, sizes were significantly different only between those two types found at Golako study, which was an artificial division. At a second ANCOVA analysis for B values we did not take into account this last group and obtained significant differences among forest units (p-value= 0.018), non significant among sizes (p-value=0.316) and very significant for the interaction between size and forest type (p-value< 0.0001), although Tukey/Kramer yielded no significant differences.

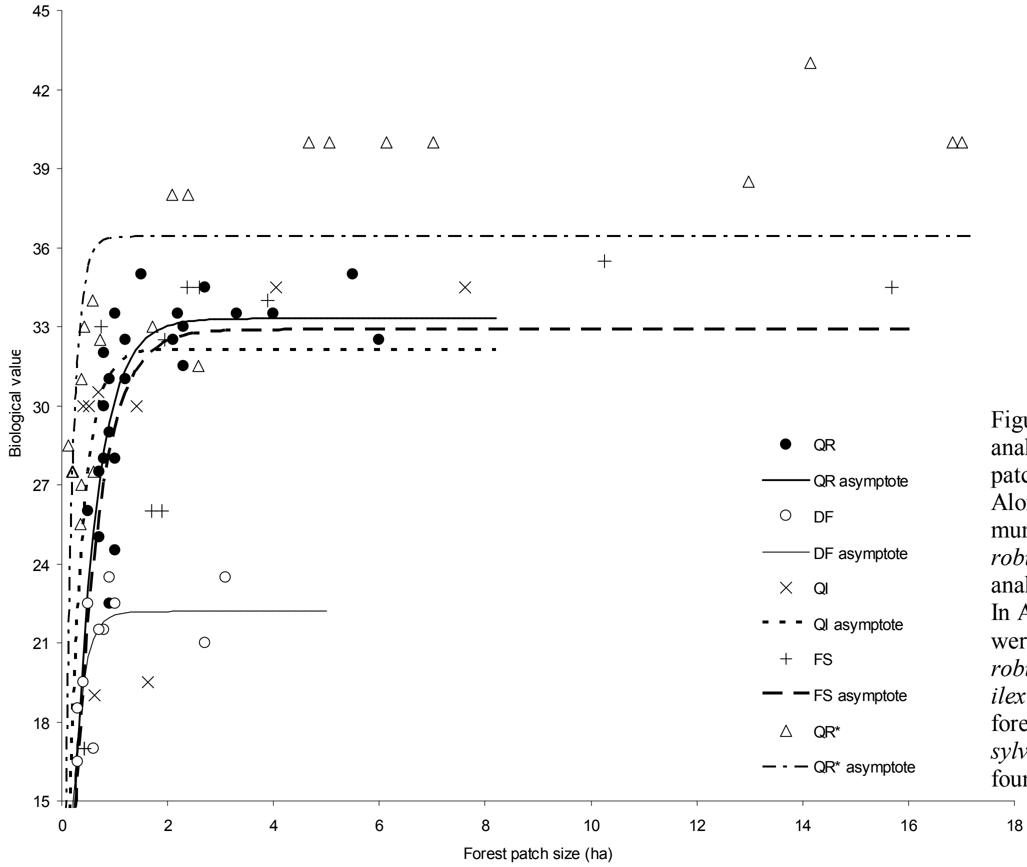

Figure 4.5. Regression analysis for all forest patches found at Alonsotegi municipality and for *Q. robur* at Golako analyzed in Fig. 4.4. In Alonsotegi there were QR, *Quercus robur*; QI, *Quercus ilex*; DF, degraded forest; FS, *Fagus sylvatica*; and QR*, found at Golako basin.

Golako is well represented by categories 1 and 3 of patch sizes (<1ha and >5ha) with B values 29.73 and 38.75 respectively (Tb. 4.4), while forest patch sizes at Alonsotegi belong to the second category (1-3 ha) which had a similar B value (33.44 at Golako).

Our vegetation assessment has shown that forest ecological quality is greater at Golako than at Alonsotegi and it could be related to the anthropic pressures which differ among both sites: while Golako is related to rural urbanization and forestry, at Alonsotegi urban and cattle grazing pressures are added to the equation.

Biscayne landscape has long been under transformation. Presence of "sel" structures in Alonsotegi and Golako is related to ancient cattle activities that colonized *Q. robur* forests (s. XI-XII) and which were later converted into agricultural lands (s. XVI). But despite the enormous land transformation undergone, the need of forest products (charcoal, ship industry, minery, and farm needs) kept forests away from total disappearance and it was not until s. XVIII that agriculture overcame and later, after industrialization and agricultural abandon (s. XX), mountains were afforested with exotic conifers that resulted in economic gains with little field work. Therefore, timber production has not initially induced forest disappearance and the process has been an afforestation of agricultural lands with exotic species, except at those sites with little soil and great slopes and altitudes were plantations were not productive (Trujillo 2004). Forest fragmentation and isolation have vegative effects on the richness and diversity of forests specialists (Kouba et al. 2014; Rodríguez-Loinaz et al. 2012). In this line, our results show that actual land-use after timber plantations constricts forest patch size which could be indirectly affecting the intrinsic characteristics of the forest, however reduced herb presence at plantations (Annex 4) implies that livestock-grazing affects mainly semi-natural units and lowers their intrinsic biological values.

The protected Golako basin has ~175 ha of *Q. robur* forests. The basin is mainly private land under intensive management and of small size (Ibarrondo & Amuchastegi 2008), although there are several public fragments directly managed by Bizkaia Provincial Council (~72 ha in 13 fragments, of which 22 ha in 5 fragments are forests, Fig. 8.4). This small property division gives little opportunity for the existence of greater patch sizes of any vegetation unit unless in the form of a consortium, as happens in the timber industry.

In contrast, Alonsotegi plantation occupancy decreases to 40% (Fig. 8.9) and gives place to a more diverse vegetation and land-use patterns, and there are more public mountains directly managed by Bizkaia Provincial Council (~1 124 ha in 24 fragments of which 235 ha are semi-natural units and only ~15 fragments are forests, Fig. 8.10). Still, this opportunity given by the existence of public land is not transformed into an increase of forest distribution related to direct management: although 42% of the forest is located at sites under the figure of Public Mountain, only 4% of this public land is covered by forests.

Besides urban and timber pressures, there is an important wandering livestock which is lowering intrinsic plant biodiversity of semi-natural habitats as well as Biological values as plantations have less herbs presence and are avoided by cattle. This value loss could be especially affecting beech forests, which show greater sizes than other forest types but whose B values are well below those found at Golako basin. In this sense, intense grazing pressure from domestic animals has been related to a lack of recruitment for long periods (80 y.) at lowland beech (*Fagus sylvatica*) and oak (*Q. robur*) forests of the Cantabrian range, whereas certain grazing low intensity activity of ungulates is beneficial for successful *Q. robur* regeneration where *F. sylvatica* is also present (Rozas 2003).

Alonsotegi's landscape heterogeneity is again related to inaccessibility or non productivity, sites not appropriate for coniferous plantations: karstic areas allow some development of *Q. ilex* forests, while at higher altitudes (>650 m asl) scrubs and *F. sylvatica* beech forests appear.

iii. References

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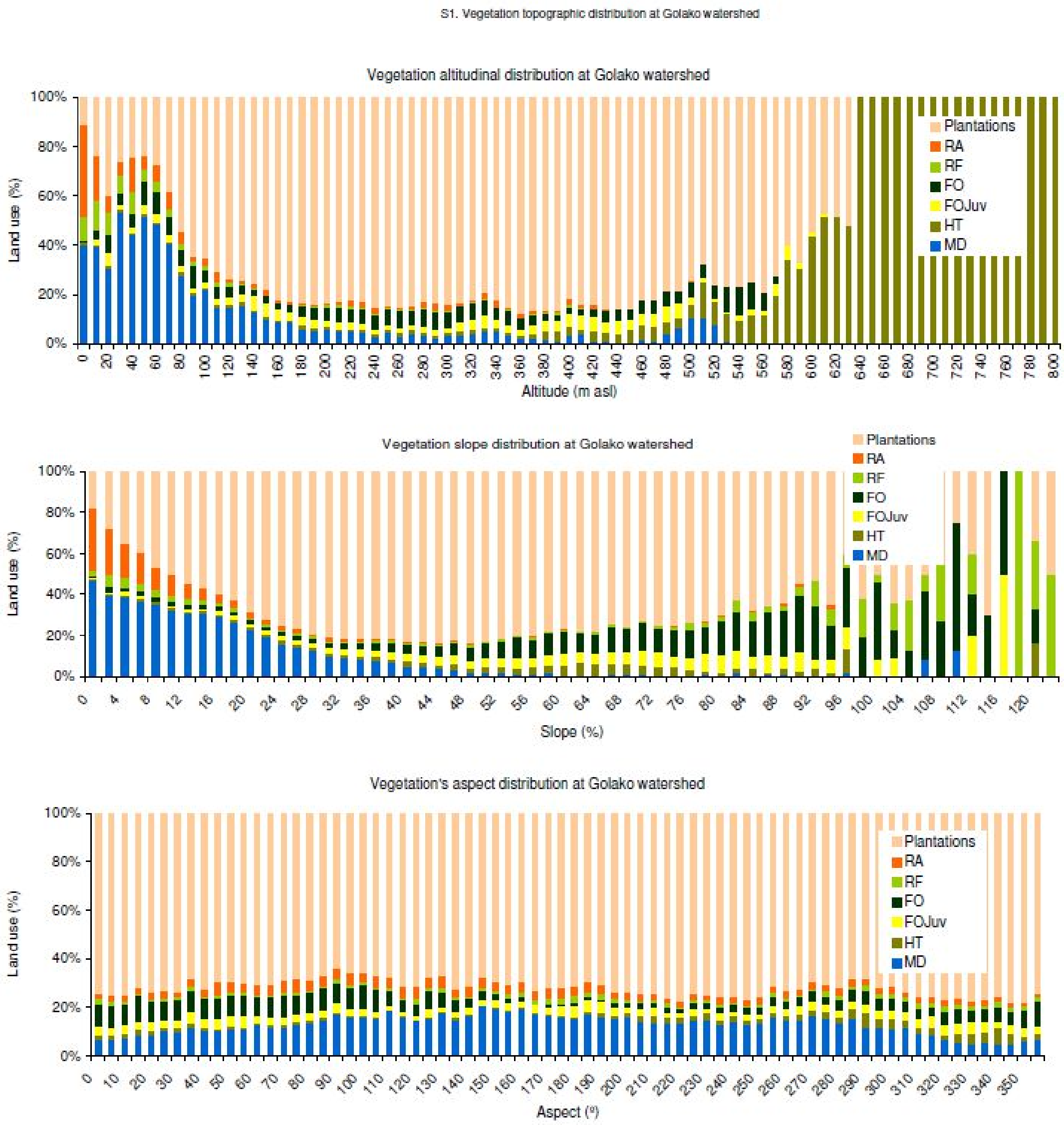
III. Complementary material: topographic characterization at Golako basin after digital elevation model (DEM) analysis

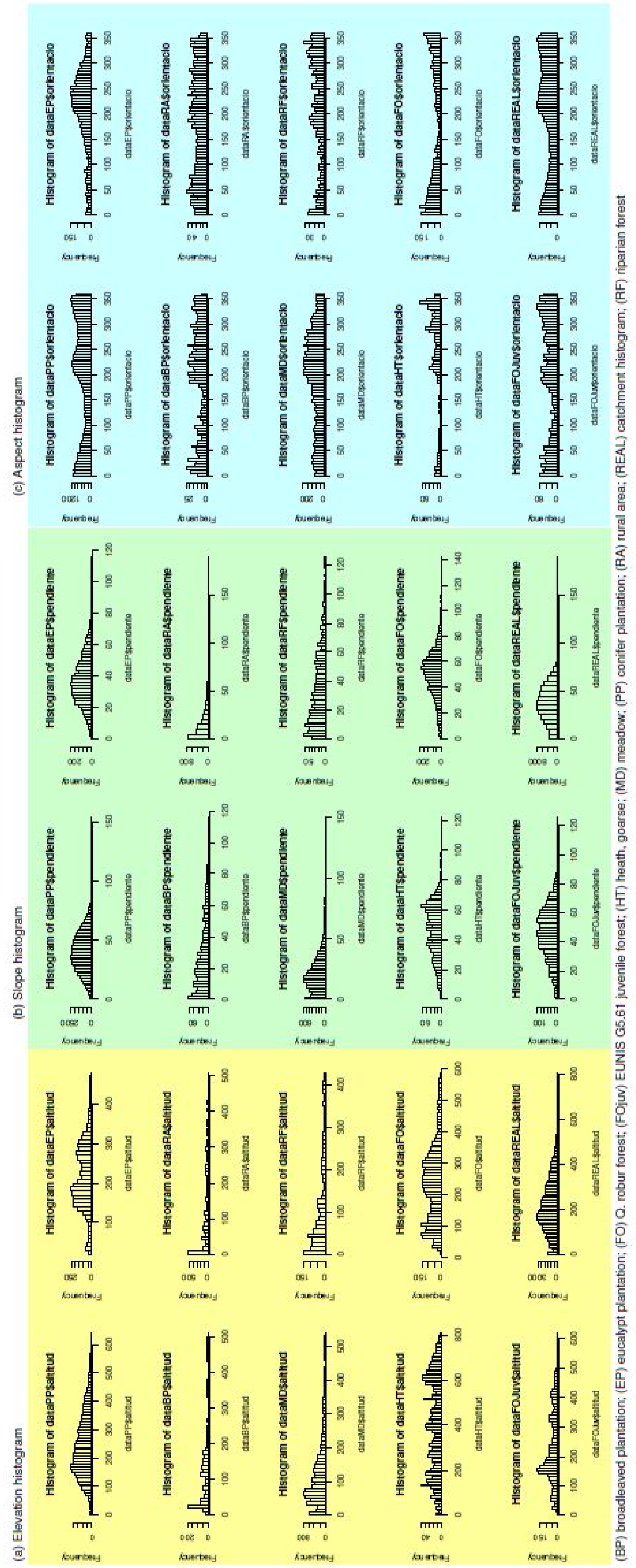
S4.1. Fig. 1. Relative vegetation unit distribution after altitude, slope and aspect parameters (% used by each VU at every 10 m, 2% and 5º interval respectively)



S4.2. Tb. 1. Anova analysis of vegetation units topographic distribution within Golako watershed ((mean±standard error; P-value<0.22E-16, 95% confidence interval).

Golako	1	2	3	4	5	6	7	8	9	**F-value**	**Tukey-HSD**
Slope	**RA**	**MD**	**BP**	**RF**	**EP**	**PP**	**FOJuv**	**HT**	**FO**		
37.93±0.06	14.9±0.3	20.7±0.1	26.1±0.6	32.6±0.7	37.6±0.2	40.8±0.1	46.5±0.3	47.3±0.4	51.0±0.3	2687.4	no s (7-8)
Altitude	**RF**	**RA**	**MD**	**BP**	**EP**	**FO**	**FOJuv**	**PP**	**HT**		
224.7±0.44	103.5±2.8	116.5±2.3	117.4±0.9	132.1±3.7	217.2±1.3	230.4±1.8	231.6±2.4	247.8±0.5	404.1±4.8	2553.3	no s (2-3) (6-7)
Aspect	**FO**	**RA**	**BP**	**MD**	**FOJuv**	**PP**	**EP**	**RF**	**HT**		
196.8±0.37	166.0±1.9	179.2±2.1	186.9±3.1	191.0±0.9	197.8±2.1	198.4±0.5	208.8±1.2	210.7±3.0	240.4±2.4	108.0	no s (2-3)(3-4)(3-5) (4-5)(5-6)(7-9)

(BP) broadleaved plantation; (EP) eucalypt plantation; (FO) *Q. robur* forest; (FOjuv) EUNIS G5.61 juvenile forest; (HT) heath, goarse; (MD) meadow; (PP) conifer plantation; (RA) rural area; (RF) riparian forest



S4.3. Fig. 2. Frequencies for each vegetation unit at each elevation, slope or aspect interval. The general picture of the basin is shown at "REAL" histogram. Data has been obtained after DEM analysis of elevation raster map with Quantum-GIS, and treated after R statistics.

5 SOIL RESISTANCE TO DESICCATION RELATED TO SOIL ORGANIC MATTER, FROM A LANDSCAPE PERSPECTIVE

Soil resistance to desiccation related to soil organic matter from a landscape perspective

Abstract

Temperature regulation and water retention are key elements in current strategies to mitigate climate change but are also soil functions that depend on soil quality and its physical, chemical and biological properties. From a landscape perspective different land uses control these functions at different levels. After assessing the organic matter and water content in the soils of the different vegetation units present in the studied area, we have focused on the influence of land use change, as it entails transformations into the relative abundance and distribution of the different vegetation units. We consider that the different vegetation units can be used as a proxy for the organic matter content, establishing a ranking indicator. Land use changes that imply large vegetation cover transformations have impacts upon soil as far as that will affect oxygen supply and water and nutrient balance. Soil-water is a driving factor of plant growth and nutrient and carbon availability, which is influenced by organic matter presence, and both are soil properties related to vegetation units. The results indicate that intensive land management negatively affects plant-soil feedbacks and that the medium intensity disturbance regimes favour the most diverse vegetation units which are those having the higher organic matter content in their soils, becoming the target in a mitigation-oriented management. Relating vegetation units with local land use types would allow a territorial management orientation towards mitigating climate change by benefiting natural and semi-natural units such as the semi-natural broadleaved forests.

Resumen

La regulación de la temperatura y la retención de agua son elementos clave en las estrategias actuales para la mitigación de cambio climático pero son, así mismo, funciones del suelo que dependen de su calidad y propiedades físicas, químicas y biológicas. Desde una perspectiva del paisaje, diferentes usos del suelo controlan estas funciones a distintos niveles. Después de analizar el contenido en materia orgánica y agua de los suelos de distintas unidades de vegetación en el área de estudio, nos hemos centrado en la influencia del cambio de uso del suelo, debido a que conlleva transformaciones en la abundancia relativa y distribución de las distintas unidades de vegetación. Consideramos que las distintas unidades de vegetación pueden utilizarse como una aproximación al contenido de materia orgánica, estableciendo un indicador por rangos. Los cambios de uso del suelo que implican grandes transformaciones de la cobertura vegetal tienen impactos sobre el suelo, llegando a afectar al aporte de oxígeno y de agua y al ciclo de nutrientes. El agua del suelo es un factor clave en el crecimiento de las plantas y la disponibilidad de nutrientes y carbono, influenciado además por la presencia de materia orgánica, estando las dos propiedades relacionadas con las unidades de vegetación. Los resultados indican que un manejo intensivo del suelo afecta negativamente la relación planta-suelo y que los regímenes de perturbación de media intensidad favorecen a las unidades de vegetación más diversas, que son aquellas que tienen mayor contenido de materia orgánica en el suelo, convirtiéndose en el objetivo de una gestión orientada hacia la mitigación. Relacionar las unidades de vegetación con tipos de uso del suelo local permitiría una gestión territorial orientada hacia la mitigación del cambio climático, beneficiando unidades naturales y semi-naturales como el bosque decíduo autóctono.

5.1 Introduction

Fresh water represents 2.8% of the total on Earth, and it is mainly in form of ice and snow (2.2%) or on the ground and soil (0.6%), while only 0.0001% is found at rivers. Therefore, water supply is a complex land management problem that involves river and land protection, conservation, control, water fair distribution and reuse (Hewlett 1982), and for which soil has an important role as water reservoir, detaining and retaining water available for live beings and ecosystems for longer periods of time. In this context, soil is a key element not only for agricultural production and land resources, but also for hydrologic regulation and, thus, for ecological sustainability. Soil supports ecological services by a multi-functionality character in the fields of biodiversity conservation, air and water quality and global climate change (carbon storage and temperature control), which are directly related to organic matter, temperature and water storage capacity of soils.

Soil is a non-renewable resource whose loss and degradation is not recoverable within a human lifespan. A comprehensible definition of soil quality is given by the Soil Science Society of America is "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al. 1997). Soil quality has been proposed as a potential indicator of sustainable land management and consequently, an effort should be done to quantify and standardize soil "quality" after a set of attributes, functionally interrelated, that characterize soil in a range of values dependent of land use and management (Larson & Pierce 1994).

The large variability of soil resources and of their inherent attributes defines on its turn a wide variety of soil functions, a complexity that is incremented when human priorities are added, and which altogether may result in a difficult search of a unique set of measurable surrogates (properties or processes) that will always be useful for soil quality evaluation (Schoenholtz et al. 2000). In this sense, as reviewed by Schoenholtz et al. (2000), **soil organic matter**, a chemical property, fulfils a relevant paper controlling not only the chemical processes of soils but also physical (Dexter et al. 2008, Gregorich et al. 1994, Rawls et al. 2003) and biological processes (Pulleman et al. 2012). Among the physical properties of soils several are recognized as critical for maintaining soil's ability to function and directly influenced by organic matter content: bulk density, water retention characteristics and matrix porosity, together with readily dispersible clay (Dexter et al. 2008). In this sense, organic C has been proposed as a parameter to calculate bulk density, water retention capacity, cation exchange capacity (CEC), and soil productivity (Larson and Pearce 1994). Additionally, the focus of soil quality examination should be extended beyond erodible lands to productive lands for which soil degradation will yield the greater loss (Schoenholtz et al. 2000).

On the other hand, soil is not the only element that informs about landscape sustainability and it should be complemented by other variables (Herrick 2000) such as plant presence. In this line, Rodríguez-Iturbe (2000) states that soil moisture is the key factor between climate fluctuations and vegetation dynamics, and defines ecohydrology as the science which *"seeks to describe the hydrologic mechanisms that underlie ecologic patterns and processes"*. Soil-water parameters could therefore be the key link between above and below ground relationship, between soil and vegetation.

Land use in Atlantic northern Spain is devoted to intensive silviculture of exotic tree especies with current harvesting practices that result in above and below ground changes. Regional research on exotic plantations have outlined devastating effects of such practices: soil nutrient depletion (Merino et al. 2005), change in soil's physical properties –organic matter, bulk density and hydraulic conductivity- that yielded greater run-off (Edeso et al. 1999), understory diversity and species richness losses (Atauri et al. 2005), increased forest fragmentation (Teixido et al.

2009) and decrement of biological value at landscape scale (see Chapter 4). However, many of the studies that address the effect of exotic plantations in this region have mainly focused on a particular vegetation type (*Pinus* sp.) rather than providing information of differing soil properties under different land uses. While such studies provide valuable insight into the long-term effects of forest management, they do not offer detailed analyses of consequences of land-use change. Moreover, there is a lack of comparative analysis of the soil quality of *Eucalyptus* plantations with other vegetation types that could be used to promote a realistic sustainable land management based on scientific evidences.

In this study we have analysed top soil quality related to vegetation presence from a landscape perspective. We have worked at an area with several regionally common land uses (mainly silviculture and mountain farming and livestock ranching), yearly flooding and drought problems and a regional protection figure (protection affects only that area above 500 m asl at Ganekogorta range as part of an ecological network and a “Natural Interest Area” of Euskadi). The general objective of this study has been to acknowledge the effect of anthropic pressure upon the landscape. The particular goals were to **identify the effects of different land uses over top soil condition, how soil has responded to different management, and threats on soil imposed by cultural practices**. Our approach has included steps to (1) identify attributes and indicators for established key functions supporting ecological functions; (2) establish baseline conditions in terms of differing land uses; (3) outline the differences in the effect of semi-natural and artificial vegetation communities, and (4) validate relationships at top soil level between bio-indicators and temperature regulation, water storage capacity, and soil conservation. The results of the present study are discussed in terms of proposing land use alternatives for increasing organic matter and water content and decreasing temperatures in top soils of the region.

5.2 Methodology

5.2.1 Site description

The study was located at Alonsotegi municipality (30TWN0088), at the Cantabro-Atlantic sector of the Atlantic European biogeographic province (EEA 2011), Spain (Fig. 8.1 and 8.9). Local altitude gap ranges from 20 m to 999 m a.s.l. and slope average is 26%, although at Sasiburu range goes up to 54%. It is a funnel-like area, divided in two by a low narrow valley (20 m a.s.l.) occupied by a main road, a village, a railway and the Kadagua main river, all NE-SW oriented. Municipality limits are defined by two main ranges home of minor watersheds that flow to Kadagua River: Sasiburu range limits at N-W (561 m) and Ganekogorta range at E-SW (999 m). This soil was a Distric Cambisol under the FAO soil classification system. Local substrate lithology is homogeneous: fine and very fine-grained sandstone alternating with mudstone or calcareous limonites (claystone), and a few scatered small areas of limestone build-ups with rudists and corals (EVE 1993) at both ranges.

Natural potential vegetation (Fig. 8.8) is mainly a *Quercus robur* oak forest below 600 m a.s.l., *Fagus sylvatica* above that altitude, and *Q. ilex* forest at several karstic areas. Differences in land use outside the urban and rural areas of Alonsotegi (Fig. 8.9) have created an anthropized landscape (95.9%), dominated at low elevations by intensive silviculture (mainly *Pinus* sp. and *Eucalyptus* sp., being largely *P. radiata* and *E. globulus*) and extensive agriculture of small vegetable gardens and meadows. Several areas show iron and sand and gravel mine wounds active until the beginning of the 20th century, now hidden beneath scrubs or forests. *Alnus glutinosa* forest is present at humid and riparian areas while *Q. ilex* holm oak forest appears at thin and drier soils. Anthropic pastures originated after fires and wandering livestock grazing (mainly illegal cows and horses) appear at greater altitudes along with scrubs, acidophilous beech forests and plantations.

As natural plant community limits are well defined by their soil types (Peralta 1992), we assume that differences in soil characteristics will be related to land use for those areas with the same natural potential vegetation and on a homogenous lithology (the same tessella). Seven vegetation units were characterized after a stratified random sampling at 22 different sites around the study area. We gathered 3 soil samples per place, and at least 3 places per vegetation unit.

5.2.2 Data source and compilation

We selected seven vegetation units as regional main vegetation representation. The procedure was as follows. For field, GIS and statistical analysis we grouped all vegetation patches described as EUNIS classes present at official vegetation map (GV 2011) onto seven vegetation units (Tb. 5.1): meadows and pastures (MD), heaths, thickets, scrubs and ferns (HT), hygrophilous forest (RF), climatophilous broadleaved deciduous and evergreen forests (FO), coniferous (PP), *Eucalyptus* (EP) and deciduous plantations (BP) and rural/urban areas (RA, not sampled). Semi-natural areas will be treated hereafter as meadows, scrubs, forests and riparian forest (MD, HT, FO and RF respectively) despite their internal variations.

Table 5.1. Crosswalk among EUNIS, syntaxonomy and vegetation units for Alonsotegi samples. Three soil cores have been taken at each site. (*) PA4 appeared on vegetation maps as hay meadow but its actual use was as small vegetable garden with seasonally grazing livestock (a dozen donkeys); PE4 was described as eucalypt plantation but it had been naturally colonized by *Quercus ilex* forest (2 soil cores). Natural potential vegetation (NPV) of each site is shown citing each forest's main species making reference to Cantabrian acidophilous oak forest (***Quercus robur***) and beech forest (***Fagus sylvatica***), Galicio-Portuguese oak woods with ***Q. pyrenaica*** and *Q. robur*, Northwestern Iberian holm-oak forests (***Quercus ilex***) and Northern Iberian ***Alnus glutinosa*** galleries, respectively. Bold type makes reference to the subtypes analysed in Table 5.4.

EUNIS	Description	VU	Syntaxonomy	NPV	No.	Soil	Site code
E1.73	*Deschampsia flexuosa* grasslands (on siliceous soils)	MDx	**Nardetalia** strictae	Acidophilous *Q. robur*	3	Siliceous	PA25
E1.73	*D. flexuosa* grasslands with *Pteridium aquilinum*	MDx	**Nardetalia** strictae	Acidophilous *Q. robur*	3	Siliceous	PA18
E2.11	Unbroken pastures	MDm	**Arrhenatherion** elatioris	*Q. pyrenaica*	3	Siliceous	PA98
E2.21	Atlantic hay meadows	MDm	**Cynosurion** cristati	*Q. pyrenaica*	3	Siliceous	PA4*
E2.21	Atlantic hay meadows	MDm	**Cynosurion** cristati	*Q. pyrenaica*	3	Siliceous	PA55
F4.23(X)	Atlantic *Erica* - ***Ulex*** (dry) heaths	HT	Calluno-Ulicetalia minoris	Acidophilous *Q. robur*	3	Siliceous	BZ19
F4.237	Cantabro-Pyrenean heaths (***Erica*** *vagans* -E. cinerea)	HT	Calluno-Ulicetalia minoris	Acidophilous *Q. robur*	3	Siliceous	BZ33
F3.11(X)	Atlantic rich-soil thickets (**Crataegus** monogyna)	HT	Prunetalia spinosae	*Q. ilex*	3	Alkaline	BZ54
G1.21(Z)	Northern Iberian [*Alnus*] galleries	RF	Populetalia albae	*Alnus glutinosa*	9	Siliceous	RF1 RF2 RF3
G1.86	Cantabrian acidophilous oak forest (***Quercus robur***)	FO	Quercetalia roboris	*Q. pyrenaica*	6	Siliceous	BM32 BD36
G2.121	Northwestern Iberian holm-oak forests (***Quercus ilex***)	FO	Quercetalia ilicis	*Q. ilex*	2	Alkaline	PE4*
G2.81	*Eucalyptus* plantation	EP	Exotic vegetation	*Q. ilex*	1	Alkaline	PE4*
G2.81	*Eucalyptus* plantation	EP	Exotic vegetation	*Q. pyrenaica*	3	Siliceous	PE14
G5.73	Young broadleaved evergreen plantation (*E. globulus*)	EP	Exotic vegetation	*Q. pyrenaica*	3	Siliceous	PF39
G5.72	Young broadleaved plantation (*Q. rubra*)	BP	Exotic vegetation	Acidophilous *Q. robur*	3	Siliceous	PF24
G5.72	Young broadleaved plantation (*Q. rubra, Fagus sylvatica*)	BP	Exotic vegetation	Acidophilous *F. sylvatica*	3	Siliceous	PF38
G5.72	Young broadleaved plantation (*Prunus* sp.)	BP	Exotic vegetation	Acidophilous *Q. robur*	3	Siliceous	PF44
G3.F(U)	*Pseudotsuga menziesii* plant.	PP (**pm**)	Exotic vegetation	Acidophilous *Q. robur*	3	Siliceous	PP47
G3.F(P)	*Pinus radiata* plantation - water protector	PP (**pr_wp**)	Exotic vegetation	Acidophilous *Q. robur*	3	Siliceous	PP68
G3.F(P)	*Pinus radiata* plantation	PP (**pr**)	Exotic vegetation	Acidophilous *Q. robur*	3	Siliceous	PP81

Once the seven vegetation units were set as a fixed factor, we obtained 66 soil cores at 22 sampling sites after randomly selecting three sampling places per factor, with one exception. Exception attained meadows: as we were working under extreme drought conditions we wanted to have a good picture of the most exposed, and one of the most variable and common semi-natural unit, MD. One forest site (three soil cores) was discarded because of sampling problems and one EP site had naturally evolved onto a second growth *Quercus ilex* forest although a small

Eucalyptus plantation still remained. After examination of EP vegetation relevés of this site two soil cores were recognized as FO and one as EP (Annex 4).

The attribution of the vegetation of the sampled area to syntaxonomic associations was done after field vegetation examination (relevés, Annex 4) using the phytosociological method (Braun-Blanquet, 1979). We related them to EUNIS using a crosswalk at alliance level. Although we worked mainly with broad units (VU), we kept track of their several phytosociological subunits and checked for differences among them whenever possible. Enough data allowed us to divide meadows (n_{MD}=15) onto mesic (MD_m, EUNIS code E2) and xeric (MD_x, EUNIS code E1): Cynosurion cristati (E2.21, six cores) and Arrhenatherion elatioris (E2.11, three cores); and Nardetalia *Deschampia flexuosa* xeric fields (three cores of E1.73 and three E1.73 with *Pteridium aquilinum* ferns). Riparian forests (n_{RF}=9) and *Eucalyptus* plantations (n_{EP}=7) were homogeneous but heterogeneity appeared again within forests (n_{FO}=8, divided onto six cores of *Quercus robur* acidophilous forest and two cores of *Q. ilex* xeric forest), scrubs (n_{HT}=9, three with *Crataegus monogyna*, three with *Erica vagans*, and three with *Ulex* spp) and coniferous plantations (n_{PP}=9, three *Pinus radiata* and three *Pseudotsuga Menziesii*, both for extraction purposes, and three *Pinus radiata* for water source protection in which soil management was conservative compared with the other two).

5.2.3 Soil collection

Top soil samples were taken first week of October (2012) with no precipitation, min/max temperatures of 6.9/26.0ºC and after an extremely dry and hot summer (one of the driest and hottest one since 1940): Total summer rainfall represented 70% of precipitation registered along the severe hot spell of 2003 and temperatures were slightly lower than in 2003. This situation gave us a baseline for maximum drought conditions.

Field measurements taken were: humidity (%), topsoil and air temperature (ºC), elevation (m a.s.l.), slope (%) and aspect (º). We took both three canopy pictures per site at 0.1 m height and 90º and three soil pictures per site at 1.5 m height and 90º of 1x1m square for ground exposure to sun analysis. Topographic values were obtained at sampling site by means of: a GPS (GARMIN GPSMap 62s) for altitude, a manual clinometer for slope and a compass for aspect. Later, they were revised with those obtained by a large resolution digital terrain model (DEM at Quantum-GIS) at 20x20m cells. Finally, they were transformed into several increasing categories for altitude and slope, while aspect was related to exposure to cold weather (according to García et al. 2005) and reclassified as: northern (316-45º), eastern (46-135º), southern (136-225º) and western (226-315º).

We assumed no geographical variation of temperature as an effect of latitude or presence of large water bodies (which influence conduction and convection processes) as samples were taken away from water bodies and at the same latitude. The effect of altitude upon the radiation budget was checked by means of air and soil temperatures. For water retention capacity cores should weight ca. 1000 g (Bautista et al. 2011, after Hildenbrand et al. 1996). In this sense, collected cores were 13.5 cm long, 9 cm in diameter, for which earth volume of the 66 samples was homogeneous: 869.06 ±70.30 ml with no significant differences (ANOVA p-value =0.16).

5.2.4 Analysis of soils

Laboratory direct and indirect determinations were pH, dry and organic matter, field water content, field capacity, bulk density, porosity and oxygen consumption. Lack of financial support has driven the election of the methods used at this study: mainly the gravimetric method for field capacity.

We performed potentiometric *pH* measurements in samples suspended in distillate water (1:1, vol/vol) with a soil pH-meter (Hanna Instruments, S.L.; model: HI 99121) of soil samples taken at 7 and 13 cm. Then, we obtained dry soil weight after samples oven dried until weight data was constant (24h at 90ºC). Field water content (FW) is the amount of water that retained the soil sample when it was first obtained, and was calculated both as the percentage of water weight in a soil sample per initial (no manipulated) soil weight ($FW = 100*W_{water}/W_{initial}$, units % g/g) and as the percentage of amount of water (in weight) per total sample volume ($FW_{vol} = 100*W_{water}/V$, units % g/cm^3). Field capacity (FC), understood as the quantity of water that can be held in the soil against the force of gravity after saturation, was calculated as the percentage of weight of soil sample at water saturation minus dry weight divided by weight of soil at water saturation ($FC = 100*W_{water}/W_{saturated}$, units % g/g) and volumetric field capacity calculated as the percentage of water content at saturation divided by sample volume at collection ($FC_{vol} = 100*W_{water\ at\ saturation}/V$, units % g/cm^3). As volume measures were more imprecise we have mainly used weighted measures for FW and FC. Organic matter (SOM) was obtained after ignition of a subsample at 450ºC for 24h, as percentage of sample that corresponded to organic matter (%). Bulk density (B) was calculated as mass of dry soil (g) divided by *in situ* volume (cm^3). Porosity was the fraction of total soil volume that is pore space (cm^3/cm^3).

COBCAL was used for sun exposure analysis: after three canopy and three ground pictures per site we obtained a canopy cover percentage (%) and a ground cover percentage (%). Vegetation maps (GV 2015) were used in gvSIG and QUANTUM-GIS programs.

Topographic data shown at the supplementary material (Tb. S5.1-S5.3) were obtained after a Digital Elevation Model (DEM) of Euskadi, downloaded from the National Centre for Geographic Information of Spain (IGN 2015). This first archive contained altitude topographic information (m asl) and it was transformed into a slope raster (%) and an aspect raster (º). In QUANTUM-GIS we divided the territory into 20x20 m cells at a regular distribution and created a grid layer. We merged all the topographic information on the rasters and the vectorial layers over to the grid layer. This way every cell of the grid had attached altitude, slope, aspect, real and potential vegetation figures.

5.2.5 Statistical analysis

Statistical analysis of the biotic and non biotic parameters measured in soil samples both "in situ" and after laboratory experimental set up followed a pattern in which major differences were initially ascertained using ANOVA procedures, in particular the Tukey-Kramer test for multiple comparisons. On a subsequent approach, functional relationships among soil parameters have been explored by different regression equations (linear, potential, exponential, etc) and ANCOVA analyses have been performed when required. Significance was set at $p<0.05$. Mean values are given followed by standard error (±SE) except were otherwise stated. Statistical packages used have been STATVIEW and SYSTAT.

Analysis of topographic data obtained in a multiple cell design has been completed using R, followed by multiple comparison test using Tukey's HSD (honest significant difference).

5.3 Results

5.3.1 Vegetation map analysis

The biogeographic classification of Alonsotegi is the Eurosiberian Region, Atlantic-European Province, Cantabrian-Basque *Sector* [*Cántabro-Euskaldun*], Santanderine-Biscayne District [Santanderino-Vizcaíno]. After GIS examination (Tb. S5.1) we observed that **natural potential vegetation** is 54.3% acidophilous *Quercus robur* oak woodland (EUNIS G1.86), 23.8% *Q. ilex* oak woodland (G2.121), 10.8% *Q. pyrenaica* woodland (G1.7B1), 8.3% *Fagus sylvatica* woodland (G1.62), 2.4% *Alnus glutinosa* riparian forest (G1.21(Z)), 0.4% mesophytic *Q. robur* woodland (G1.A1(X)). Their topographic affinities are mentioned on Tb. S5.2.

Real land cover distribution (Tb. S5.1) was 52.7% semi-natural areas (meadows and pastures, woodlands, heaths, thickets, ferns and scrubs), 40.1% plantations (coniferous, *Eucalyptus*, broadleaved), 6.6% rural and urban areas and 1.2% aquatic areas. Forests were divided onto three groups: Hygrophilous forests (RF), climatophilous forests (FO) and juvenile forests (DF). RF were *Salix* carr and fen scrub (F9.2(Y)), and *Alnus glutinosa* riparian forest (G1.21(Z). Despite scarce climacic forest presence, it was heterogenously conformed by acidophilous *Quercus robur* oak forest (G1.86), *Fagus sylvatica* acidophilous beech forest (G1.62), Mediterranean evergreen *Quercus ilex* woodland (G2.121), non riverine woodland with *Sorbus* (G1.91), and deciduous woodlands of *Q. pubescens* (G1.71) and *Castanea sativa* (G1.7D). After field work we observed that juvenile forests (EUNIS G5.61) were mainly acidophilous *Q. robur* at much degraded stages or early stages of forest regeneration.

Fragmentation basic vectorial data and topographic data after digital elevation model analysis (DEM) are shown in Tables S5.2 and 3. In general terms, forests (RF, FO, DF) covered 187.3 ha, fragmented into 91 patches while plantations were distributed in 185 patches that occupied 808.1 ha, and with a largest patch of ca. 46 ha (ca. 20 ha for BP, 31 ha for EP and 46 ha for PP). Main forest type, acidophilous *Q. robur*, which had a potentiality to appear at ca. 54% of the municipality had been reduced to ca. 3% (62 ha) divided onto 28 patches, with the largest patch of ca. 10 ha. Anthropic pressure affects half of the territory with land use transformation onto silviculture and, at those areas where semi-natural units still exit, forests are scarce, fragmented and of small size.

5.3.2 Soil parameters for VU and internal variation

Soil analysis determinations were calculated for every vegetation unit to compare mean variance between the units (Tb. 5.2). Figure 5.1 shows vegetation unit ranking and sub-grouping after non-significant mean differences at Tukey-Kramer analysis.

Table 5.2. Values obtain for each soil parameter at vegetation unit level (mean±SE) and results for ANOVA.

	MD	HT	FO	PP	EP	BP	RF	P-value
Soil samples	15	9	8	9	7	9	9	
Field data								
Air Temp (ºC)	25.07±0.72	18.28±0.72	21.38±0.42	20.00±0.76	22.57±0.43	22.00±0.0	20.00±0.50	<0.0001
Soil Temp (ºC)	23.60±0.76	17.89±0.48	20.62±0.42	16.78±0.22	22.57±0.48	18.11±0.48	16.67±0.60	<0.0001
Canopy cover (%)	0.0±0.0	15.17±3.05	82.28±5.56	68.01±2.56	67.02±4.90	78.18±4.66	83.98±1.16	<0.0001
Ground cover (%)	61.79±8.10	67.37±6.69	22.71±5.73	34.17±14.55	3.68±0.55	34.29±7.68	37.01±3.82	<0.0001
Laboratory data								
pH at 13 cm	4.98±0.29	4.86±0.21	5.39±0.31	4.57±0.15	6.14±0.52	5.11±0.23	6.24±0.44	0.0036
FC (%, g/g)	28.59±0.97	33.71±1.16	29.51±1.78	29.80±2.73	28.59±0.97	29.60±1.75	23.76±1.94	0.024
FW (%, g/g)	17.12±0.83	27.64±2.76	16.79±1.56	19.50±3.31	12.69±1.49	19.00±2.38	22.93±3.21	0.0019
SOM (%)	9.58±0.71	15.91±1.70	13.20±1.67	14.25±2.75	10.94±1.53	13.77±1.78	5.02±0.76	0.0002
BD (g/cm3)	0.76±0.05	0.53±0.59	0.65±0.04	0.59±0.08	0.85±0.07	0.56±0.05	0.93±0.07	<0.0001
Porosity (cm3/cm3)	0.19±0.03	0.43±0.06	0.30±0.04	0.32±0.07	0.12±0.06	0.34±0.04	0.08±0.04	<0.0001

BD: Bulk density; FC: field capacity, FW: field water content; SOM: soil organic matter
MD: meadow; HT: heath; FO: forest; PP coniferous plantation; EP: *Eucalyptus* plantation; BP: broad-leaved plantation; RF: riparian forest

Because of the large variability found at several vegetation units, we calculated means within them for MD, HT, FO and PP units, while for EP we calculated means without the soil sample taken at a karstic area (Tb. 5.3). Every parameter is independently analysed in the next subsections with an effort on a VU ranking.

5.3.3 Laboratory determinations of pH in soil cores

Although pH taken at 7 cm soil depth did not covariate with vegetation units (ANOVA p-value<0.138), it was statistically significant at 13 cm soil depth (ANOVA p-value<0.0036), with increasing VU ranking: PP, HT, MD, BP, FO, EP, RF; and significant differences of PP with EP and RF (Tb. 5.3.a).

Table 5.3. Tukey-Kramer analysis of soil parameters for main vegetation units encountered at Alonsotegi.

a)

pH 13cm	Coniferous plantt.	Heathland	Meadows	Deciduous plantt.	Climatophilous forest	Eucalypt plantt.	Hygrophilous forest	P-value	n_{TOT}
Mean	4.56	4.86	4.98	5.11	5.39	6.14	6.24	0.0036	66
SE	0.153	0.214	0.288	0.232	0.310	0.520	0.444		
T-K 1	1	1	1	1	1				50
T-K 2		2	2	2	2	2	2		57
NS	(1) 4.96±0.12				(2) 5.36±0.15				

b)

Air Temp (ºC)	Meadows	Eucalypt plantt.	Deciduous plantt.	Climatophilous forest	Coniferous plantt.	Hygrophilous forest	Heathland	P-value	n_{TOT}
Mean	25.07	22.57	22.00	21.38	20.00	20.00	18.28	<0.0001	66
SE	0.72	0.43	0.48	0.42	0.76	0.50	0.32		
T-K 1	1	1							
T-K 2		2	2	2	2	2			22
T-K 3					3	3	3		
NS	(1) 24.27 ± 0.56			(2) 21.20 ± 0.27		(3) 20.00 ± 0.44			

c)

Soil Temp (ºC)	Meadows	Eucalypt plantt.	Climatophilous forest	Deciduous plantt.	Heathland	Coniferous plantt.	Hygrophilous forest	P-value	n_{TOT}
Mean	23.60	22.57	20.63	18.11	17.89	16.78	16.67	<0.0001	66
SE	0.76	0.48	0.42	0.48	0.48	0.22	0.60		
T-K 1	1	1							21
T-K 2		2	2						15
T-K 3			3	3	3				26
T-K 4				4	4	4	4		36
NS	(1) 23.43 ± 0.54		(2) 21.53 ± 0.40	(3) 18.81 ± 0.36		(4) 17.36 ± 0.25			

d)

Canopy cover (%)	Meadows	Heathland	Eucalypt plantt.	Coniferous plantt.	Deciduous plantt.	Climatophilous forest	Hygrophilous forest	P-value	n_{TOT}
Mean	0.00	15.17	67.02	68.01	78.18	82.28	83.98	<0.0001	66
SE	0.000	3.052	4.898	2.559	4.657	5.559	1.158		
T-K 1	1								15
T-K 2		2							9
T-K 3			3	3	3	3			33
T-K 4				4	4	4	4		35
NS	(1) 0.0 ± 0.00	(2) 15.17 ± 3.05	(3) 74.03 ± 2.41	(4) 81.45 ± 2.34					

e)

Ground cover (%)	Eucalypt plantt.	Climatophilous forest	Coniferous plantt.	Deciduous plantt.	Hygrophilous forest	Meadows	Heathland	P-value	n_{TOT}
Mean	3.68	22.71	34.17	34.29	37.01	61.79	67.37	<0.0001	66
SE	0.552	5.731	14.548	7.677	3.823	8.103	6.691		
T-K 1	1	1	1	1	1				42
T-K 2		2	2	2	2	2	2		59
NS	(1) 27.54±4.045				(2) 48.67±4.35				

f)

FC (% g/g)	Eucalypt Plantt.	Hygrophilous forest	Meadows	Climatophilous forest	Deciduous Plantt.	Coniferous Plant.	Heathland	P-value	n_{TOT}
Mean	24.56	23.76	28.59	29.51	29.60	29.80	33.71	0.0059	66
SE	2.170	1.940	0.970	1.780	1.750	2.730	1.160		
T-K 1	1	1	1	1	1	1			57
T-K 2			2	2	2	2	2		50
NS	**(1) 27.81±0.78**			**(2) 30.06±0.75**					

g)

FW (% g/g)	Eucalypt Plantt.	Climatophilous forest	Meadows	Deciduous Plantt.	Coniferous Plant.	Hygrophilous forest	Heathland	P-value	n_{TOT}
Mean	12.69	16.79	17.12	19.00	19.50	22.93	27.64	0.0019	66
SE	1.490	1.560	0.830	2.380	3.310	3.210	2.760		
T-K 1	1	1	1	1	1	1			57
T-K 2				2	2	2	2		36
NS	**(1) 18.12±0.93**			**(2) 22.27±1.52**					

h)

SOM (% g/g)	Hygrophilous forest	Meadows	Eucalypt Plantt.	Climatophilous forest	Deciduous Plantt.	Coniferous Plant.	Heathland	P-value	n_{TOT}
Mean	**5.02**	**9.58**	**10.94**	**13.20**	**13.77**	**14.25**	**15.91**	0.0002	66
SE	0.763	0.705	1.526	1.674	1.775	8.25	5.107		
T-K 1	1	1	1						31
T-K 2		2	2	2	2	2			48
T-K 3			3	3	3	3	3		42
NS	(1) 0.09 ±0.037		(2) 0.12 ±0.053	(3) 0.14 ±0.009					

i)

BD (g/cm^3)	Hygrophilous forest	Eucalypt plantt.	Meadows	Climatophilous forest	Coniferous plantt.	Deciduous plantt.	Heathland	P-value	n_{TOT}
Mean	0.925	0.854	0.759	0.649	0.594	0.557	0.525	<0.0001	66
SE	0.07	0.066	0.046	0.041	0.077	0.045	0.059		
T-K 1	1	1							16
T-K 2		2	2						22
T-K 3			3	3					23
T-K 4				4	4	4	4		35
NS	(1) 0.88 ± 0.058		(2) 0.76 ± 0.040	(3) 0.72 ± 0.034		(4) 0.58 ± 0.029			

j)

P (cm^3/cm^3)	Hygrophilous forest	Eucalypt Plantt.	Meadows	Climatophilous forest	Coniferous Plant.	Deciduous Plantt.	Heathland	P-value	n_{TOT}
Mean	0.08	0.12	0.19	0.30	0.32	0.34	0.43	<0.0001	66
SE	0.04	0.06	0.03	0.04	0.07	0.04	0.06		
T-K 1	1	1	1						31
T-K 2		2	2	2	2	2			48
T-K 3				3	3	3	3		35
NS	(1) 0.14 ± 0.024		(2) 0.25 ± 0.023		(3) 0.35 ± 0.028				

5.3.4 Air and soil temperatures: influence of canopy and ground cover

Since sampling was intentionally designed to cover maximum variability as regards slope or aspect in a valley characterized by abrupt transit from near 0 to 1000 m altitude above sea level, and orientation of vegetation units exhibited some preferences (*Crataegus*-HT site and all EP were south oriented, HT and RF were at northern aspects, MD and FO were east oriented and broadleaved and coniferous plantations occupied eastern and western aspects) we performed ANOVA tests to establish potential influence of both variables on air and soil temperature with the following result:

1. There was no significant topographic influence of slope and altitude (ANOVA $p\text{-value}_{slope}$= 0.129 and $p\text{-value}_{altitude}$= 0.280) upon air temperature.
2. Altitude did not explain soil temperature ($p\text{-value}_{altitude}$= 0.059). Indeed, despite the fact that xeric meadows appeared at greater altitudes (ca. 540 m a.s.l. MD_{xeric}, ca. 124 m a.s.l. MD_{mesic}), differences in soil temperature between xeric and mesic meadows were not related to altitude (ANOVA p-value<0.059, n=15, Tukey-Kramer no significant).
3. Air temperatures of Northern oriented VUs (HT and RF) showed significant differences as regards southern oriented VUs (*Crataegus*-HT site and EP) with $p\text{-value}_{aspect}$= 0.006.
4. We observed significant differences for soil temperature means with aspect categories (ANOVA p-value<0.0001, n=66). From coolest to hottest categories: NW-NE (N, 17.07± 0.28), SW-NW (W, 19.33± 0.33), NE-SE (E, 20.50± 0.51) and SE-SW (S, 23.00± 0.76). After Tukey-Kramer analysis they were grouped N+W, W+E and S, with significant differences among them. These differences are largely explained by lowest temperatures of North oriented riparian forest and highest from southern oriented eucalypt plantations that will be discussed elsewhere.

As an overall result, mean air temperatures differed among vegetation units (Tb. 5.3.b) and Tukey-Kramer analysis revealed a ranked classification with lower temperatures defined by scrubs and higher by meadows, *Eucalyptus* exhibiting no significant differences with meadows and the later not showing within differences once separated according to xeric or mesic profile (xeric 26.0±0.0, mesic 24.4±1.2, Tb. 5.4.a).

As regards top soil temperature Tukey/Kramer test gave no significant differences between fully exposed meadows and eucalypt plantations with 33% exposure (Tb. 5.3.c) and a second subset included EP and FO. A last set showed that coniferous and hygrophilous forests had lowest topsoil temperatures.

In order to test possible effect of canopy cover on both soil and air temperatures we distributed vegetation units into three categories:

- Sunny (<25% canopy cover):	MD-HT	(n=24, 21.48ºC±0.76)
- Mixed (25-75% canopy cover):	EP-BP-PP	(n=18, 18.78ºC±0.57)
- Shaded (>75% canopy cover):	BP-RF-FO	(n=24, 18.73ºC±0.58)

We found no differences for mean air temperatures (p-value=0.13) whereas significant differences for soil temperatures between the sunny category with mixed and shaded categories (p-value= 0.0041) were evident. As a consequence, and after excluding fully exposed meadows, Tukey-Kramer test distributed soil temperatures into two groups: *Eucalyptus* and forests (FO) appeared significantly warmer than BP, HT, PP and RF (Tb. 5.5). Nevertheless, a paired comparison between EP and FO (ca. 2ºC) excluding the others units rendered significant differences (p-value=0.0185).

Table 5.4. Values obtain for each parameter within a single vegetation unit (mean±SE): meadows (MD), scrubs (HT), forests (FO), coniferous plantations (PP) and *Eucalyptus* plantation (EP). Intra-group variability included main phytosociological units found in Alonsotegi and was analysed by ANOVA and Tukey-Kramer test, except for EP (no sample on alkaline soils in EPsi).

a)	**MD**	**MD xeric (x)**	**MD mesic (m)**	**p-value**	**TK**	***Arrhenaterion* (ar)**	***Cynosurion* (cy)**	***Nardetalia* (na)**	**p-value**	**TK**
Soil samples	15	6	9			3	6	6		
Air Tº (ºC)	25.07±0.72	26.00±0.0	24.44±1.18	0.3071	NS	26.00±0.0	23.67±1.73	26.00±0.0	0.3042	NS
Soil Tº (ºC)	23.60±0.76	22.33±0.33	24.44±1.18	0.1794	NS	26.00±0.0	23.67±1.73	22.33±0.33	0.2163	NS
CC (%)	0.0±0.0	0	0	-		0	0	0	-	
GC (%)	61.79±8.10	84.25±2.84	47.19±10.67	**0.0162**	(x-m)	66.76±1.75	37.41±14.67	84.25±2.84	**0.0160**	cy-na
FC (% g)	28.59±0.97	27.08±1.39	29.56±1.27	0.2174	NS	32.55±2.42	28.11±1.19	27.08±1.39	0.1035	NS
FW (g/g, %)	17.12±0.83	16.75±1.67	17.36±0.91	0.7298	NS	18.16±2.15	16.97±0.98	16.75±1.67	0.8373	NS
FW/FC	0.60	0.62	0.59			0.56	0.60	0.62		
SOM (%)	9.58±0.71	10.95±1.26	8.67±0.73	0.1150	NS	10.17±0.67	7.92±0.92	10.95±1.26	0.1430	NS
BD (g/cm3)	0.76±0.05	0.69±0.06	0.81±0.06	0.2055	NS	0.62±0.07	0.90±0.06	0.69±0.06	**0.0166**	(ar-cy)(cy-na)
P (cm3/cm3)	0.19±0.03	0.24±0.04	0.15±0.04	0.2228	NS	0.29±0.06	0.09±0.03	0.24±0.04	**0.0165**	(ar-cy)(cy-na)

b)	**HT**	***Erica* (er)**	***Crataegus* (cr)**	***Ulex* (ul)**	**p-value**	**T-K**
Soil samples	9	3	3	3		
Air Tº (ºC)	18.28±0.72	19.00±0.0	18.83±0.17	17.00±0.0	**<0.0001**	(ul-er)(ul-cr)
Soil Tº (ºC)	17.89±0.48	18.67±0.33	18.67±0.33	16.33±0.88	**0.0448**	NS
CC (%)	15.17±3.05	11.78±9.21	16.72±4.02	17.02±1.48	0.7849	NS
GC (%)	67.37±6.69	93.37±1.35	50.90±3.95	57.85±0.91	**<0.0001**	(er-cr)(er-ul)
FC (% g)	33.71±1.16	33.89±1.61	30.14±0.22	37.10±1.17	**0.0153**	(cr-ul)
FW (g/g, %)	27.64±2.76	26.97±0.51	18.59±1.10	37.36±1.29	**<0.0001**	(er-cr)(er-ul)(cr-ul)
FW/FC	**0.82**	**0.80**	0.62	**1.01**		
SOM (%)	15.91±1.70	17.26±1.21	10.21±0.87	20.36±2.24	**0.0090**	(er-cr)(cr-ul)
BD (g/cm3)	0.53±0.59	0.43±0.05	0.75±0.01	0.40±0.3	**0.0008**	(er-cr)(cr-ul)
P (cm3/cm3)	0.43±0.06	0.55±0.12	0.24±0.02	0.49±0.01	**0.0437**	(er-cr)

c)	**FO**	***Q. ilex***	***Q. robur***	**p-value**	**T-K**
Soil samples	8	2	6		
Air Tº (ºC)	21.38±0.42	19.50±0.50	22.00±0.0	**<0.0001**	S
Soil Tº (ºC)	20.62±0.42	20.00±0.0	20.83±0.54	0.4325	NS
CC (%)	82.28±5.56	57.37±2.37	90.58±1.47	**<0.0001**	S
GC (%)	22.71±5.73	6.71±0.52	28.05±6.21	0.1087	NS
FC (% g)	29.51±1.78	34.85±2.15	27.73±1.75	0.0782	NS
FW (g/g, %)	16.79±1.56	22.23±2.84	14.97±1.16	**0.0277**	S
FW/FC	0.57	0.64	0.54		
SOM (%)	13.20±1.67	20.07±0.64	10.91±1.0	**0.0026**	S
BD (g/cm3)	0.65±0.04	0.61±0.02	0.66±0.06	0.6211	NS
P (cm3/cm3)	0.30±0.04	0.43±0.01	0.25±0.04	0.0557	NS

d)	**PP**	**pm**	**pr**	**wp**	**p-value**	**T-K**
Soil samples	9	3	3	3		
Air Tº (ºC)	20.00±0.76	18.00±0.0	23.00±0.0	19.00±0.0	>0.9999	(pm-pr)(pm-wp)(pr-wp)
Soil Tº (ºC)	16.78±0.22	16.67±0.33	16.33±0.33	17.33±0.33	0.1780	NS
CC (%)	68.01±2.56	74.78±3.90	68.08±0.07	61.19±4.14	**0.0702**	(pm-wp)
GC (%)	34.17±14.55	2.86±.75	7.39±1.15	92.26±1.36	**<0.0001**	(pm-pr)(pm-wp)(pr-wp)
FC (% g)	29.80±2.73	25.87±3.74	24.50±2.35	39.04±2.40	**0.0224**	(pm-wp)(pr-wp)
FW (g/g, %)	19.50±3.31	11.48±0.86	15.97±1.80	31.06±4.75	**0.0082**	(pm-wp)(pr-wp)
FW/FC	0.65	0.44	0.65	**0.80**		
SOM (%)	14.25±2.75	7.88±0.60	11.53±2.47	23.33±4.37	**0.0224**	(pm-wp)(pr-wp)
BD (g/cm3)	0.59±0.08	0.71±0.09	0.74±0.10	0.33±0.05	**0.0227**	(pm-wp)(pr-wp)
P (cm3/cm3)	0.32±0.07	0.21±0.08	0.19±0.07	0.55±0.06	**0.0161**	(pm-wp)(pr-wp)

e)	**EP**	**EPsi**	**%dif**
Soil samples	7	6	
Air Tº (ºC)	22.57±0.43	23.00±0.0	-1.91
Soil Tº (ºC)	22.57±0.48	23.00±0.26	-1.91
CC (%)	67.02±4.90	68.70±5.44	-2.51
GC (%)	3.68±0.55	3.97±0.55	-7.88
FC (% g)	28.59±0.97	23.52±2.25	**17.73**
FW (g/g, %)	12.69±1.49	12.53±1.76	1.26
FW/FC	0.44	0.53	
SOM (%)	10.94±1.53	10.60±1.76	3.11
BD (g/cm3)	0.85±0.07	0.88±0.07	-3.53
P (cm3/cm3)	0.12±0.06	0.09±0.05	**25.00**

BD: bulk density; CC: canopy cover; GC: ground cover; EPsi: Eucalypt plantations at siliceous soils; FC: field capacity; FW: field water content; SOM: soil organic matter content; pm: *Pseudotsuga menziesii*; pr: *Pinus radiata* for extractive purposes; wp: *P. radiata* for water protection. P: porosity.

Table 5.5. Mean soil temperature variation among forested vegetation units, ANOVA and Tukey-Kramer non-significant grouping (mean±SE). NS: non-significant.

Soil Temp (ºC)	Meadows	Eucalypt plantt.	Climatophilous forest	Deciduous plantt.	Heathland	Coniferous plantt.	Hygrophilous forest	P-value	n
Mean		22.57	20.63	18.11	17.89	16.78	16.67	<0.0001	66
SE		0.48	0.42	0.48	0.48	0.22	0.60		
Tukey/Kramer									
1									15
2									36
NS (mean ± SE)			(1) 21.53 ± 0.40			(2) 17.36 ± 0.25			

Data for canopy cover had been analyzed in search of within group variation (Tb. 5.4). On strict terms, sample size restricted the analysis to meadows where no differences appeared between mesic or xeric categories in accordance with previous results for air temperatures. However, although data for *Quercus ilex* was scanty (two samples) significant differences with *Q. robur* forests (n=8) were probably consistent in view of large canopy cover distance between them: 57.37±2.37 for *Q. Ilex* and 90.58±1.47 for *Q. Robur*. In the same way, although it cannot be concluded from this work, differences between *Pseudotsuga menziesii* and *Pinus radiata* for water protection plantations appeared consistent.

Consequently, an analysis of the effect of VU's mean canopy cover (%) on VU's mean air temperature has been undertaken revealing that, scrubs excluded, a linear relationship (p-value= 0.03) between both parameters explaining 72% of air temperature variation can be established:

Eq. 5.1 Air temperature (ºC) = - 0.0504 *Canopy Cover (%) + 25.026 (n= 6; R^2= 0.72)

Additionally, in terms of vegetation units' mean temperatures, top soil temperature can be related lineally to air temperature and the relationship explaining 69% of variability appears virtually isometric (p-value =0.0209) indicating air temperature would be exceeding soil temperature by about 3ºC.

Eq. 5.2 Soil temperature (ºC) = 1.061 *Air temperature (ºC) – 3.182 (n= 7; R^2= 0.69)

As a consequence we have tested the simultaneous effects of air temperature and canopy cover (%) upon top soil temperature by means of an ANCOVA with canopy cover as a factor and air temperature as a covariate including their interaction (Table 5.6). As expected from previous regression treatments, the three predictors are significant, air temperature exhibiting higher degree of influence (p = 0.0002).

Table 5.6. ANCOVA for topsoil temperature (n= 66)

	F-value$_{df}$	**P-value**
Canopy cover (%)	$3.716_{2,51}$	0.0312
Air Temperature (ºC)	$16.536_{1,51}$	0.0002
Canopy*AirTemp	$3.940_{2,51}$	0.0256

Differences in mean values of ground cover data (%) among units were statistically significant (Tb. 5.2) although only two subgroups were obtained after Tukey-Kramer analysis: on one hand all forested habitats appeared grouped (nor MD neither HT belong to this category with a mean value of GC = 27.54%) and, on the other, all VU except EP (Table. 5.3.e). Therefore, we analyzed the influence of ground cover (%) on soil temperature of forested areas (excluding meadows and scrubs) by means of a linear regression where both slope (0.178) and elevation (23.641) were highly significant (p≤ 0.01), the equation explaining 91% of variability (Fig. 5.1). Again, intragroup differences between *P. radiata* for water protection plantations and *Pseudotsuga menziesii* and *Pinus radiata* for extractive purposes appeared consistent for ground cover.

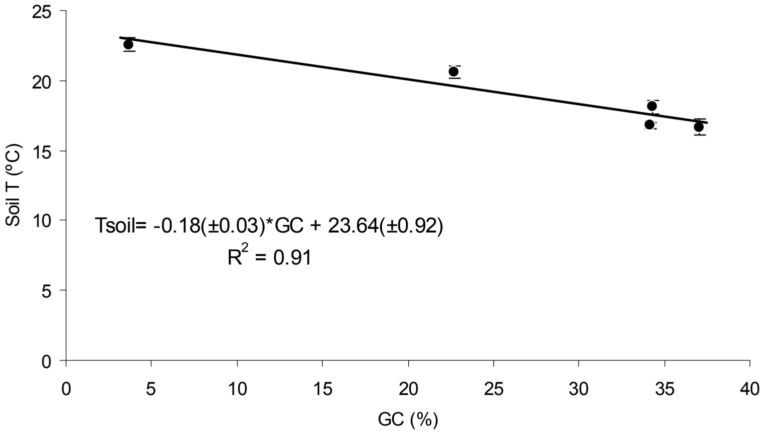


Figure 5.1 Relationship between mean soil Temperature (ºC) of forested units and mean ground cover (%). Ground cover by green herbs explains 91% of top soil temperature of forests and plantations. (±SE shown)

Simultaneous effects of both canopy and ground cover shading on soil temperature have been undertaken by simply adding both percentages, producing a unit-less magnitude that retains, nevertheless, significance in terms of comparing different vegetation units. As a result a linear relationship explaining 63% of variation can be established where both elevation (p =0.003) and slope (p = 0.036) are significant (Eq. 5.3).

Eq. 5.3 Soil temperature (ºC) = 0.1 Canopy+Ground covers (%) + 28.842 (n =7; R^2= 0.63)

5.3.5 Field capacity (FC) and field water content (FW)

We measured **field capacity** for water absorption at maximum drought in terms of weight and significant differences among vegetation units (p-value= 0.0059, n=66) were found. Tukey-Kramer analysis showed differences only between extremes: HT with EP and RF (Tb. 5.3.f). Differences intra-units for FC were only found significant for HT (*Crataegus* category with *Ulex*) although sample size restricts further interpretation and the same is true for PP (*P. radiata* plantation for water protection with the other two extractive categories) (Tb. 5.4). Indeed, greatest field capacity values were found at *Pinus radiata* plantation for water protection (PP), *Q. ilex* (FO) and *Ulex* (HT) subcategories, followed by *Arrhenaterion* (MD).

Differences associated to vegetation profile were evident as regards **field water content** (FW) after extreme drought. Water content means of vegetation units showed statistical differences (Table 5.3.g) between HT as the wettest unit and the driest EP, FO and MD, while BP, PP and RF shared water content similarities with both subgroups. As previously stated for temperature analysis, within intra-group variations could only be undertaken for meadows where we found no significant differences for water content nor among the four EUNIS classes (p-value= 0.55), neither for the subdivision between xeric and mesic meadows (p-value= 0.41) (Tb. 5.4.a). The fact that wide differences were evident between acidophilous *Quercus robur* (mean FW= 14.97±1.16 %; n=6) and *Quercus ilex* woodland (Mean FW= 22.23±2.84 %; n=2) with significant differences in terms of Tukey test, along with the reduced number of samples of xeric woodland led us to exclude it from the mean, taking *Q.robur* data as representative. The same was true for the VU consistent in coniferous plantations where extractive species (by *Pseudotsuga menziesii* and *Pinus radiata,* Mean FW= 13.72± 1.38 %; n=6) differ from water source protective plantation of *Pinus radiata* (Mean FW= 31.06± 4.75 %; n=3) the later exhibiting maximum water content values of all vegetation units analyzed. Therefore, we excluded *Pinus radiata* from the ANOVA analysis shown in Table 5.7.

Table 5.7. Tukey/Kramer results for mean field water content (% g/g) within vegetation units. (*) indicates changes in sample numbers: Climatophylous forest shows results for *Q. robur* woodlands and coniferous plantations include a mean of those for extractive purposes (*P. menziesii* and *P. radiata*).

FW (weight)	**Eucalypt plantt.**	**Coniferous plantt.***	**Climatophilous forest***	**Meadows**	**Deciduous plantt.**	**Hygrophilous forest**	**Heathland**	**P-value**	**n_{TOT}**
Mean	12.69	13.73	14.97	17.12	19.00	22.93	27.64		
SE	1.49	1.340	1.160	0.83	2.38	3.210	2.760		
T-K								<0.0001	61
	1	1	1	1	1			43	
					2	2	2	27	
NS			**(1) 16.02±0.73**			**(2) 23.19±1.70**			

Two main groups appeared: driest soils (16.02% FW) consisting in *Eucalyptus* plantations, extractive coniferous plantations, *Q. Robur* climatophilous forests, meadows and wettest soils including hygrophilous forests (RF) and scrubs (23.19% FW, with broadleaved plantations as a frontier group. ANOVA analysis of **water content with ground cover** data as a factor gave significant figures (p-value= 0.0079, n=66) with Tukey-Kramer differences between those sites with bare ground (FW_{cat1}= 16.47± 0.94) and the second category (FW_{cat2}= 22.53± 2.27) but not with the third one (FW_{cat3}= 22.15± 2.05). Therefore, we undertook the possibility of a functional relationship in forested areas by means of linear regression analysis, excluding as already mentioned *Quercus ilex* samples (n=2) and considering the coniferous plantation as two units, extractive and water retention (Fig. 5.2).

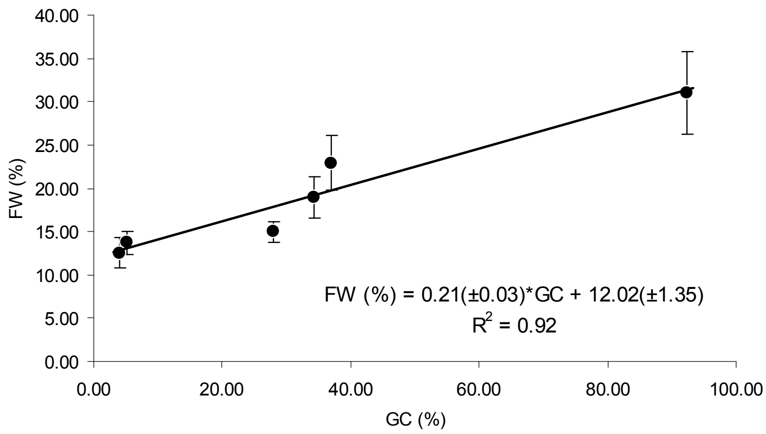


Figure 5.2. Linear regression between top soil water content (FW%) and ground cover (%) of forested units: *Q. robur* FO, riparian forests (RF), broad leaved plantations (BP), extractive (pm, pr PP) and protective (wp PP) coniferous plantations and eucalypt plantations (EP).

As shown, the equation explained 92% of variation of water retained by top soil sampled in the driest season of the year in terms of ground cover with lowest figures determined by *Eucaliptus* and extractive conifer plantations, and highest values by conifer plantations for water retention.

Since potential maximum water retention (FC) showed variation in a range from 24.76% (*Eucalyptus* plantations) to 33.71% (scrubs) and Tukey test exhibited significant differences (Table 5.3.f) we analysed the relationship between water content (FW) and potential maximum (FC) by means of a regression equation in which riparian forest had been excluded as being actually flooded. (Fig. 5.3). The exponential equation explained 66% of variability in field water content indicating that, along with ground cover, top soil nature had a significant influence on water retention capacity both in forested and exposed areas.

Eq. 5.4 $FW = 3.234 \cdot e^{(0.058 \cdot FC)}$ $R^2=0.66$ **n=57 (no riparian forest)**

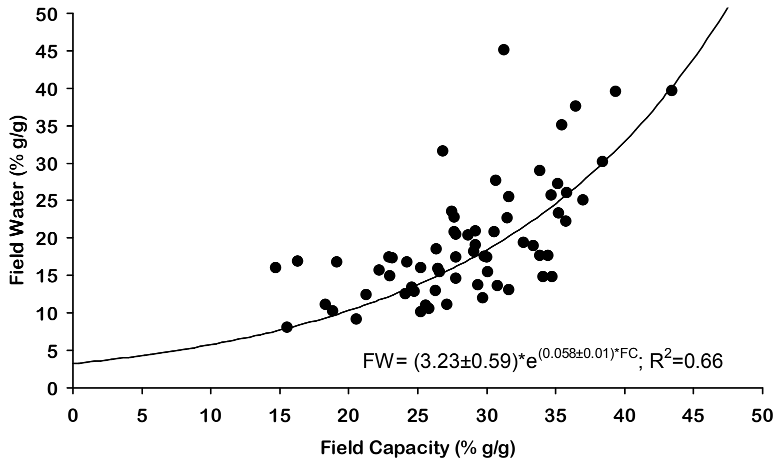


Figure 5.3. Regression between field water content (FW, % g/g) and field capacity (FC, % g/g) for water retention.

At drought conditions, FC values of 15-25% result in water content ca. 10%, and it is not until FC values of 25% are reached that water content values start increasing above 10-15%.

5.3.6 Organic matter (%) and its relation to other soil parameters

Soil organic matter content (SOM) ranked from lowest amount for hygrophilous forest (5.0±2.3) to highest for heath (15.9±5.1) (Tb. 5.2, Tb. 5.3.h). Washed hygrophilous forest shared group with meadows and eucalypt plantations, although internal mean differences within the meadow unit existed (Tb. 5.4). Scrubs showed large variability of OM within the group which followed GC tendencies (Tb. 5.4.b). Large differences in mean organic content within FO group (Tb. 5.4.c) led us to include only SOM mean value for *Q. robur* forests (SOM=10.91±1.00, n=6) excluding *Q. ilex* forest (SOM=20.07±0.64, n=2) in Tb. 5.8.

Although testing within differences as regards coniferous plantations presented the restriction of sample size, we took the approach of testing differences in SOM means segregating the vegetation unit into three groups (n=3 in each group): water source protector *Pinus radiata* plantation (SOM= 23.33±4.37) and extractive plantations of *Pinus radiata* (SOM=11.53±2.47) and *Pseudotsuga menziesii* (SOM=7.88±0.60). In fact, with the mentioned restriction, Tukey-Kramer test accorded significance to these large differences where *Pinus radiata* for water protection plantations doubled *Pinus radiata* extractive plantations in organic matter content (Tb.5.4.d). This tendency of decreasing SOM content values in coniferous soils was coincident with their ground cover (90.3%, 9.4%, 3.4% respectively).

Table 5.8. Means (±SE) and Tukey/Kramer results for soil organic matter content (g/g) within vegetation units. Climatophylous forest shows results for *Q. robur* woodlands and coniferous plantations include a mean of those for extractive purposes (*P. menziesii* and *P. radiata*).

SOM (% g/g)	Hygrophilous forest	Meadows	Coniferous plantt.	Climatophilous forest	Eucalypt plantt.	Deciduous plantt.	Heathland	P-value	n_{TOT}
Mean	**5.02**	**9.58**	**9.70**	**10.91**	**10.94**	**13.77**	**15.91**		
SE	0.763	0.705	1.398	1	1.526	1.775	5.107		
Tukey/ Kramer								<0.0001	61
1	1								36
2									43
3									31
NS	(1) 8.68 ± 0.566			(2) 10.88 ± 0.589		(3) 13.20 ± 0.867			

Vegetation units showed bulk density (BD) ranking values, extremes defined by a subgroup (RF-EP) with largest values and HT with lowest (Fig. 5.3.i). Among meadows we observed differences between *Cynosurion* and the other two EUNIS classes (Tb. 5.4.a). Soil bulk density decreased along with increased presence of ground vegetation increased, with significant differences on BD means (p-value=0.01, n=66) between GC<40% and GC>70% categories.

Bulk density and porosity covariated with topsoil organic matter and their relationship with the later can be explained by exponential and linear equations following opposite tendencies explaining both 73% of variability (Fig. 5.4 and 5.5).

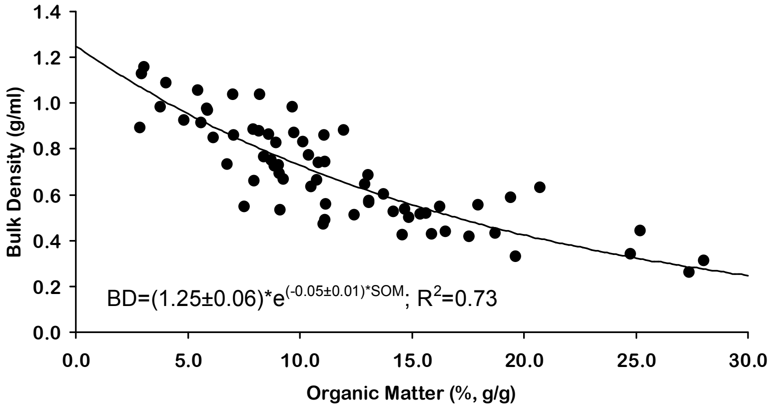


Figure 5.4. Exponential negative regression between bulk density and organic matter content (%) in top soil (±SE are shown).

Equation 5.5 **$BD= 1.25*e^{(-0.05*SOM)}$** **$R^2=0.73$** **n=66**

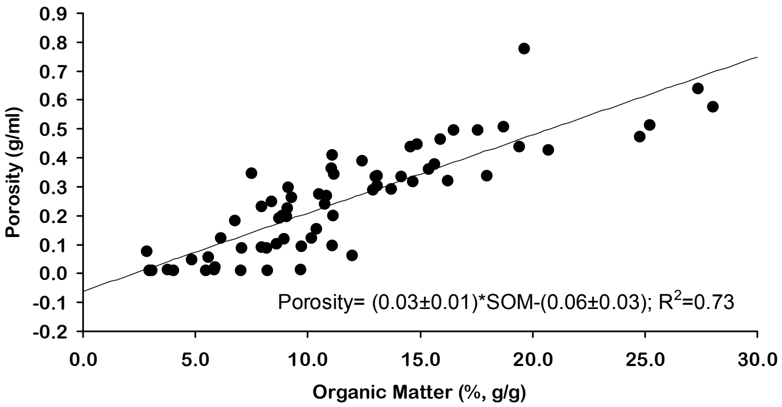


Figure 5.5. Linear regression between porosity (g/ml) and organic matter (weight %) for the 66 soil cores (±SE are shown).

Influence of top soil organic matter on porosity has led to relate both field capacity and field water content to organic matter with the following results (Fig. 5.6 a and b). Although both equations (5.6 and 5.7) explain only 48% and 57% of field capacity and field water variability, the slopes are highly significant (p-value<0.01). This indicates that, in the case of field water, there is virtual isometry between the amount of soil organic matter and the ability to retain water.

Eq. 5.6	**FC = 20.25+0.72*SOM**	**$R^2=0.48$**	**n=66**
Eq. 5.7	**FW= 5.56 + 1.05*SOM**	**$R^2=0.57$**	**n=57 (no riparian forest)**

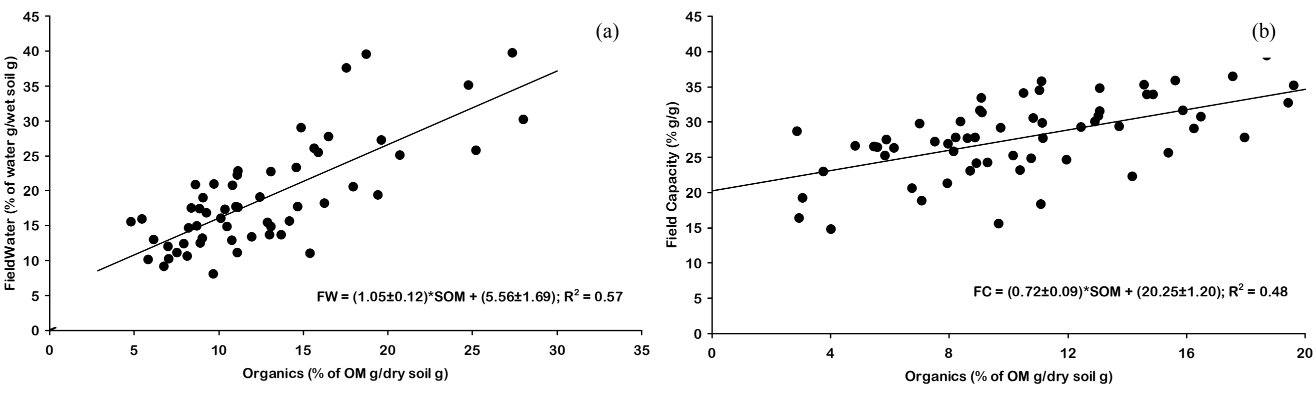


Figure 5.6. Relationship between (a) field capacity for water retention (FC, %) and soil organic matter content (SOM) and (b) between field water content (FW, %) and soil organic matter.

Since only partial explanation of field water content could be obtained from a simple relationship with SOM we have considered the presumable effect of soil temperature on the ability to retain water (FW/FC) taking into account mean data for every VU with forest, coniferous and heath divided into their significant subunits (Fig. 5.7). Given that lowest water retention associated to low soil temperature appeared for extractive coniferous, we excluded such value and obtained an exponential relationship explaining 74% of variability (Fig. 5.7).

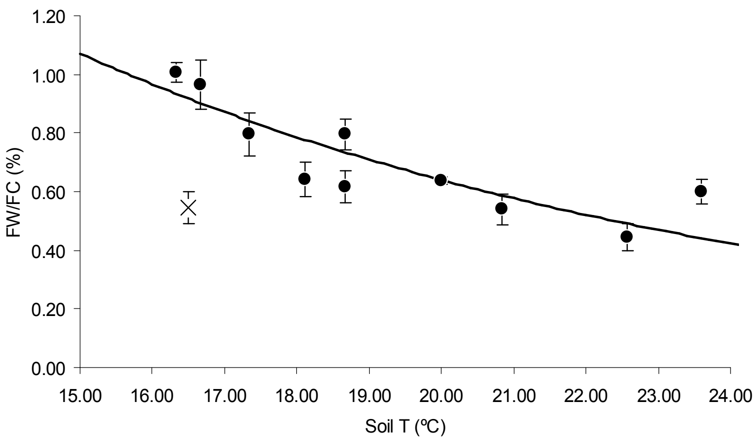


Figure 5.7. Linear regression between the ability to retain water (FW/FC) and soil temperature for vegetation units: meadows, three scrub subunits, *Q. robur* and *Q. ilex* forests, coniferous for water protection, *Eucalyptus* and deciduous plantations. Extractive coniferous plantations (X) are not included in the equation.

Consequently, both top soil organic matter content and temperature would be determining soil capacity to retain water at the period of maximum drought.

In an attempt to explain differences in top soil organic matter between vegetation units we related top soil organic matter in forested areas to canopy cover and found a correlation of 69% between both parameters. We undertook a similar comparison with ground cover and found that, once riparian forest was excluded due to continuous loss of organic matter by washing, the relationship could be explained by an exponential function which accounts for 94% of variability of organic matter:

Eq. 5.8 $$SOM (\%) = 9.557\ e^{0.0094*GC} \qquad R^2 = 0.94 \qquad n=5$$

5.4 Discussion

Soil properties and processes' assessments are included within the soil quality concept as they relate to soil ability to function effectively as part of a healthy ecosystem (Schoenholtz et al. 2000). To accomplish this assessment, soil attributes are analyzed as soil quality indicators, but depending on which soil function is of interest there will be a monitoring of an array of soil physical, chemical and biological properties and processes as determinants of soil quality. Despite existing variability of soil quality indicators, soil organic matter (SOM), recognized as a first order chemical indicator (e.g. Schoenholtz et al. 2000), is widely used as a predictor of soil quality and may measure several soil functions simultaneously.

Increased levels of organic matter have been related with formation of aggregates (e.g. Six et al. 2004) which increase matrix porosity (e.g. Dexter et al. 2008), improving soil structure and water retention capacity (except for fine-textured soils with low organic carbon values, in Rawls et al. 2003). Porosity determines aerobic conditions for microorganisms and plant roots needed for metabolic processes in which nitrogen is made available for plants. Therefore, a soil rich in organic matter would mean a great presence of microorganisms that develop several important soil processes and functions which increase soil fertility (Wardle & van der Putten 2002): production of hormones and other chemicals that work as plant pathogens or that promote plant growth; decomposition of organic matter yielding nutrients available for plants; bacteria symbiosis with plant roots; bacteria symbiosis with macro-invertebrates such as earthworms.

Soil moisture, on its hand, has a crucial link between hydrological and biogeochemical processes (Rodriguez-Iturbe 2000): water is necessary for soil vegetation as it has a key role directly in the metabolism of carbon by controlling photosynthesis (e.g. Granier et al. 2007); and indirectly for soil nitrogen mineralization rate for micro and macro fauna to develop their functions properly, specially as water is the medium where biological and chemical nitrogen transformations occur (Nielsen et al. 1973, Silvertown et al. 2015). Meanwhile, at landscape level nutrient pools are affected by spatial dynamics: surface runoff and water transport creates spatial distribution of moisture and nutrient which in turn affect spatial plant distribution. In this sense, Silvertown and colleagues (2015) defined spatial niche segregation as: (1) partitioning of space on fine-scale soil moisture gradient (e.g. García-Baquero et al. 2016); (2) partitioning of water as a resource; and/or (3) partitioning of recruitment opportunities among years. These authors summarize in a comprehensive review that the differences in the response of plant species to tolerance of water deficit or water excess yield plant segregation in hydrological gradients. Although they fail to demonstrate that plant species coexistence depends upon the presence of niche differences, their review points out the importance of soil moisture variation onto plant composition changes on a below-above ground direction. In this line, we have observed that, irrespective of fine-scale hydrological gradients and with a possible emphasis on the second type of spatial niche segregation, plant community artificial distribution originated after land use changes creates an inverse effect upon soil water availability on the above-below ground direction, modifying intrinsic characteristics of soils which could have a feedback effect upon plants affected by spatial niche segregation.

5.4.1 VU ranking after pH

Soil pH has an important role in many biochemical reactions that affects, among others, nutrient availability and yields different results depending on vegetation and land-uses, but it is that great variety of pH influences that makes it difficult to achieve any direct information about soil quality and analysis should be done defining optimum ranges for native biota (Schoenholtz et al. 2000).

Observed pH values are in the range of those observed by Ganuza and Almendros (2003) for soils of native and exotic VU (coniferous plantations, scrubs, forests and pastures) of the Atlantic Euskadi. At coniferous plantations pH was slightly (but not significantly) lower than at the other soils. Weathering and eluviation of the soil by running water has yielded RF as the most alkaline unit, followed by EP, while conifer presence promotes soil acidification. It has been observed that changes in tree species drive changes in soil physicochemical parameters (such as pH, total C or N), with significant impacts on soil microbial community (e.g. Ushio et al. 2008 and 2010). Therefore, regional forestry based on exotic tree species could be enhancing impacts on soil biota.

5.4.2 Air and soil temperatures under drought conditions: influence of vegetation unit

With the objective of registering upper boundary of thermal conditions we located our study at the driest season in our area (early fall: first week in October). Our survey took place in 2012, after a particularly dry and hot summer where mean maximum temperatures had been maintained between 25.0 and 28.3ºC, from June to September, reaching maxima of 36ºC along September (solar radiation >7% over normal conditions) with persistent southern wind and tropical nights (Euskalmet 2012). So, results subsequently discussed constitute a good approach to the stated purpose.

In this basin air temperatures are largely determined by canopy cover (from 0% in meadows to 90% in *Quercus ilex* forest), and soil temperature covariates with air temperatures exhibiting wide differences among vegetation units: meadows and *Eucalyptus* plantations display highest values (23.4ºC) and riparian forest lowest (16.6ºC) in close connection with river waters temperature (15ºC) for the later. Interestingly enough, soil and air temperatures for *Eucalyptus* and meadows were similar in spite of reduced sun exposure for the exotic plantation (60% canopy cover). In forested areas the influence of ground cover is very relevant, explaining 92% of soil temperature variation among the various vegetation units and, at this respect, *Eucalyptus* plantations rank lowest (mean ground cover = 3.7%). Since soil temperature can be lineally related to the added effects of canopy and ground cover explaining 63% of variation, these figures for meadows (61.7) and *Eucalyptus* (70.7) appear as lowest and comparable.

In any case, soil temperature influences the activity of roots and soil organisms and, in consequence, organic matter degradation increases in soils submitted to high temperature regimens (Kimmins 1996; Kirschbaum 1995). At this respect, we have observed at laboratory conditions that *Eucalyptus* plantation soils had a greater oxygen demand (greater decomposition rates) than broadleaved forest or broadleaved scrub soils for the same temperature (non-published data). According with our results, Ganuza and Almendros (2003) found in regional soils increased levels of soil organic C with decreasing annual air temperatures for plantations and semi-natural units and Londo et al. (1999) found similar increasing tendencies between soil respiration and soil temperature for three different management techniques at a hardwood forest (R^2 between 0.31 and 0.58).

No influence of topographic parameters such as altitude or slope upon temperature becomes evident and the shadow effect of mountain range may be explaining this result, although slight effects of aspect, restricted mainly to southern orientation, can be found.

5.4.3 Field water retained at maximum drought followed a VU ranking and depended on Field capacity

As mentioned as regards temperature data, the choice of the season targeted towards determining minimum hydration figures in topsoil. At this respect, total rainfall along summer season and September was from 50 to 70% of normal figures and, additionally, no precipitations had taken place along a week before sampling (Euskalmet 2012).

Within temperate climates about 75% of all precipitation enters the surface of the soil and becomes soil water: either soil moisture in unsaturated soil or ground water in saturated one (Hewlet 1982). Young cambisols, such as those found at Alonsotegi, show poorly developed litter (L), fermentation (F) and humus (H) layers, where humus and clay are scarce, and A, B and C horizons are present although weakly differentiated. Soil moisture storage includes water detained for a short period of time and water retained for a longer period at A and B horizons of the unsaturated zone, but also at higher L, F and H horizons (Hewlet 1982). At this respect, we have found top soil hydration depends exponentially on field capacity (maximum water retained at saturation), and water storage has been found maximized in scrub, emphasizing the importance of this unit to preserve humidity under drought conditions and, on the contrary, *P. meziesii* (PP) and *Eucalyptus* plantations represent driest units. As the large specific heat capacity of water provides soils with large water content a soil temperature buffering capacity (Kimmins 1996), high temperatures found on EP could be related to the fact that it is the driest unit.

As we have observed water content for different vegetation types only at a shallow soil profile, our next question was whether summer drought would reduce water availability only at the top soil, affecting in a greater extent herbs than scrubs or trees, but not working as indicators for deeper layers. At a study in a cold desert Schwinning et al. (2005) observed that summer drought decreased soil moisture both in shallow and deeper soil layers and reduced the infiltration depth of next winter precipitation and, consequently, had effects on soil moisture at almost all depths (0-100 cm) through the following summer. Initially no differences were found in water plant status among a shallow-rooted perennial herb, a sub-scrub with dimorphic roots and a woody scrub with deeper roots, but after drought occurrence increased only deep-rooted scrub species continued taking water while the other two species were dead or dormant.

In this line, at a review on hydrological niches in terrestrial plant communities performed by Silvertown and colleagues (2015), it can be observed that for deeper soil profiles and at those vegetation units in which trees are dominant, and where scrub and tree roots could have access to deeper soil layers, depth of water sources used varied in many different ways (among seasons, precipitation patterns, species or even intra-specific) in such way that authors could not describe the precise mechanism that governs plants to obtain and use water. Therefore, our results of differences on topsoil water content at drought at seven VU could be interpolated to a deeper soil profile and conclusions could be taken in terms of VU rank for water availability within the basin.

5.4.4 Soil bulk density and porosity are explained by organic matter content

Among physical indicators soil texture is the most critical property controlling water, nutrient, gas exchange, retention and uptake and influences most other properties and processes, but it is insensible to changes in management and bulk density has been proposed instead (Schoenholtz 2000). Further, bulk density is determined by structure, texture, porosity and organic matter content of soils (Kimmins 1996). Our results indicate an exponential decrease of soil bulk density associated to organic matter increase ($\boldsymbol{BD} = \mathbf{1.25} * \mathbf{e}^{(-0.05*SOM)}$) indicating that compaction is favoured in soils poor in organic matter as it is the case for flooded areas (i.e. riparian forests) where low density particles (organic matter) are easily washed out.

The characteristics of soil impose edaphic constraints which affect the supply of O_2, water and nutrient to roots: soil pore spaces can be filled by water or air, but an excess of any of them will deprive the plant of the other, as review by Silverton and colleagues (2015). At our study, at drought conditions large porosity values are related to large values of organic matter and field water content, obtained by scrubs and the subgroup conformed by deciduous plantations (especially *Q. ilex*), coniferous plantations (especially *P. radiata* for water protection) and climatophilous forests, meaning that attained porosity values have not reached that critical drying point. On the other side, low porosity values are related to low water and organic matter content, attained by meadows and *Eucalyptus* plantations. We have obtained a linear regression between porosity and OM: $\boldsymbol{BD} = \mathbf{1.25} * \mathbf{e}^{(-0.05*SOM)}$.

5.4.5 Field capacity for water retention and soil water content are related to SOM

We have observed that, at sandy soils and after extreme drought, water retention capacity and content were lowest for soils with low organic matter content with linear increasing tendencies at both relationships.

We describe the relation FC to OM at drought conditions by a linear regression: ***FC = 20.25+ 0.72*SOM***. A reduction of the field capacity of a soil below 25% yields water content values between 3 and 12% (3 and 12 water g for 100 soil g). Our results are in agreement with those of Rawl et al (2003) who related increments of organic matter content with an increment of water content for sandy soils, but not for fine-textured soils. These authors observed that sensitivity of soils to water retention decreased when organic content increased, which would support the use of a potential equation in our results for FC and SOM regression (R^2=0.48, a=14.48±1.39, b=0.29±0.04, n=66, $y=ax^b$). We discarded it because for vegetation units separately analyzed, only PP, BP and RF could be explained (R^2=0.76, 0.32 and 0.39 respectively) while linear equation fitted for all units except MD and EP.

Clearly, in drought conditions top soil organic matter (SOM) determines water content of that soil (FW): a linear regression equation between field water content (% g/g) and organic content (% g/g) indicates an isometric relation: ***FW* = 0.056 + 1.051*SOM***.

Predictions of soil water content at large territories based upon correlations observed at small soil surveys could be from unsatisfactory to good. In this line, Nielsen and colleagues (1973) found superior results for soil-water content field measurement when these were taken in terms of percentage of saturation (%) rather than volume (cm^3/cm^3). Further, these authors support the idea that the relationship that we have observed between FW and BD, although it is not very strong, could be an indicative that this soil survey has a relative good value for predicting soil-water retention.

5.4.6 Differing soil resources

Presence of OM in soils contributes to gas exchange reactions, water and carbon cycles, and nutrient availability. Temperature increment reduces (by increasing metabolic rates) soil organic matter content (Kirschbaum 1995) with a concomitant reduction of water content and temperature buffering capacity of soils. This analysis is in accordance with our results for increased respiration rates related to greater soil temperatures of EP, HT and FO (non-published data).

This ability of a single indicator to give an overall idea of a soil's quality has made of SOM a valuable index. In accordance with points 5.4-5.7, our results show the relationship of several soil parameters with OM (linear positive for FW, FC, P and exponential negative of BD), which support the general idea of the importance of OM as a soil quality indicator. At drought conditions of a sandy top soil, simple equations can be used to predict field capacity for water retention, field water content, bulk density or porosity as functions of organic matter. Nevertheless, mean values of OM content for EP were half way of the UV ranking, but this unit was the driest and with less capacity for holding water, had the greatest bulk density and least porosity among the seven units. Therefore, generalization of OM content as a valuable indicator should be accomplished with caution and other aspects should go along with OM as soil quality descriptors to avoid masking important ecological impacts incurred by non-sustainable forest management (see *Eucalyptus* plantation ahead).

Soil is closely related to the vegetation that supports. In fact, in forested areas and with the exception of riparian forest were low density organics resulting from the activity of both producers and decomposers is continuously washed out, we have found a direct relationship between organic matter content of soils associated to vegetation units and percentage of ground cover explaining 94% of variation. These subsystems are dependent upon each other and direct and indirect interactions between them have the potential to operate as major drivers at community, population and ecosystem-level processes. Further, this complex interaction enlarges differences between the inherent characteristics of soil parameters. Soil quality can be severely damaged after land uses that modify intrinsic characteristics of soil in a different way for each vegetation type as we have observed in this study for water and organic matter content on siliceous soils or as shown by Lu et al. (2014) for nutrient dynamics on karst ecosystems.

Studies have previously concluded that reducing the intensity of harvesting or selecting native tree species planted would improve soil organic content and reduce soil nutrient loss (e.g. Merino et al. 2005; Ushio et al. 2008), preserve local soil biodiversity (e.g. coleopters at *Quercus* native forest compared to coniferous exotic plantations, Wiezik et al. 2007; increased earthworm diversity by tree species identity, Schwarz et al. 2015) or improve chemical properties by enhancing soil biota (Jouquet et al. 2014), among others. We have seen that also water content and soil temperature can be improved by the same management premises.

At our study, among those vegetation units that most modify top soil temperature, water and organic content, bulk density and porosity appear eucalypt plantations followed by extractive coniferous plantations. These results are in accordance with those of regional studies undertaken mainly for coniferous plantations (Atauri et al. 2004, Merino et al. 2005, Edeso et al. 1999). Local land use, however, is divided almost equally between semi-natural use and artificialization. The later is devoted mainly to silviculture, although rural and urban areas are present. Moreover, natural old forests have disappeared, and the existing forest set's territorial distribution numbers (9%) are less than half the "fragmentation threshold" (20%), below which habitat fragmentation may affect population persistence, and slightly above the minimum value considered as "extinction threshold" (4%) for a population to go extinct (Fahrig 2001).

5.4.7 Results analysed for each vegetation unit from the perspective of future regional management

Differences in organic matter production by soil micro and mesofauna of the seven vegetation units yielded differences in soil properties explained by organic matter content: water holding capacity, water content after extreme drought, bulk density and porosity. Further, these differences existed even within forested units suggesting that not all forestry management techniques are sustainable. Further, we have observed that plantation grounds show a great difference in species composition, especially in herbs and scrubs, when compared with semi-natural units: low species presence (<10 u) at plantations makes of them poor areas in terms of plant biodiversity conservation.

Large extent of the municipality is devoted to **coniferous plantations**, with largest patch sizes among all units. Conifers promote soil acidification. We have found statistical differences for all soil parameters studied, except for soil temperature, between those areas managed with extractive purposes and that with water source protection. Compared with the other VUs, *Pinus radiata* for water protection shows soil quality factors as good as the best results obtained in the study (generally HT), while extractive *Pseudotsuga menziesii* and *Pinus radiata* yielded extremely low values of ground cover, field capacity, field water content, soil organic matter, porosity, and among the largest bulk density values. Further, *P. menziesii* had lower water and organic matter content than the EP unit and equal water content efficiency. For *P. radiata* water and organic content could be increased by better management techniques that would allow presence of herbs (ground cover). Lower values of soil organic matter in those vegetation units with extractive purposes (those of PP and EP) could be an indicative of long term nutrient loss subsequent to harvesting management in which nutrient exports exceeds natural inputs (Merino et al. 2005). Our study shows that harvesting leads to organic matter and water content reduction in top soil. In this sense, Merino et al. (2005) concludes that a selection of tree species and more sustainable harvesting procedures would reduce harvesting nutrient loss. Among the harvesting procedures, they mention reducing tree densities and increasing the length of rotation, especially for *Eucalyptus* (above 18 and 50 years for *Eucalyptus globulus* and *Pinus radiata*, respectively), while nowadays tendency is to fell bellow 12 and 30 years old, respectively (X. Barreiro, ranger from the Regional Government of Bizkaia, Pers. Comm.).

***Eucalyptus* plantations** in the study area occupied more territory than forests (including riparian, acidophilous *Quercus robur* oak forest, *Fagus sylvatica* acidophilous beech forest, Mediterranean evergreen *Quercus ilex* woodland, non riverine woodland with *Sorbus*, and deciduous woodlands of *Q. pubescens* and of *Castanea sativa*). EP was present at areas with steep slopes (maximum found ca. 40% regardless of its lack of ground cover), dry -water consuming- and compacted soils, and with yearly peak flows, all despite its larger water repellence during dry periods (e.g. Leighton-Boyce et al. 2003) and fire history of the municipality which can increase hydrophobicity (non-wettability) and surface runoff and erosion (DeBano and Krammes, 1966), and despite small presence of alive ground cover and therefore low storm-flow water detention capacity (Hewlett 1982). Although soil was either totally covered by *Eucalyptus* bark and leaves or bare soil (after litter raking), presence of herbs was almost null, probably after largely toxic terpenes that inhibit seed germination and herb growth (del Moral & Muller, 1970).

Compared with other units, EP had lowest field capacity, field water content, and porosity, largest bulk density and high degree of dehydration (44% of potentiality) and oxygen consumption rates (data not shown), and middle values for organic matter content which only surpassed that of meadows and riparian forests. The forest floor plays an important role as a source of dissolved organic matter into deeper soil layers, but at a study of soil organic matter content at *Eucalyptus* plantations in Cantabria province (less than 100 km west of Alonsotegi) Ortiz et al. (2013) found similar organic matter content at three different soils: haplic cambisol, haplic umbrisol and cambic umbrisol, with no significant differences among them (Horizon A, C_{tot}= 3.24%, 2.90% and 1.68% respectively, while at our study C_{tot}=5.5% for the first 13.5cm of Horizon A); and indeed, they cite values of 3.85% at sandy soils of Euskadi. Conversely, differences were found among horizons, with values below 0.44% for B and below 0.14% for C. In our case, we have found differences among the first 3 cm and the first 13.5 cm of soil (32.08% and 14.00% of organic matter content respectively) that follow this tendency of organic matter accumulation at the first centimetres of the soil (non-published data). In this same line, at tropical sandy soils with large infiltration rates and low adsorption capacities, and despite being soils considered large exporters of dissolved organic matter, it was observed that after the second year of planting *Eucalyptus*, organic compounds produced in the litter layer were mainly consumed by microorganisms or retained in the first 15 cm of soil, with low exchanges between soil solutions and organic matter (Versini et al. 2014 and references therein).

In sum, soil high temperatures at eucalypt plantations were not similar to those achieved by local deciduous forests with similar canopy cover shade values, and were as high as that of exposed meadows. High organic matter content appeared at first soil's 3 cm, linked to presence of a bark and leaves layer that does not enriched layers below, and was related to large metabolic rates (non-published data). This large metabolic energy could be stored as heat with a consequent change in temperature of the body (Landsberg and Sands, 2010) due to a high decomposition rate of organic matter by soil microorganisms (heterotrophic decomposition) and root respiration. In our study, other than organic matter, we also found greater water content, field capacity and highest soil temperatures at the first three centimetres of soil in contrast with data for 12 cm deep (non-published data).

Broadleaved plantations, composed of exotic and native species and with two different species at each stand, have low distribution numbers despite the fact that they achieved, in general terms, large quality values in comparison with the other units. There are not substantial differences between mean values obtained for FO and BP in field and laboratory analysis, except for slightly greater water content and lesser bulk density for BP. On the contrary, plant species diversity was greater at FO. The most important stakeholder on ecosystem processes is belowground community composition which directly affects physical and chemical properties of soil, particularly soil carbon and nutrient cycle. Maintaining a healthy soil community would therefore benefit soil properties. In this sense, Korboulewsky et al. (2016), in a throughout review of numerous papers on soil biology after the premise that above ground vegetation affects below ground fauna, found that soil biology benefits from mixtures of litter types with different functions, but it is not tree richness what matters but species composition and tree identity. These authors conclude that the focus of forest management should be upon which tree species is beneficial and which detrimental to soil conditions. We conclude that mixed broad leaved plantation seems the most sustainable forestry practice and should be promoted to replace that of EP and of several PP species and management techniques, but not on the cost of semi-natural forests whose extent and quality is already too limited.

Meadows show a large variety of sub-units (six Eunis classes) in Alonsotegi and, although there is a representation of two main types (xeric and mesic meadows) and more samples were taken (5 sites), results should be handled with care. Differences in management could have important effects upon results within *Cynosurion* class which might not be representing truly Atlantic hay meadows, as both sites were used by livestock, with different number of animals (donkeys) and at different periods of the year. *Nardetalia* class meadow was used by wandering livestock (cows and horses), while part of the *Arrhenaterion* field was used as a fruit garden. This study gives a picture of several meadow classes, all largely affected by human land use. Xeric meadows show a greater capacity to buffer soil temperatures related to large air temperatures than mesic ones. Both MD categories have field water content values above those of eucalypt and coniferous plantations with extractive purposes and organic content above that of *P. menziesii*, whereas bulk density is large, particularly for mesic category (*Cynosurion*) which could be exposed to livestock overpressure. From a management perspective those MD classified as “Atlantic hay meadows”, that relate to properties closer to the farm, seem to be more affected by land use overpressure (too many domestic animals, and other uses such as vegetable and fruit orchards) than uphill xeric meadows intensively used by wandering livestock.

Scrub is the unit better represented at the municipality in terms of distribution numbers. HT shows the best soil parameter results, although differences among classes exist: mainly of more deteriorated alkaline *Prunetalia spinosae* –*Crataegus monogyna*- with any of the other two. *Crataegus*-HT sampling site was a karstic area, and it was intensively used by wandering livestock (cows, horses and sheep) moving from shelters to pastures and water ponds used by domestic animals found at this part of Sasiburu range.

We observed a smaller amount of livestock (cows and horses) at the other two sampling sites at Ganekogorta range, *Erica*-HT and *Ulex*-HT, in which an increased presence of plants associated to their class, could be an indicator of less livestock pressure. However, the area has recently been cut during maintenance works of an electricity line and domestic animals wander inside the patch nowadays. If we compare relevés obtained at the sampling site before (2012) and after (2016) maintenance works (Annex 4, HT#2 and 3) we observe fewer number of HT related species. Our results show that three HT types have greatest field capacity for water holding, but among VUs *Crataegus*-HT yielded medium values while the other two gave greatest water content values. Indeed, *Ulex*-HT water content values doubled those of any other VU. As scrubs have a great regional threat of seasonal fires for pasture (V. Carrecedo, pers. comm.), management should outline HT capacity for water retention, less oxygen consumption and less soil temperatures and preserve them from fires, while pasture needs should be considered by transformation of other land uses if policies for climate change adaptation want to be promoted.

Forest unit refers to climatophilous acidophilous *Q. robur* deciduous forest and *Q. ilex* evergreen forest. *Q. robur* was sampled at siliceous soils while *Q. ilex* at alkaline one. Xeric woodland data came from 2 soil samples and should be taken with care. *Q. robur* woodland presence represented <6% of their potentiality, and patches were small (mean patch area is 1.88 ha ±1.56 SD). Sampling sites were degraded in different ways: fragmented by roads, terraced or close to a livestock shelter. Mean values for most of the parameters locate this unit in the middle area of the rank, although xeric woodland has water content values as great as those of RF and the greatest organic content. Despite a relatively large soil temperature, we have observed a different response to drought of forests compared with the other units seen in the water content field capacity ratio, which could derive from tree root capacity to reach deeper reservoirs of soil water (Bonan 2008).

Water content found at acidophilous *Q. robur* forests was only slightly larger than that of EP and extractive PP which evidences a degraded soil quality in FO. As bare soil is found at plantations (PP, BP, EP) large numbers of wandering livestock feed at non-fenced prairies (~160ha), open scrubs (previously fired for grazing) or forests (~85ha), which exert a great pressure upon soil characteristics of semi-natural units. Further, although we have found superior species richness values at semi-natural habitats than at artificial ones, the former group has still lower values than those found at areas with little livestock pressure (Agut et al. 2008; Onaindia et al. 2013). If we follow general tendencies obtained for all units, we think that soil parameters for forests could improve with better practices within forest use, with an effort on ground cover improvement and a decrement on livestock use.

Riparian forests are narrow strips of gallery forests (<20m wide) that are scarcely represented at vegetation maps as a result of their small width, and usually constricted by plantations. RF showed lowest soil temperature values, being largely recognized as functional temperature buffer units. Their field capacity for water holding could have been lowered by presence of rocks, a possible indicator of their degraded state. Small organic content and large pH is caused by continuous washing effect of running water.

5.4.8 Climate change mitigation and land use management

It has been described that climate change and management practices changes can alter organic matter content and composition affecting soil structure and adsorption properties, and in a last extent water retention capacity, but, on the other way around, soil properties after changes in management practices could affect climate: an increment in temperature leads to a decrease in soil organic C, and this C would have to be oxidized to CO_2 further increasing atmospheric values and contributing to global warming (Kirschbaum 1994). Although possible actions to mitigate climate change are to reduce temperature and to reduce CO_2 in the atmosphere by enhancing carbon sequestration in the forms of plant biomass, we have found substantial differences in temperature and in oxygen consumption (non-published data) among forested areas. Therefore, we think that not all forestry management techniques are sustainable, neither all of them contribute to climate change mitigation. Despite the small size population limitation of the study, we present evidence that regional oak forest and broadleaved plantations share similar results in organic matter content, temperature and canopy and ground cover that differentiate them from *Eucalyptus* and coniferous plantations for extractive purposes. Indeed, eucalypt exotic plantations contribute locally, but in a higher extent than native vegetation, to the warming cycle. In this sense, Naudts and colleagues (2016) support the idea that converting deciduous forests into coniferous plantations has contributed to climate warming. Nevertheless, we have observed that these authors have only discriminated between broadleaved deciduous and evergreen coniferous tree species, in the same line as national forest inventories, where *Eucalyptus* plantations are included within the broadleaved unit and, thus, reducing the temperature gap between native forests and plantations and concealing a greater effect of forestry practices upon climate change.

In sum, we agree that land management approaches to climate change mitigation should account for land-cover changes and for changes in forest management, but our contribution is that not all broad leaved forested areas help equally to cool the climate and a special emphasis on acknowledging exotic species' effects at temperate areas should be undertaken.

In this study we relate the influence of land use change, and derived transformation into plant community presence, on organic matter, and propose vegetation unit as a proxy for organic matter content, establishing a ranking indicator of soil quality and functionality on mitigation of climate change impact on soil warming and drying. Land use changes that imply large vegetation cover transformations have impacts upon soil that will affect oxygen supply and water and nutrient balance. As soil-water is a driving factor of plant growth and nutrient and carbon availability, which is influenced by organic matter presence, and both OM and FW are soil properties related to vegetation units and their land use, we think that intensive land management negatively affects plant-soil feedbacks.

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Table S5.1. After real and potential vectorial vegetation maps we developed a vegetation crosswalk between Alonsotegi's vegetation units (VU) and EUNIS code and obtained fragmentation data per VU and EUNIS class over a territory of 2022 ha. After a DEM analysis of raster images (QUANTUM-GIS) we obtained topographic data for 20*20m cells, natural potential vegetation distribution (NPV, %), real vegetation presence (% of the territory) and the relation real to potential distribution is shown. S1-a) summarizes these data for main vegetation units and S1-b) for forest units.

a) Main units

VU	Description	EUNIS	Real (%)	Patch no.
AC	Aquatic areas	C2/J5.3	1.2	4
AN	Anthropic areas	H5.6/J3.2/J3.3/J4/J4.1/J4.2	2.1	16
MD	Meadows	E1.26/E1.27/E1.72/ E1.73/E2.11/E2.21	14.4	79
HT	Heaths	E5.31(X)/E5.31(Y)/F3.11(X)/ F3.11(Y)/ F4.21(X)/F4.21(Y)/ F4.23(X)/ F4.237/F5.21(Y)/FA.3	28.9	123
FO	Forests	See (b)	9.0	91
PP	Coniferous plant.	G3.F(M)/G3.F(P)/G3.F(Q)/ G3.F(T)/G3.F(U)/G5.74/G5.82	28.6	106
EP	*Eucalyptus* plant.	G2.81/G5.73/G5.81	7.7	42
BP	Broadleaved plant.	FB.4/G1.C2/G1.D(X)/ G2.83(X)/G5.72	3.6	37
RU	Karstic areas	H3.2	0.4	5
RA	Rural areas	I1.2/J1/J2	4.0	27
	Semi-natural units	MD/HT/FO	52.7	293
	Plantations	BP/EP/PP	39.9	185
	RA and AN		6.2	43

b) Forest units

FO	Description	EUNIS	NPV	Real (%)	Real/NPV	Patch no.
DF	Juvenile forests	G5.61	-	3.3	-	36
AG	*Alnus glutinosa*	G1.21	2.4	0.1	0.0	2
SA	*Salix atrocinerea*	F9.2(Y)	-	0.05	-	1
FS	*Fagus sylvatica*	G1.62	8.3	1.2	0.1	11
QR_ac	*Quercus robur* (ac)	G1.86	54.3	3.1	0.1	28
QI	*Quercus ilex*	G2.121	23.8	0.9	0.0	9
QP	*Quercus pubescens*	G1.71	-	0.1	-	2
CS	*Castanea sativa*	G1.7D	-	0.03	-	1
BA	*Betula alba*	G1.91	-	0.2	-	1
QR_me	*Q. robur* (me)	G1.A1	0.4	-	-	-
QPy	*Quercus pyrenaica*	G1.7B1	10.8	-	-	-
Total			100	9.0	0.1	91

Abbreviations: ac: acidophilous; me: mesophytic; VU: vegetation units

Table S5.2. Alonsotegi topographic characterization of natural potential vegetation. ANOVA (P-value< 2.2e-16) and Tukey-HSD (<0.05) non significant grouping are shown.

	Max.	Mean	1	2	3	4	5	6	F-value	T (ns)
Altitude			**AG**	**QPy**	**QI**	**QR_ac**	**QR_me**	**FS**		
	996.7	330.8	69.2±1.5	186.3±1.3	299.0±1.3	308.9±1.0	656.1±2.0	659.8±1.6	6114.1	(5-6)
Slope			**QR_me**	**AG**	**QPy**	**QR_ac**	**FS**	**QI**		
	73.4	26.1	17.4±0.4	22.7±0.4	25.0±0.1	25.2±0.1	28.7±0.1	29.4±0.1	346.6	(5-6)
Aspect			**QPy**	**AG**	**QR_ac**	**QI**	**FS**	**QR_me**		
	-	189.0	147.0±0.9	159.3±2.0	184.1±0.7	189.2±0.9	234.1±2.3	236.6±4.9	291.9	3

AG: *Alnus glutinosa*; FS: *Fagus sylvatica*; ns: no significant; QI: *Quercus ilex*; QPy; *Quercus pyrenaica*; QR_ac: *Quercus robur* acidophilous; QR_m: *Q. robur* mesophytic.

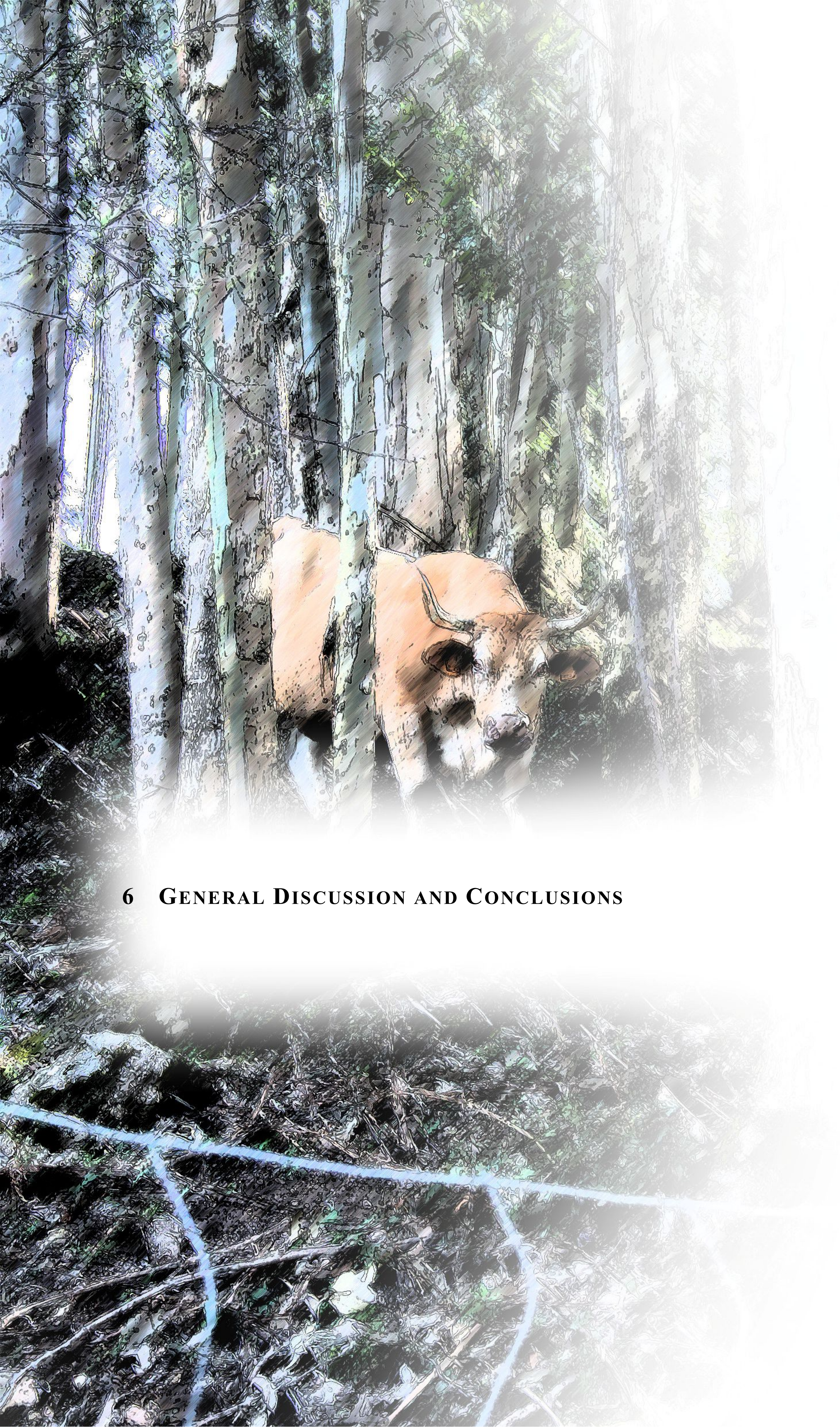
Table S5.3. Fragmentation and topographic basic data (mean±SE) for main vegetation units found at Alonsotegi municipality. Data was obtained after digital elevation model analysis at Quantum-GIS. Total data is for all the units found at the municipality, some of them not shown. See VU codes in table S1.

a) Fragmentation basic data

	MD	HT	DF	FO	PP	EP	BP	RF	Total
nº fragment	79	123	36	53	105	42	38	2	530
Area (ha)	287.4	573.3	52.3	110.5	571.7	156.0	80.4	24.5	2022

b) Topographic data after DEM (mean±SE)

	Max.	Mean	1	2	3	4	5	6	7	8
Altitude			RF	EP	DF	FO	HT	PP	BP	MD
	996.7	330.8	73.8±10.5	192.4±1.4	282.7±5.9	337.1±3.6	338.0±1.5	372.1±1.2	418.1±4.1	430.8±3.3
Slope			MD	RF	BP	PP	HT	EP	FO	DF
	73.4	26.1	23.2±0.1	23.2±1.8	26.9±0.2	27.7±0.1	27.9±0.1	28.0±0.1	28.2±0.2	28.6±0.2
Aspect			BP	FO	EP	DF	PP	HT	MD	RF
	360.0	189.0	155±3.2	160.9±2.4	164.4±1.5	169.0±2.9	186.7±0.9	195.9±0.9	211.7±1.3	278.6±12.5



6 General Discussion and Conclusions

6.1 About the ecological valuation of the Biscayan Atlantic landscapes

International markets are dominating and ruling the landscape, inducing a homogenization and fragmentation process across Europe, where cultural landscapes and their biological diversity decline and only remnants remain (Jongman 2002). In the hilly landscapes of Biscay we have observed that this homogenisation and fragmentation is due to forestry and cattle industries, where plantations occupy large areas limiting the presence of semi-natural units to smaller fragments, and where exotic species and wandering animals affect vegetation and soil functionality and, therefore, decrease the intrinsic value of the vegetation unit.

Despite the positive "green" attitude of the Basque society, with many strategies already developed (biodiversity protection strategy, ecological network development, climate change mitigation plan, sustainable development, tourism and industry, etc), our results show that inaccessibility seems to be the driving factor rather than actual protective and sustainable management or policies. As already cited along this thesis, our conclusions are in accordance with those of many other regional and international scientists that outline similar results in other areas of ecological specialization, making evident a need of change of nowadays ineffective, but supposedly sustainable, paradigms.

According to our own observations at rural landscapes of Golako basin (Chapter 4), Jongman (2002) expected an urbanisation claim ~2-3% of the land in Europe for 2020, although the influenced area at the urban fringe would be much larger, after agriculture abandon and (semi-) natural units' substitution by artificial gardens or recreation facilities used to fulfil aesthetic, social or educational needs. But on the other hand, and in contrast with what this author observed in the rest of Europe, we have noted that abandon of agricultural lands has not result in natural afforestation with native species: for the last decade and a half at Golako basin there has been an artificial afforestation process of exotic plantations.

Our aim was to acknowledge not only this landscape change but how much did it affect its quality. In sum, urban and rural areas and their area of influence are becoming more artificial whereas the green landscape is under an intensive silviculture which reduces vegetation and soil functionality and plant diversity. At those areas not good enough for forestry production, semi-natural units have to coexist with cattle grazing needs. Not protected sites neither public mountains show a better treatment becoming an opportunity for this spin towards biodiversity restoration.

6.2 About the index performance

Strenghts

1. CI has a stand scientific ground that enables it as a high quality index to be used in territorial management and biodiversity protection (Chp. 2 and 3).

   Vegetation description and classification provide units, needed for basic scientific research, which become the grounds of a tool to be used in land management and protection (Peet and Roberts, 2013). Plant community studies through a phytosociological approach are critical to scientific research. The European Union is already using phytosociologically defined vegetation type approach to map European habitats (EUNIS) and to define endangered habitats or habitats under protection of the Habitat Directive (Loidi et al, 2007; Mucina 2013).

2. Biological value worked fine with forests (riparian, degraded and mature) (Chapter 4).
   Forest valuation has yielded a heterogeneous ranking that account for different forest conservation stages which we have related to increasing patch size, slope and altitude.

CI index emphasizes in biotic and abiotic entities that create ecosystem services, not in the services *per se*, aiming to protect ecosystem functions and related biodiversity from the ecological perspective and not from the human actual needs. Actual needs fluctuate mainly according to economic situations (Chan et al. 2007) and therefore a long term valid valuation should be based upon ecosystem functions.

Biodiversity protection is not assured by nature commoditisation neither by anthropogenic ecological needs protection (Chan et al. 2007): it is not a matter of we (conservationist) or them (people), we must pursue conservation as protecting nature we protect humankind, but the question is how to achieve it as it is usually economics, rather than ecology, which informs policy, and it is not only conservation that matters, but poverty and associated human suffering.

Accordingly, we do not think that society should preserve biodiversity because of the benefits that humankind obtains from it, which is because of its services, but because of the system's functions. Today's human needs and interests might not be tomorrow's ones, so if we worked preserving today's services we could be unbalancing the system. Further, as it is not clear which elements provide which services, we think that the preserving work should be upon the ecosystem stability and functionality as it is known that a good quality system will also provide good services to humankind (Mori et al. 2013). Humanity is a part of today's system so protecting the system we protect ourselves.

Moreover, taking into account ecosystem functionality and not its services will avoid possible market failures due to social or political failure: perceived unpopularity of certain and nevertheless needed services, lack of comprehension or information by people or policymakers, etc. Further, as market forces will not always be on our side and goods and services can become obsolete or go bankrupt (Janzen 2001 *apud* Chan et al. 2007) we should not assume that economics can rescue conservation.

Weaknesses:

1. Some natural and seminatural vegetation units got a very low CI value that encounters with **actual protection needs of some landscape figures**, such as meadows and heather (Annexe 1, Orrantia et al, 2008). Biological values for meadows (MD) and scrubs (HT) have been reconsidered after a landscape evolution study (Chp. 4.4.4 and Annex 5) that shows an increasing pressure on the first and an opportunity on the second. Further, soil analysis has shown the importance of scrubs for soil quality (high water holding capacity and content, great organic matter content and porosity, less bulk density).

2. Initially **biological value (B)** covered a group of characteristic taxons but not all the sintaxonomical classes were present in the definition. Further, the vegetation units present at Golako basin's plots do not cover all the range present at the biogeographical sector. Besides, natural and semi-natural vegetation is classified after a phytosociological approach (vegetation units), while plantations are classified after EUNIS system (land use units).

   There were **vegetation units that are present in the Santander-vizcaine district** (biogeographic sector) but not at the initial definition (Chp. 2 and 3), which left on the hands of the person who was using CI to punctuate those other classes. In addition, there had been a change on the designation of some of the taxons (Rivas-Martínez et al. 2011) that affected the definition of biological value, B.

   Therefore, within this research we have worked onto different levels following those categories proposed by Rivas-Martinez et al. (2011) (Tb. 6.1). Firstly we have developed CI index for all vegetation units thought to be present at the biogeographic region: "Cantabro-Euskaldun Sector", studying both districts: "santanderino-vizcaíno" and "navarro alavés". After, we have valuated the main taxons of those VU. The valuated categories are mainly classes (51), followed by 4 subclasses, 20 orders and 3 alliances (Tb. 6.2). Annual vegetation has been described and added to the classification typology defined by Rivas-Martínez and colleagues (2011) and Loidi et al. (1997).

On the other hand, artificial vegetation needed to be valuated under the same index to allow us to compare functional roles on either type of vegetation, but it was not present in the initial index description (Loidi 1994). B values for plantations were proposed (Chp. 2 and 3) and have been revised and modified.

Table 6.1. Natural and semi-natural vegetation units (2013) proposed after Rivas-Martinez et al. (2011) and its relationship with earlier code (2003).

	Sinecological groups of the perennial, biennial and annual phytosociological classes	VU 2003	UV[d] 2013	VU 2013
A	Aquatic perennial vegetation of lakes, springs, fens and bogs	NP[b]	AC	AQ
B	Coastal and inland halophilous perennial vegetation	NP[b]	CO	CO
B2	Coastal and inland halophilous annual vegetation[a]	NP[b]	CO	CO
C	Chasmophytic and scree vegetation	OS[c]	RU	RO
D	Perennial and biennial synanthropic vegetation	RA	AN	AN
D2	Annual synanthropic vegetation[a]	RA	AN	AN
E	Forest fringe and megaforbic vegetation	OS[c]	LI	ED
F	Supratimberline perennial vegetation	NP[b]	OR	AL
G	Perennial grassland and meadow vegetation	PA	PA	MD
G2	Annual grassland vegetation[a]	PA	PA	MD
H	Seral dwarf scrub vegetation	BZ	BZ	HT
I	Scrub and woodland potential natural vegetation	BD/BM/BR	BO	FO

[a] Annual groups added by the author; [b] no present; [c] out of scale; [d] Acronyms in Spanish

3. Vegetation units (**MD, HT, PP) had a too wide scope** and there was a need to describe subcategories of some of these VUs.

   Analyzing CI outcomes (Ch. 2 and 3) it could be assumed that we worked at Golako's basin on a vegetation unit level for meadows, heathers and coniferous plantations which yielded to a homogenization of B values for those VU. Soil analyses have also shown a need to work on subcategories for those units on soil, indicator.

4. Forest's classification in "**degraded, riparian and mature forests" (Chapter 2 and 3) yielded to confusion** as there were some minor well developed forests included in the DF group, and most of the Biscayan mature forests are somehow managed or degraded.

   Degraded forest (DF), mature forest (MF) and riparian forest (RF) units have became a unique unit (fruticose and forest potential vegetation FO) which is then analyzed after its classes and several orders.

5. **The use of different vegetation classification systems by the scientific community** yielded to uneven results difficult to relate CI index with available cartographic data.

   We were working on a multiple scale system defined by plant community presence on semi-natural vegetation and land use on artificial one. Meanwhile, GIS work and the main cartographic database are in EUNIS system that deals with a cartographic scale defined mainly by soil uses. Although working with vegetation classification schemes is scale transgressive (Peet and Roberts, 2013) as there is no one correct scale for observing vegetation (Peet et al, 1998), in order to understand among different systems and use all the information provided by each of them, there is a need of working at different scales. We have developed a Biological value chart with maxima figures for each phytosociological class and several alliances (Tb. 6.2).

6. **Soil, Hydrological regulation and Carbon retention initial indicators** (Chp. 2 and 3) did not give extra information other than that given by B.

We had defined soil (S), water (H) and Carbon retention (C) indicators on a VU level which also yielded homogeneous values for all the units (Chp. 3). At Chp. 5 we define the basis for a ranking valuation of VU according to our results on soil functionality.

Table 6.2. Biological values for main phytosociological classes and orders. After Rivas-Martínez et al. (2011) except those COD with "L" that are after Loidi et al. (1997). N: naturality, P: Resilience; T: threat; F: floristic value; R: rarity (see definitions in pg. 33).

			Class and order		N	P	T	F	R	B
1	**A**	**A**	**Vegetación acuática, lacustre, fontinal y turfófila perennes**							
			Aquatic perennial vegetation of lakes, springs, fens and bogs							
2	A	3	*Potametea*	AQ	10	5	9	3		27
3	A	10	*Littorelletea uniflorae*	AQ	10	5	9	8		32
4	A	11	*Montio fontanae-Cardaminetea amarae*	AQ	10	6	9	8		33
5	A	12	*Magnocarici elatae-Phragmitetea australis*							
6	A	12a	*Phragmitetalia*	AQ	10	5	9	3		27
7	A	13	*Oxycocco palustris-Sphagnetea magellanici*	AQ	10	8	10	9		37
8	A	14	*Scheuchzerio palustris-Caricetea nigrae*							
9	A	14a	*Scheuchzerietalia palustris*	AQ	10	8	10	8		36
10	A	14b	*Caricetalia nigrae*	AQ	10	8	10	8		36
11	A	14c	*Caricetalia davallianae*	AQ	10	8	10	9		37
12	**B**	**B**	**Vegetación litoral y halófila perennes**							
			Coastal and halophilous perennial vegetation							
13	B	16	*Euphorbio paraliae-Ammophiletea arenariae*							
14	B	16a	*Ammophiletalia*	CO	10	5	10	6		31
15	B	16b	*Crucianelletalia maritimae*	CO	10	5	10	6		31
16	B	16c	*Artemisio lloydii-Koelerietalia albescentis*	CO	10	5	10	8		33
17	B	19	*Crithmo maritimi-Limonietea*	CO	10	8	9	5		32
18	B	20	*Juncetea maritimi*	CO	10	5	9	4		28
19	B	23	*Sarcocornietea fruticosae*	CO	10	5	9	6		30
20	B	24	*Spartinetea maritimae*	CO	10	5	9	4		28
21	**B2**	**B2**	**Vegetación litoral y halófila anual**							
			Coastal and halophilous annual vegetation							
22	B2	L.38	*Thero-Salicornietea*	CO	10	5	8	4		27
23	B4	L.39	*Saginetea maritimae*	CO	10	5	8	4		27
24	B8	L.41	*Cakiletea maritimae*	CO	10	5	10	4		29
25	**C**	**C**	**Vegetación rupícola y saxícola**							
			Chasmophytic and scree vegetation							
26	C	26	*Adiantetea capilli-veneris*	RO	10	5	1	4		20
27	C	27	*Asplenietea trichomanis*	RO	10	8	1	6		25
28	C	28	*Parietarietea judaicae*	RO	1	8	4	4		17
29	C	29	*Petrocoptido pyrenaicae-Sarcocapnetea enneaphyllae*	RO	10	9	1	6		26
30	C	30	*Anomodonto viticulosi-Polypodietea cambrici*	RO	8	7	4	4		23
31	C	32	*Phagnalo saxatilis-Rumicetea indurati*	RO	10	8	1	5		24
32	C	33	*Thlaspietea rotundifolii*	RO	10	8	1	6		25
33	**D**	**D**	**Vegetación antropógena perenne y bienal**							
			Perennial and biennial synanthropic vegetation							
34	D	34	*Artemisietea vulgaris*							
35	D	34A	*Artemisienea vulgaris*	AN	2	2	1	1		6
36	D	34e	*Brassico oleraceae-Lavateretalia arboreae*	AN	2	2	1	2		7
37	D	34B	*Onopordenea acanthii*	AN	2	2	1	1		6

38	D	35	*Epilobietea angustifolii*	AN	2	2	1	1	6
39	D	37	*Pegano harmalae-Salsoletea vermiculatae*	AN	2	2	1	3	8
40	**D2**	**D2**	**Vegetación antropógena anual**						
			Annual synanthropic vegetation*						
41	D2	L.27	*Stellarietea mediae*						
42	D3	L.27A	*Stellarienea mediae*	AN	1	1	1	1	4
43	D6	L.27B	*Chenopodienea muralis*	AN	2	1	1	1	5
44	D12	L.28	*Bidentetea tripartitae*	AN	3	1	3	1	8
45	D14	L.29	*Polygono-Poetea annuae*	AN	1	1	3	1	6
46	**E**	**E**	**Vegetación de lindero de bosque y megafórbica**						
			Fringe and megaforbic vegetation						
47	E	40	*Galio aparines-Urticetea maioris*	ED	2	2	2	1	7
48	E	42	*Mulgedio-Aconitetea*	ED	6	9	4	10	29
49	E	43	*Trifolio medii-Geranietea sanguinei*	ED	4	5	3	2	14
50	**F**	**F**	**Vegetación altioreina turbófoba perennes**						
			Supratimberline perennial vegetation						
51	F	44	*Carici rupestris-Kobresietea myosuroidis*	AL	10	9	1	9	29
52	F	45	*Kobresio myosuroidis-Seslerietea caeruleae*	AL	10	9	1	9	29
53	F	46	*Caricetea curvulae*	AL	10	9	1	9	29
54	F	47	*Loiseleurio procumbentis-Vaccinietea microphylli*	AL	10	9	1	9	29
55	F	48	*Salicetea herbaceae*	AL	10	9	1	9	29
56	F	49	*Festucetea indigestae*						
57	F	49a	*Festucetalia curvifoliae*	AL	10	9	1	9	29
58	F	49b	*Jasiono sessiliflorae-Koelerietalia crassipedis*	AL	5	4	3	6	18
59	**G**	**G**	**Vegetación pratense y pascícola perennes**						
			Perennial grassland and meadow vegetation						
60	G	51	*Festuco valesiacae-Brometea erecti*	MD	4	4	3	3	14
61	G	52	*Festuco hystricis-Ononidetea striatae*	MD	5	4	2	5	16
62	G	53	*Koelerio glaucae-Corynephoretea canescentis*	MD	4	4	3	3	14
63	G	54	*Poetea bulbosae*	MD	4	4	7	3	18
64	G	55	*Sedo albi-Scleranthetea biennis*	MD	6	4	2	3	15
65	G	56	*Lygeo sparti-Stipetea tenacissimae*	MD	5	4	3	3	15
66	G	57	*Stipo giganteae-Agrostietea castellanae*	MD	5	4	3	3	15
67	G	59	*Molinio caeruleae-Arrhenatheretea elatioris*						
68	G	59a	*Molinietalia caeruleae*	MD	5	4	3	8	20
69	G	59b	*Arrhenatheretalia elatioris*						
70	G	59.4	*Arrhenatherion elatioris*	MD	5	4	9	6	24
71	G	59.6	*Cynosurion cristati*	MD	5	4	3	6	18
72	G	59c	*Holoschoenetalia vulgaris*	MD	5	4	3	6	18
73	G	59e	*Plantaginetalia majoris*	MD	1	2	3	3	9
74	G	60	*Nardetea strictae*	MD	5	5	5	8	23
75	**G2**	**G2**	**Vegetación pratense y pascícola anual**						
			Annual grassland and meadow vegetation						
76	G2	L.21	*Helianthemetea guttati*	MD	4	1	1	3	9
77	**H**	**H**	**Vegetación serial fruticosa**						
			Seral dwarf scrub vegetation						
78	H	61	*Calluno vulgaris-Ulicetea minoris*	HT	5	3	3	3	14

80	H	62	*Cisto-Lavanduletea stoechadis*	HT	5	3	2	3	13
81	H	65	*Cytisetea scopario-striati*	HT	6	6	3	3	18
82	H	66	*Rhamno catharticii-Prunetea spinosae*	HT	6	6	3	6	21
83	**I**	**I**	**Vegetación potencial boscosa y fruticosa** **Scrub and woodland potential natural vegetation**						
84	I	68	*Alnetea glutinosae*	FO	9	10	9	10	38
85	I	70	*Nerio oleandri-Tamaricetea*	FO	9	7	9	10	35
86	I	71	*Salici purpureae-Populetea nigrae*	FO	7	6	9	10	32
87	I	71a	*Populetalia albae*	FO	9	7	9	10	35
88	I	71b	*Salicetalia purpureae*	FO	8	6	9	7	30
89	I	74	*Junipero sabinae-Pinetea ibericae*	FO	9	8	6	8	31
90	I	75	*Quercetea ilicis*						
91	I	75a	*Quercetalia ilicis*	FO	9	8	8	6	31
92	I	75b	*Pistacio lentisci-Rhamnetalia alaterni*	FO	8	8	4	6	26
95	I	76	*Querco-Fagetea sylvaticae*						
96	I	76a	*Fagetalia sylvaticae*	FO	8	7	8	7	30
99	I	76b	*Quercetalia roboris*	FO	9	7	8	6	30
111	I	76c	*Quercetalia pubescenti-petraeae*	FO	9	7	8	7	31
112	I	76.9	*Quercion pubescenti-petraeae*						
113	I	76.10	*Aceri granatensis-Quercion fagineae*	FO	8	3	7	7	25
114	I	76d	*Betulo pendulae-Populetalia tremulae*	FO	7	7	4	6	24
117	I	77	*Vaccinio-Piceetea abietis*	FO	9	9	6	8	32

6.3 General conclusions

About the ecological valuation of the Biscayan Atlantic landscapes:

1. Biscay has a very anthropized landscape, mainly devoted to forestry production.
2. Timber industry decreases vegetation and soil quality of those lands were plantations appear and of those occupied with semi-natural habitats.
3. Only those areas not good enough for forestry production are not managed for the timber industry, but other uses sum to topographic constraints (mainly extensive no-managed cattle grazing). Environmental protective policies are not enough for forest protection. For *Quercus ilex* forests the main protective factor is non-productivity (too thin soils for timber), while for *Quercus robur* forests only inaccessibility works. Timber pressure over tha territory reduces scrub and forest patch sizes while wandering cattle grazing affects intrinsic ecological value of scrubs, *Q. ilex*, *Q. robur* and *Fagus sylvatica* forests.

About the index performance:

4. CI index can be used for naturalistic evaluation of protected sites
5. Economic evaluation of a site should be founded on an ecological valuation based upon above and below ground functional assessment
6. CI index can be used also for artificial vegetation valuation
7. Evaluation at a vegetation unit (VU) level show little variability of the values achieved, probably due to the index definition: Both vegetation and soil differences are not well illustrated nor among the semi-natural vegetation units meadows (MD) and scrubs (HT) neither for coniferous plantations. Work should be done at an alliance phytosociological level.
8. "Biological value" indicator performance, based upon a phytosociological assessment of the vegetation type:
    i. Fragment size of the analysed vegetation unit is intrinsic to B
    ii. Forests valuation shows variability of the B indicator values achieved, but not on any of the other units.
    iii. Silviculture rules the land-use of the landscape.

9. “Soil quality factor” indicator has shown a ranking valuation among vegetation units (and at alliance level) for the main functions analysed: soil water holding capacity and content, soil physical quality (after bulk density, porosity and organic matter content) and soil temperature.

6.4 References

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7 CONTRIBUTIONS OF THIS THESIS

a. Scientific contributions/ Contribuciones científicas

- *Servicios ambientales del bosque: un ensayo en el bosque atlántico europeo inspirado en la experiencia del bosque tropical centroamericano* (2008, Revista de Biología Tropical Vol. 56 (4): 2087-2098). http://rbt.biologia.ucr.ac.cr/pages/vols/vol56-4.html

- *Vegetation science and the implementation of the Habitat Directive in Spain: up-to now experiences and further development to provide tools for management* (2008, Fitosociología, Italia) http://www.scienzadellavegetazione.it/sisv/rivista/articoloCerca.do?idArticolo=57

- Tesis de Master: "*Pago por Servicios Ambientales como herramienta para promover la conservación de recursos naturales del País Vasco*. Trasladando La experiencia y saber-hacer de Costa Rica". (Evaluación de calidad ecosistémica de una cuenca hidrográfica por medio de Índice IC y posterior propuesta de conversión a pago por servicios ambientales). 2002-04. Universidad de Costa-Rica - Universidad del País Vasco. Financiado por el Programa Red ALFA-GIACT (Unión Europea).

b. Presence at scientific conferences / Participación en congresos científicos

- Póster: "**Fragmentation pattern of an extinguishing lowland temperate forest**". VII Congreso de Biología de la Conservación de Plantas. SEBICOP. Vitoria, 2015. Coautora

- Póster: "**Relevancia de la gestión y la protección de la flora catalogada de Bizkaia**". VII Congreso de Biología de la Conservación de Plantas. SEBICOP. Vitoria, 2015. Coautora

- Póster "**Analyzing topsoil characteristics associated to vegetation types in Atlantic Iberian Peninsula: soil resistance to desiccation as related to organic matter**". Global soil biodiversity initiative. Dijon, Francia. 2014. Coautora

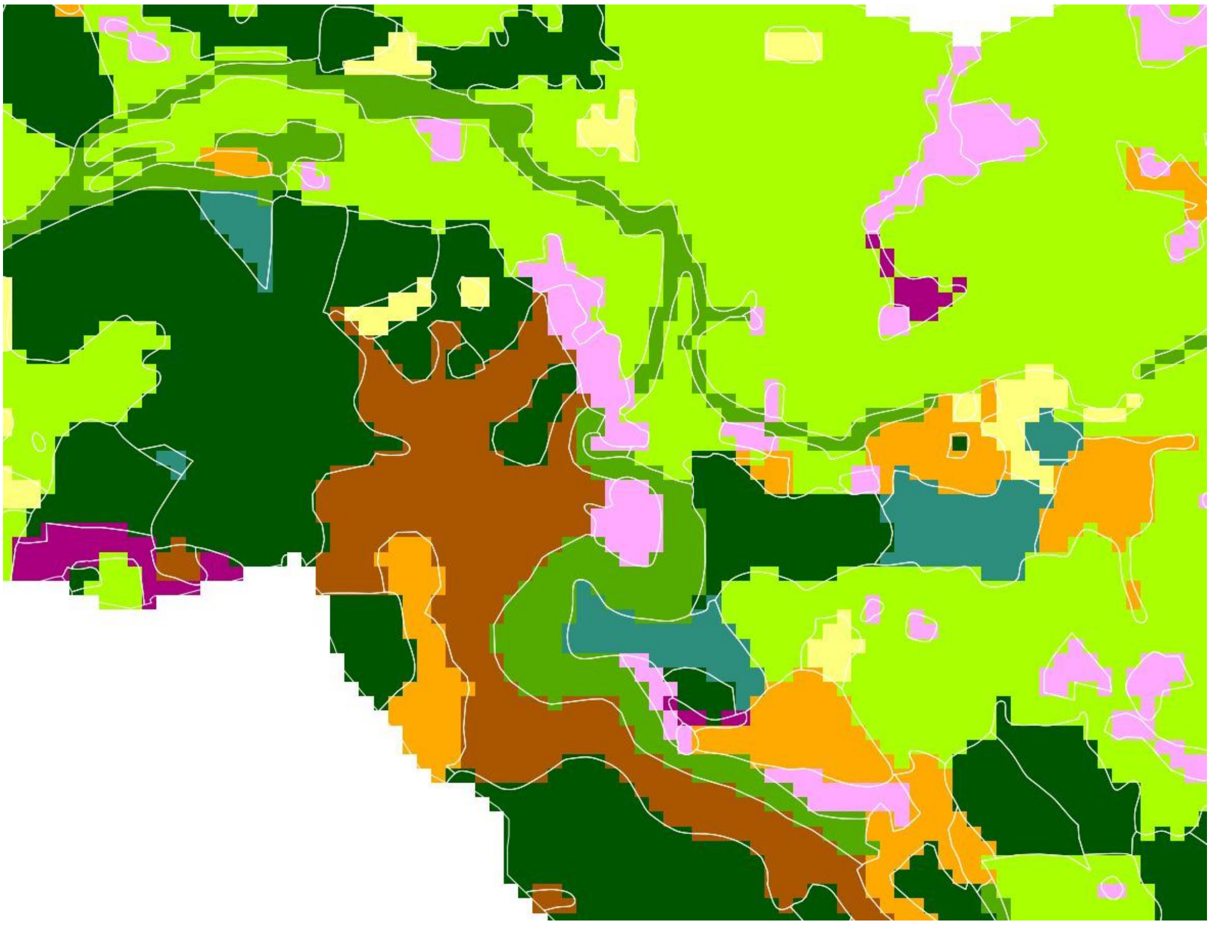
- Ponencia "**"Zizare Earthworm Lab. Educating soil ecology at preschool"**. Dijon, Francia. 2014 **http://www.globalsoilbiodiversity.org/?q=SoilBiodiversityEducation**

- Póster "Interés de conservación del brezal y la pradera en la Reserva de la Biosfera de Urdaibai". IV Congreso de Biodiversidad. Bilbao 2013. Coautora

- Integración de la conservación de la biodiversidad en la gestión del territorio municipal: el caso de Alonsotegi. I Congreso de Urbanismo y Ordenación del Territorio. Colegio de Ingenieros de Caminos, Canales y Puertos. Bilbao, 2008. http://www.ciccp.es/biblio_digital/Urbanismo_I/congreso/pdf/010305.pdf

- Ponencia "Vegetation science and the implementation of the Habitat Directive in Spain: up-to now experiences and further development to provide tools for management". Congreso Internacional de Fitosociología, Italia). Loidi, J., Ortega, M., Orrantia, O. 2007.

- Ponencia "Servicios ambientales del bosque: una herramienta para su fomento". XII Jornadas de Urdaibai sobre Desarrollo Sostenible. UNESCO Etxea, 2006. http://www.euskadi.net/contenidos/libro/jornadas_68/es_doc/adjuntos/68_es.pdf http://www.unescoetxea.org/dokumentuak/XIIJornadas_Comunicaciones.pdf



8 ANNEXES

Annex 1. Golako and Alonsotegi location at regional and European levels
Annex 2. Golako's natural potential and real vegetation maps and topographic characterization
Annex 3. Alonsotegi's natural potential and real vegetation vegetation and topographic characterization
Annex 4. Relevés at Alonsotegi
Annex 5. Posters

Annex 1. Golako and Alonsotegi location at regional and European levels

Oak forest potential and real presence vegetation map and sites' location

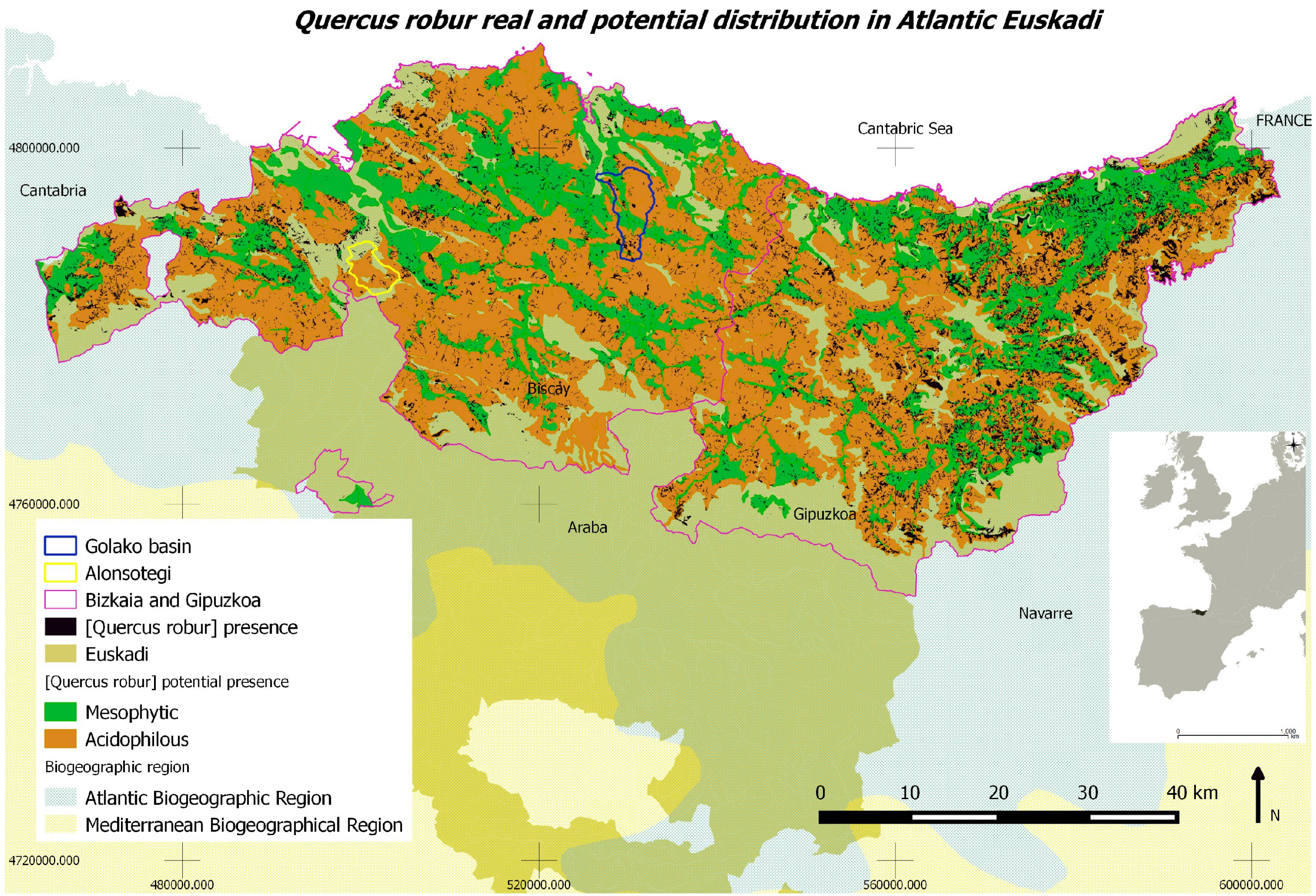


Figure 8.1 Golako basin and Alonsotegi municipality location (blue line, right and yellow line left) at the Atlantic coast of Euskadi. Northern territories are located at the Atlantic biogeographic region (light blue). Superposed appears two main types of natural potential vegetation: Atlantic mesophytic *Quercus robur* oak forests (green) and acidophilous (brown),

Annex 2. Golako's cartographic information

Golako's natural potential and real vegetation maps and topographic characterization

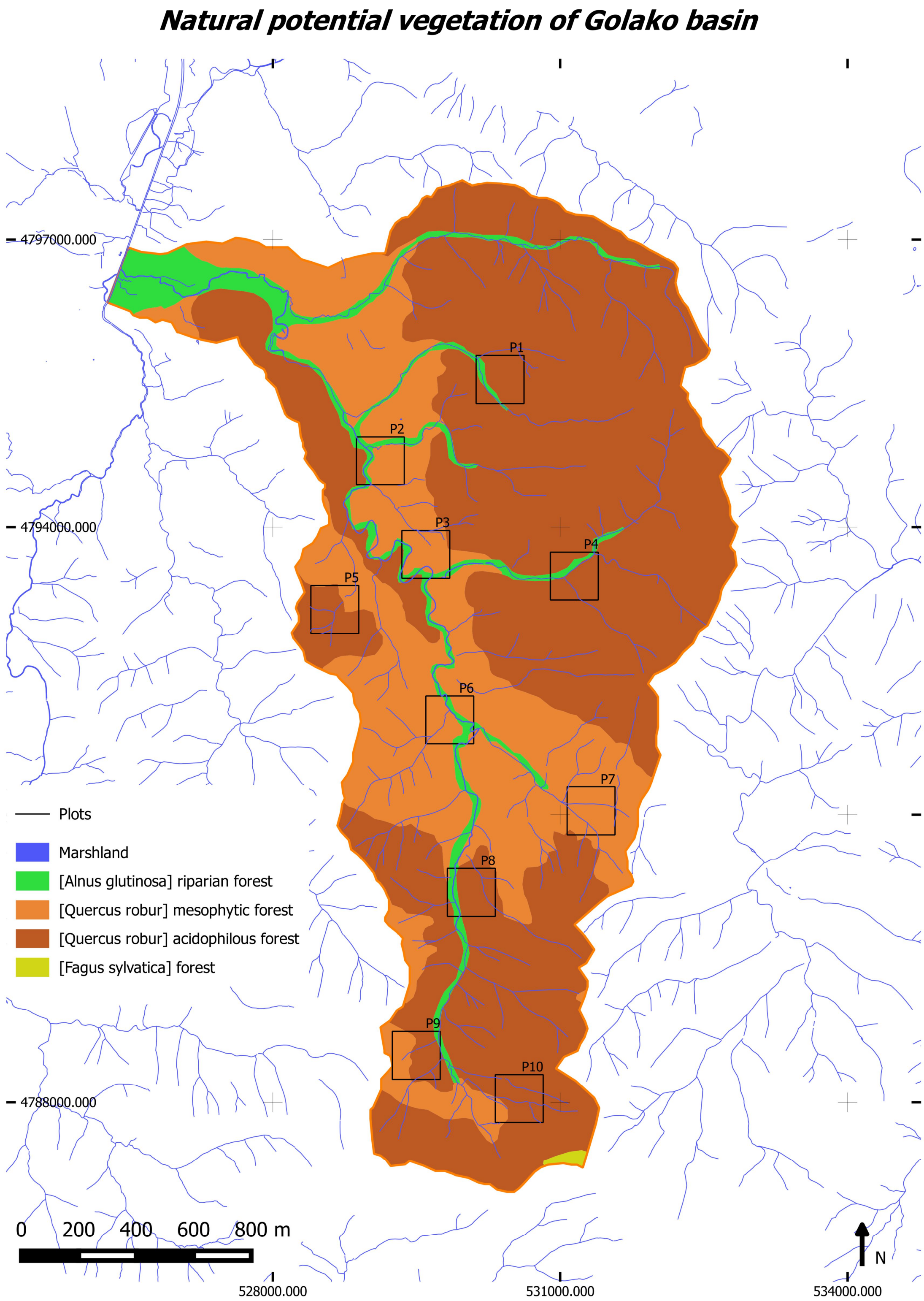


Figure 8.2 Natural potential vegetation at Golako basin and plots location (P1-P10): *Alnus glutinosa* riparian forests, Atlantic mesophytic *Quercus robur* oak forests, acidophilous *Quercus robur* oak forests, Fagus sylvatica acidophilous beech fores and marshland (upper left corner).

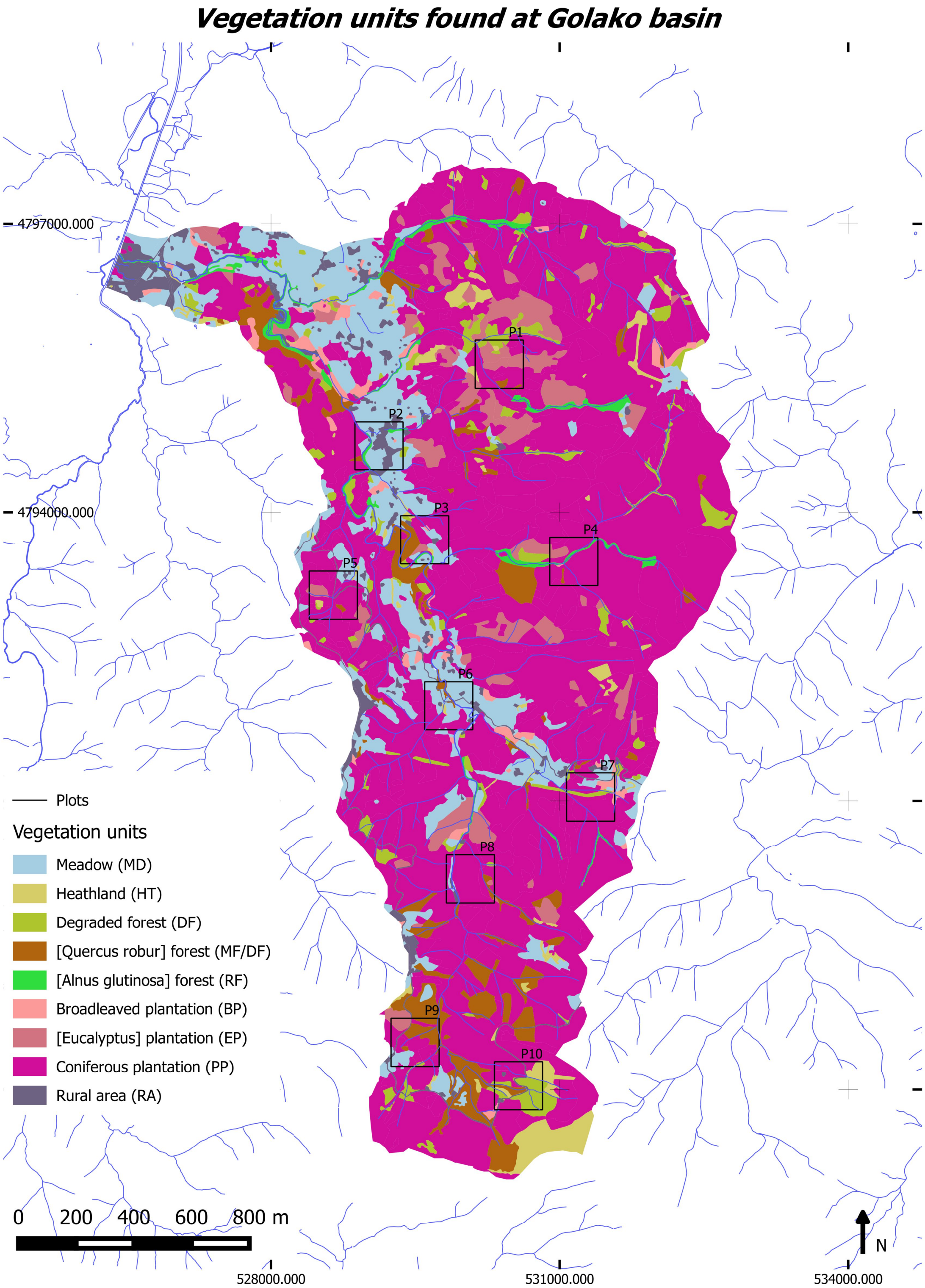


Figure 8.3. Real vegetation at Golako basin and plots. Heathlands belong to the scrub unit (HT)

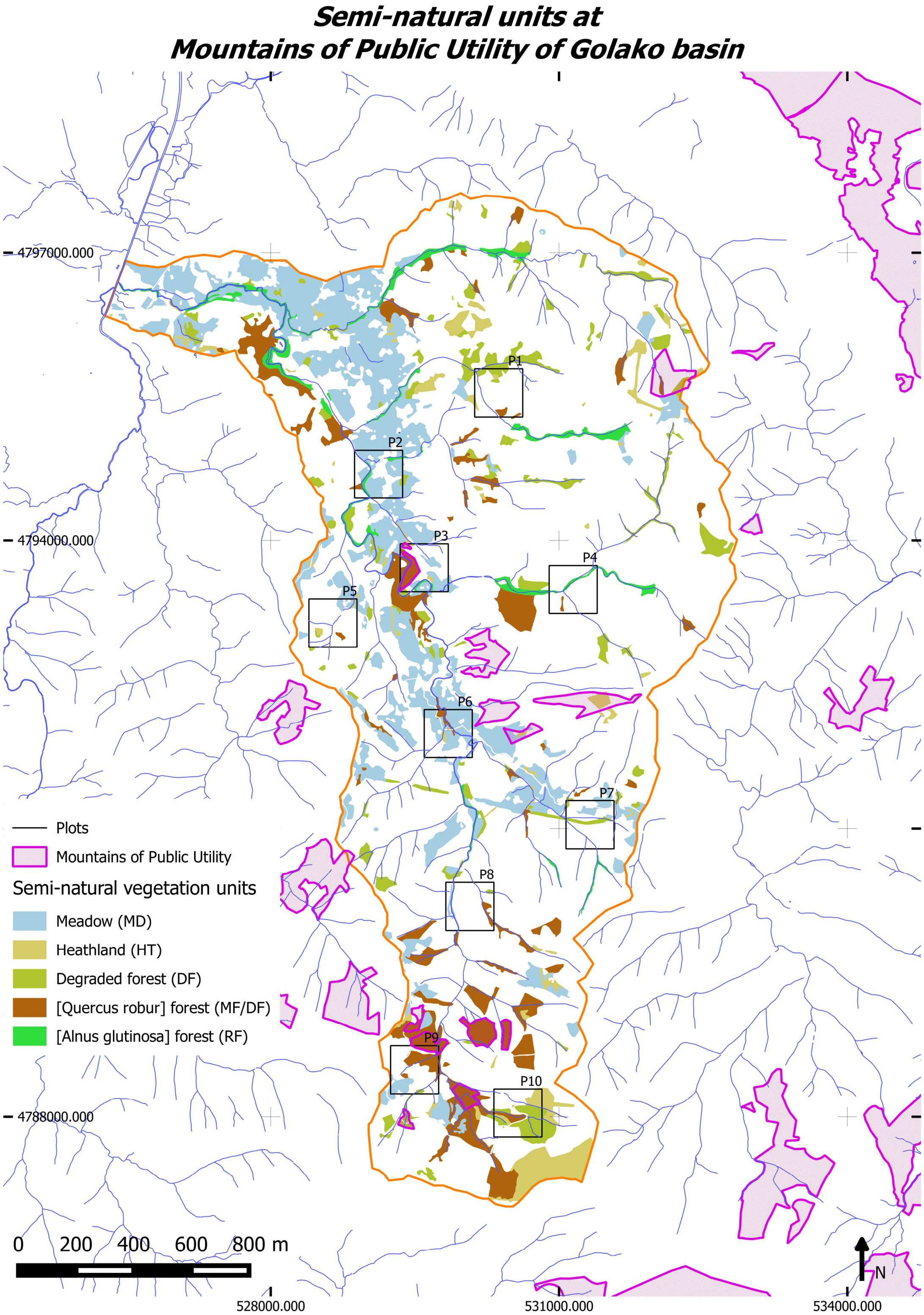
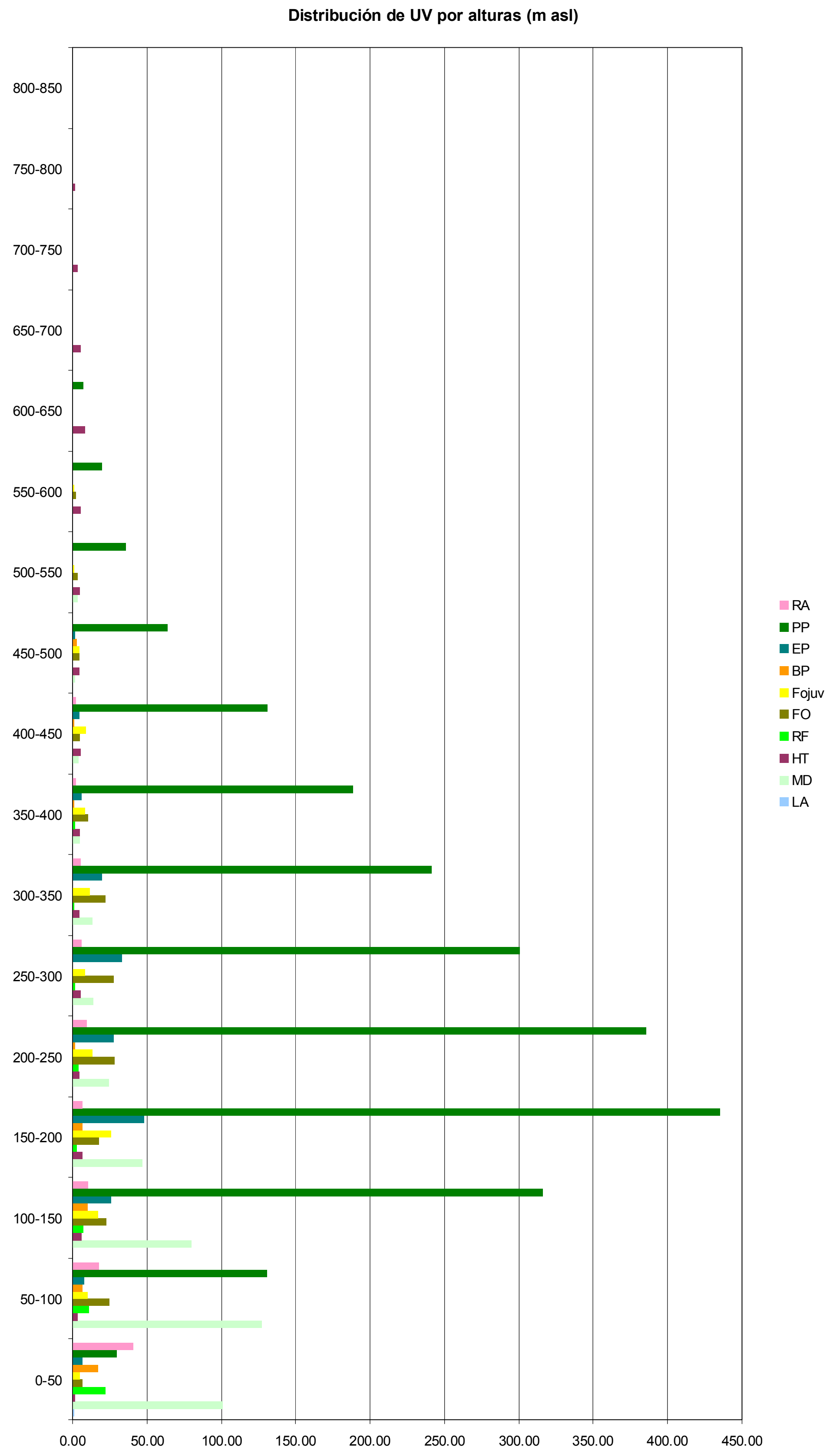


Figure 8.4. Map of the Golako basin showing semi-natural units and Mountains of Public Utility managed by the Council of Biscay (Diputación Foral de Bizkaia). Heathlands belong to the scrub unit (HT)

Figure 8.5. Vegetation units' altitude characterization at Golako basin obtained after DEM analysis with QuantumSIG



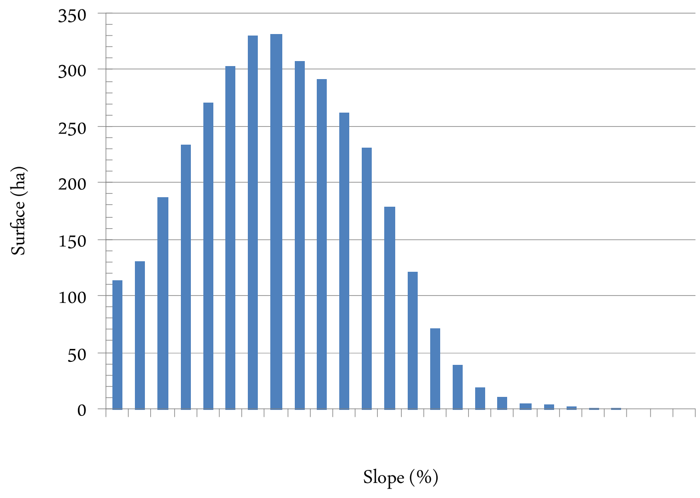


Figure 8.4. Vegetation units' slope characterization at Golako basin after digital elevation models (DEM). Basin's surface slope characterization (top right) and vegetation units distribution (main figure) show surface at 5% slope increments.

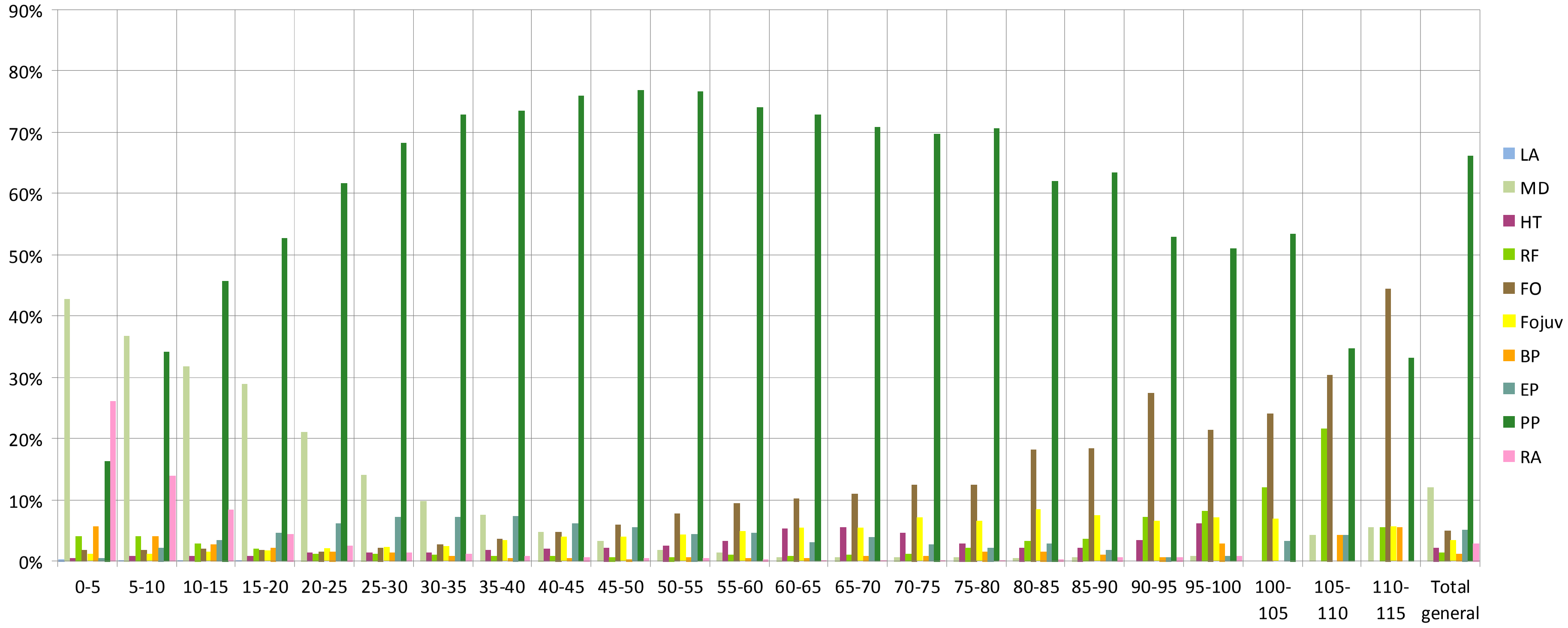
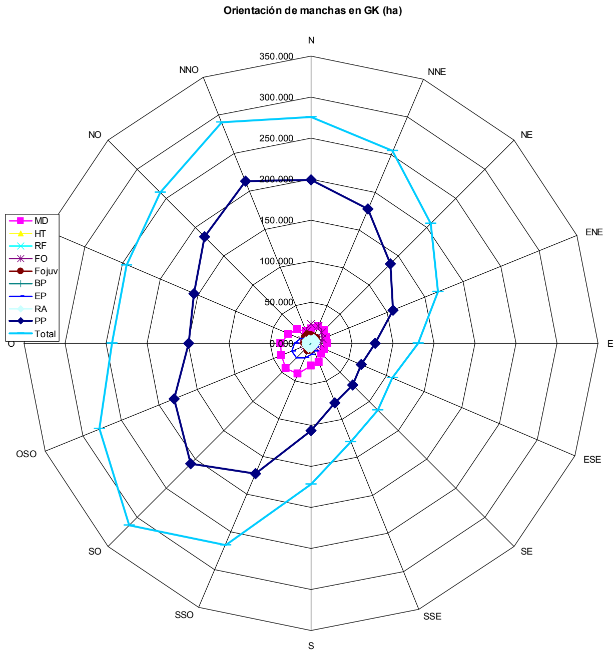
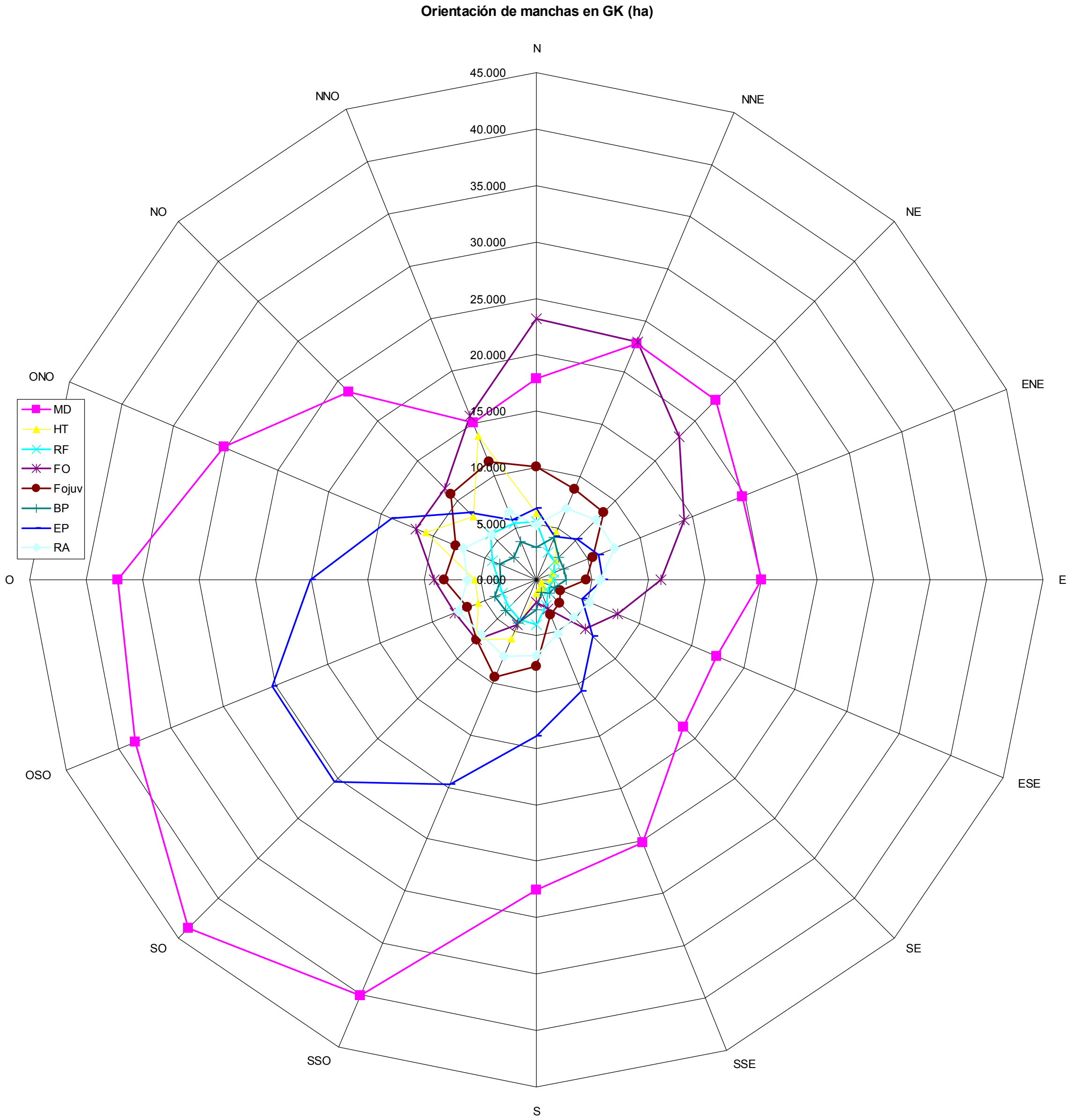


Figure 8.5. Vegetation units' aspect characterization at Golako basin, after digital elevation models (DEM). General outline of the basin and conifer plantation distribution is only shown at the top right figure.





Annex 3. Alonsotegi's cartographic information

Alonsotegi's natural potential and real vegetation maps
Protected areas and Public Mountains
and B value index performance

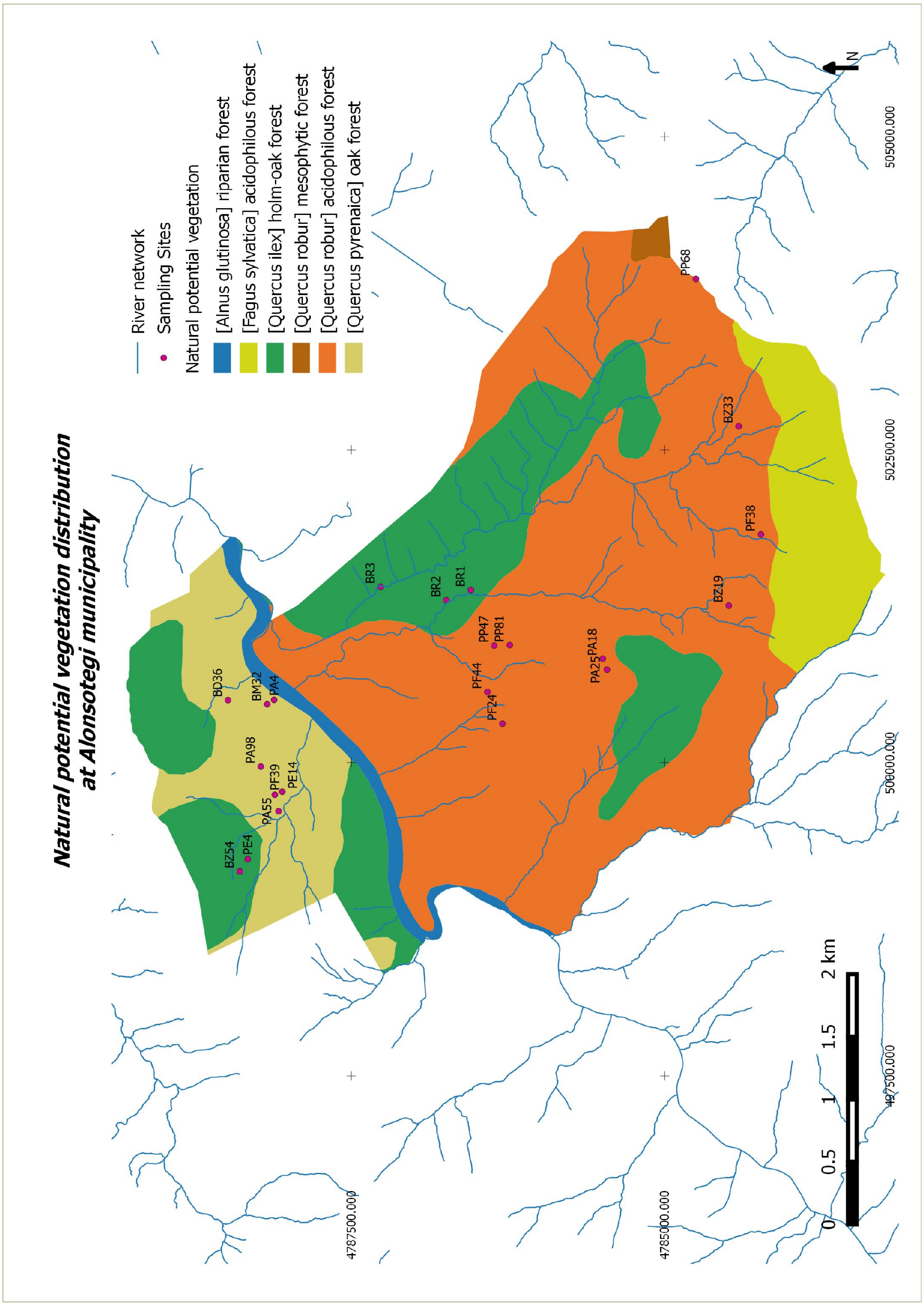


Figure 8.8. Natural potential vegetation found at Alonsotegi. Dots show sampling sites (see codes in Tb. 5.1)

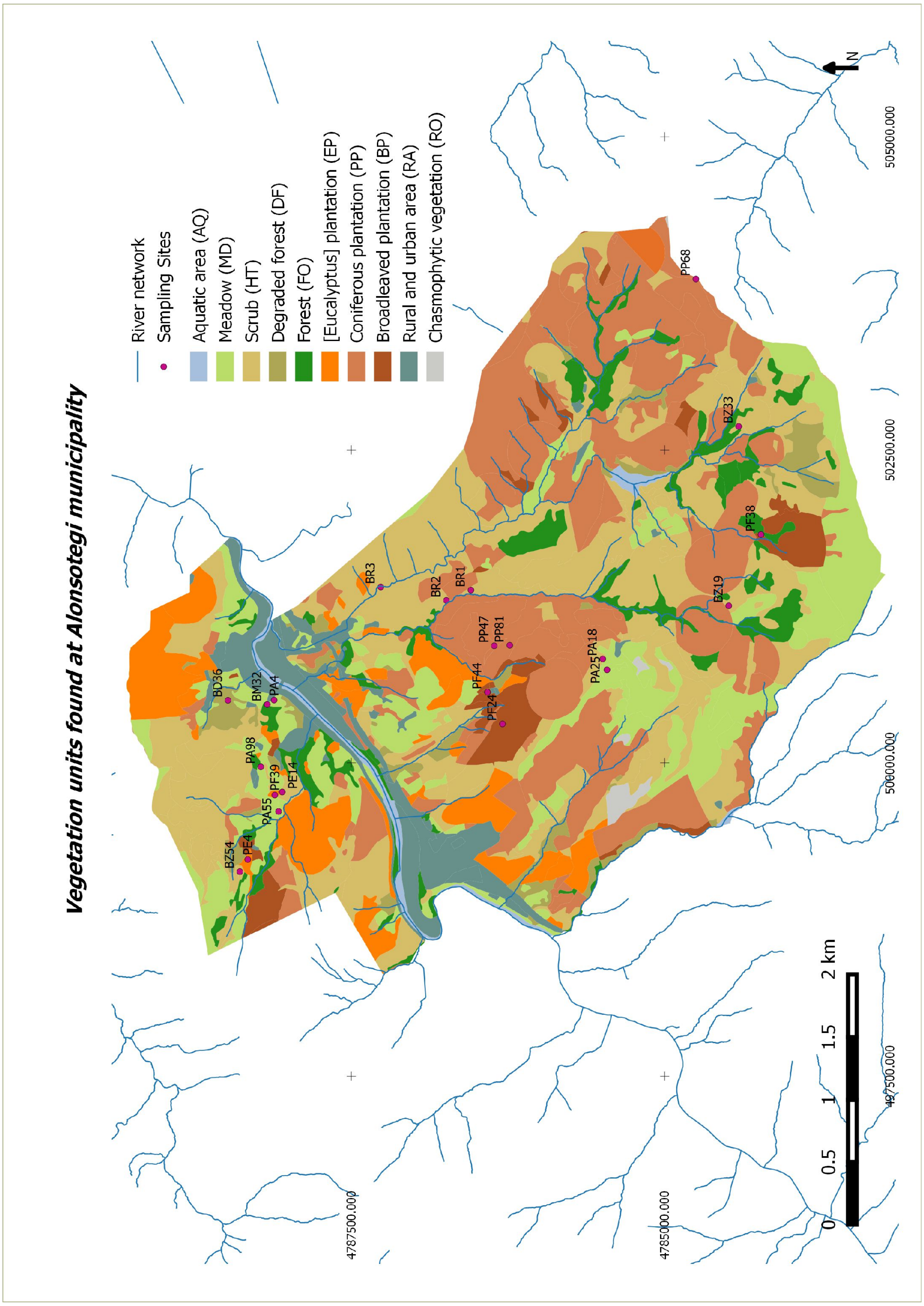


Figure 8.9. Alonsotegi's main vegetation units are shown and sampling sites.

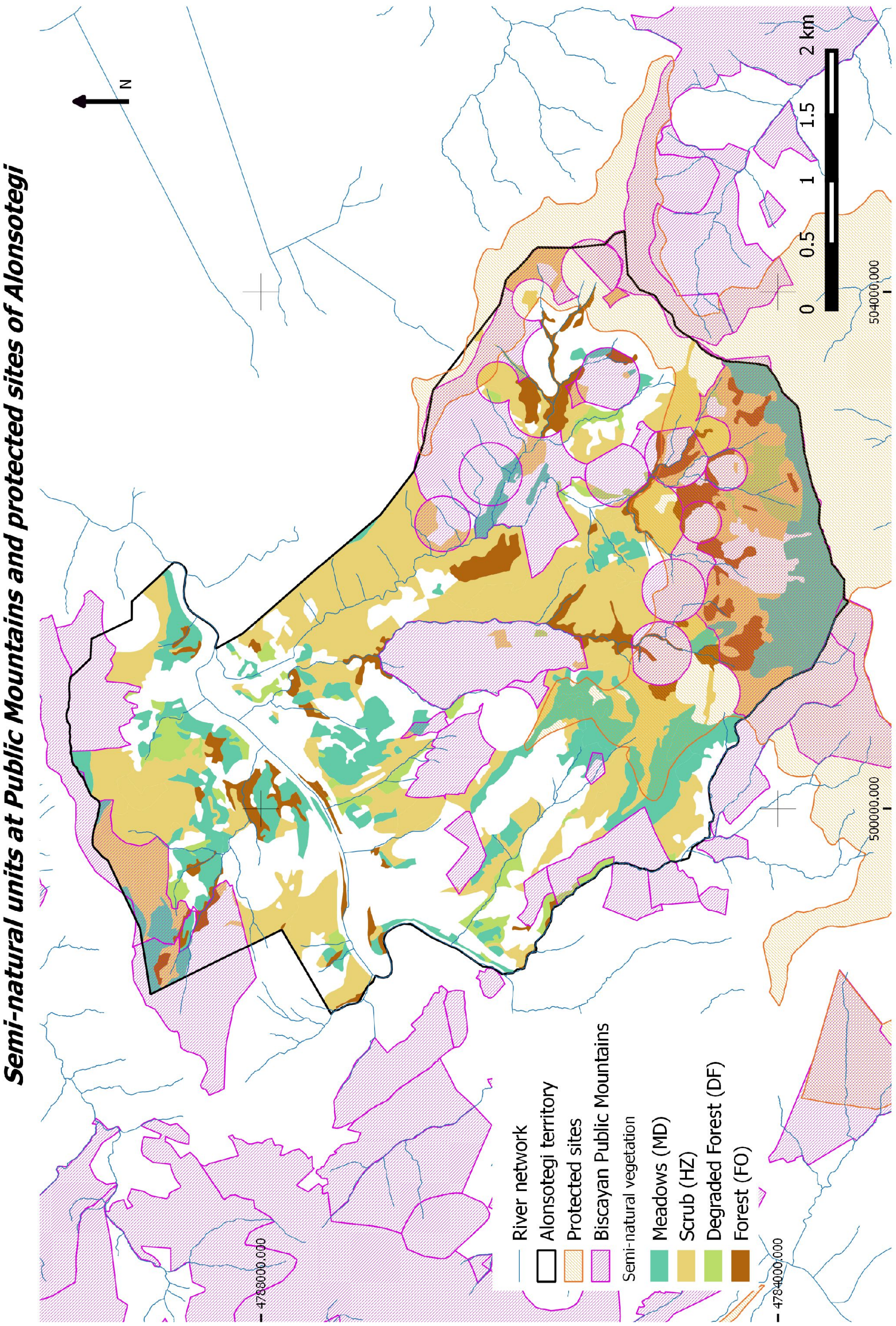


Figure 8.10. Semi-natural vegetation found at Alonsotegi and presence of protected areas and Mountains of Public Utility

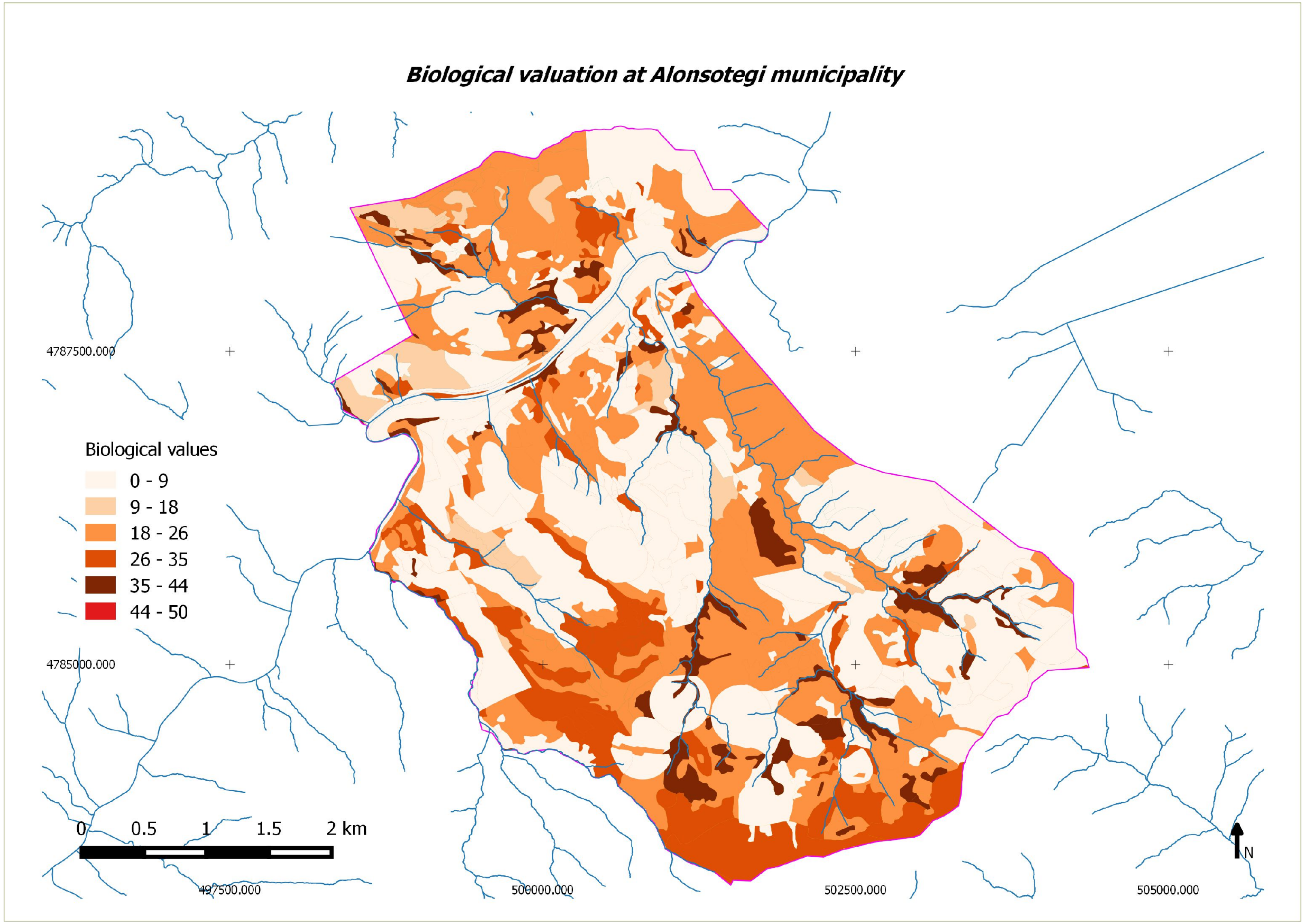


Figure 8.11. Theoretical biological values attained at Alonsotegi (values range from 1 to 50).

Annex 4. Relevés

Species presence and Abundance Dominance Index
(18 pag.)

Meadows

Relevé	#	07/24/2012	10/04/2012	04/10/2016
			Date	
Relevé	**#**			**1**
Nardetalia strictae	MD			
Sampling Site	**PA25**			
Number of species				6
Species			ADI	
Brachypodium pinnatum				2
Agrostis curtisii				1
Viola riviniana				1
Trifolium pratense				1
Romulea bulbocodium				+
Scilla verna				+

Relevé	**#**	07/24/2012	10/04/2012	**2**
Nardetalia strictae with *Pteridium aquilinum*	MD			
Sampling Site	**PA18**			
Number of species				11
Species			ADI	
Brachypodium pinnatum				2
Agrostis curtisii				1
Pteridium aquilinum				1
Trifolium pratense				1
Viola riviniana				1
Erica vagans				+
Lithodora prostrata				+
Potentilla montana				+
Romulea bulbocodium				+
Scilla verna				+
Ulex europaeus				+

Relevé	**#**	**3**	10/04/2012	04/10/2016
Arrhenaterion elatioris	MD			
Sampling Site	**PA98**			
Number of species		20		
Species			ADI	
Anthoxanthum odoratum		2		
Brachypodium pinnatum		2		
Hypochoeris radicata		2		
Agrostis curtisii		1		
Briza maxima		1		
Cynosurus cristatus		1		
Cynosurus echinatus		1		
Danthonia decumbens		1		
Daucus carota		1		
Gamochaeta coarctata		1		
Lapsana communis		1		
Lotus corniculatus		1		
Paspalum dilatatum		1		
Poa compressa		1		

Prunella vulgaris	1
Vulpia ciliata	1
Centaurium erythraea	+
Dianthus armeria	+
Plantago media	+
Silene gallica	+

Relevé	**#**	**4**
Cynosurion cristati	MD	
Sampling Site	**PA4**	
Number of species		30

Species	ADI
Brachypodium pinnatum	3
Dactylis glomerata	3
Festuca arundinacea	3
Cynosurus cristatus	2
Holcus lanatus	2
Lotus corniculatus	2
Agrostis capillaris	1
Acer pseudoplatanus	+
Anthoxanthum odoratum	+
Avena barbata	+
Cirsium eriophorum	+
Danthonia decumbens	+
Daucus carota	+
Galium mollugo	+
Hypochoeris radicata	+
Juglans regia	+
Lapsana communis	+
Lathyrus pratensis	+
Lolium perenne	+
Malva moschata	+
Paspalum dilatatum	+
Plantago media	+
Prunella vulgaris	+
Prunus avium	+
Pyrus communis	+
Ranunculus repens	+
Rumex acetosa	+
Taraxacum gr. *officinale*	+
Trifolium pratense	+
Trifolium repens	+

Relevé	**#**	**5**	**6**
Cynosurion cristati	MD		
Sampling Site	**PA55**		
Number of species		12	14

Species		ADI	
Prunus avium		2	2
Arbutus unedo		1	1
Brachypodium pinnatum		1	1
Corylus avellana		1	1
Crataegus monogyna		1	1
Eucalyptus globulus		1	1
Prunus spinosa		1	1
Bellis perennis			+
Frangula alnus		+	+
Ligustrum ovalifolium			+
Pteridium aquilinum		1	+
Quercus robur		+	+
Ranunculus nemorosus			+
Rumex acetosa		+	+
Paspalum dilatatum		+	

Relevé	**#**	**7**
Cynosurion cristati	MD	
Sampling Site	**PA111**	
Number of species		23

Species		ADI
Anthoxanthum odoratum		1
Brachypodium pinnatum		2
Agrostis curtisii		1
Lapsana communis		1
Quercus ilex		1
Rumex angiocarpus		1
Verbascum pulverulentum		1
Agrostis capillaris		+
Andryala integrifolia		+
Carlina vulgaris		+
Cynosurus echinatus		+
Erica cinerea		+
Gamochaeta coarctata		+
Helianthemum nummularium		+
Linum bienne		+
Malva moschata		+
Polygala vulgaris		+
Prunella vulgaris		+
Silene nutans		+
Tuberaria guttata		+
Ulex gallii		+
Viola riviniana		+

Relevé	#	8
Cynosurion cristati	MD	
Sampling Site	**PA75**	
Number of species		8

Species	ADI
Pinus pinaster	5
Salix alba	5
Pteridium aquilinum	3
Arrhenatherum album	+
Erica ciliaris	+
Frangula alnus	+
Lobelia urens	+
Brachypodium pinnatum	+

Relevé	#	9
	MD	
Sampling Site	**PA85**	(Cont. of PA55)
Number of species		11

Species	ADI
Corylus avellana	2
Frangula alnus	+
Crataegus monogyna	1
Quercus robur	+
Eucalyptus globulus	1
Prunus avium	2
Prunus spinosa	1
Pteridium aquilinum	1
Arbutus unedo	1
Rumex acetosa	+
Brachypodium pinnatum	1

Scrubs

Relevé	#	07/24/2012	10/04/2012	04/10/2016
				1
Erico vagantis-Ulicetum europaei	HT			
Sampling Site	BZ19			
Number of species				17

Species		ADI		
Erica vagans				1
Ulex europaeus				1
Pteridium aquilinum				2
Ilex aquifolium				+
Pinus radiata				+
Viola riviniana				1
Scilla verna				1
Taraxacum gr. Officinale				1
Bellis perennis				+
Brachypodium pinnatum				5
Hypochoeris radicata				+
Stachys officinalis				+
Hypericum pulchrum				+
Blechnum spicant				+
Potentilla erecta				+
Potentilla montana				+
Asphodelus albus				+

Relevé	**#**		**2**	**3**
Calluno-ulicetalia minoris	HT			
Sampling Site	BZ33			
Number of species			12	13

Species		ADI		
Erica cinerea			2	1
Erica vagans			2	1
Erica lustanica			1	1
Erica arborea			1	
Daboecia cantabrica			1	
Agrostis curtisii			1	5
Pteridium aquilinum			1	2
Ulex europaeus			1	+
Rubus ulmifolius			+	+
Blechnum spicant			+	
Pinus sp.			+	+
Viola riviniana				1
Lithodora prostrata			+	+
Scilla verna				+
Bellis perennis				+
Taraxacum gr. Officinale				+

Relevé	**#**	**4**		
Prunetalia spinosae	HT			
Sampling Site	BZ5			
Number of species		8		

Species		ADI		
Quercus ilex		1		
Phillyrea latifolia		+		
Pistacia terebinthus		1		
Arbutus unedo		1		
Erica vagans		+		
Brachypodium pinnatum		+		
Arrhenatherum elatius		+		
Pteridium aquilinum		2		

Relevé	**#**	**5**
Prunetalia spinosae	HT	
Sampling Site	BZ54	
Number of species		18

Species	ADI
Crataegus monogyna	1
Arbutus unedo	1
Pistacia terebinthus	1
Phillyrea latifolia	+
Quercus faginea	+
Genista hispanica subsp. *occidentalis*	1
Erica cinerea	1
Ulex europaeus	+
Brachypodium pinnatum	2
Asphodelus albus	1
Sanguisorba minor	1
Campanula glomerata	+
Plantago major	+
Sedum dasyphyllum	+
Sedum sediforme	+
Seseli cantabricum	+
Endressia castellana	+
Trifolium ochroleucon	+

Relevé	**#**	**6**
Prunetalia spinosae	HT	
Sampling Site	BZ3	
Number of species		17

Species	ADI
Pteridium aquilinum	3
Erica cinerea	+
Ulex gallii	+
Rubus ulmifolius	+
Crataegus monogyna	+
Brachypodium pinnatum	+
Erica vagans	+
Potentilla reptans	+
Prunella vulgaris	+
Pinus radiata	1
Danthonia decumbens	+
Arrhenatherum elatius	+
Lithodora prostrata	+
Chamaemelum nobile	+
Sisyrinchium rosulatum	+
Calluna vulgaris	+
Cistus salvifolius	+

Forests

		Date		
		07/24/2012	**10/04/2012**	**04/10/2016**
Relevé	**#**	**1**		
Hyperico pulchri-Querco roboris S.	FO			
Sampling Site	BM32			
Number of species		39		

Species	ADI
Quercus robur	4
Quercus ilex	2
Fraxinus excelsior	1
Corylus avellana	2
Arbutus unedo	+
Laurus nobilis	+
Prunus avium	+
Salix atrocinerea	+
Crataegus monogyna	+
Daboecia cantabrica	+
Erica arborea	+
Erica cinerea	+
Euonymus europaeus	+
Ulex gallii	+
Hedera helix	1
Rubus ulmifolius	1
Smilax aspera	1
Angelica sylvestris	+
Arum italicum	+
Asplenium adiantum-nigrum	+
Blechnum spicant	+
Brachypodium sylvaticum	1
Centaurea debeauxii	+
Euphorbia amygdaloides	+
Euphorbia dulcis	+
Geum urbanum	+
Hypericum androsaemum	+
Lonicera periclymenum	+
Polystichum setiferum	+
Pteridium aquilinum	1
Pulmonaria longifolia	+
Ranunculus repens	+
Rubia peregrina	1
Ruscus aculeatus	+
Scrophularia alpestris	+
Stachys officinalis	+
Tamus communis	+
Teucrium scorodonia	1
Vicia sativa	+

Relevé	**#**	**2**	**3**
Hyperico pulchri-Querco roboris S.	FO		
Sampling Site	BD36		
Number of species		33	16
Species		ADI	
Quercus robur		3	1
Quercus ilex		+	+
Corylus avellana		2	
Hedera helix		2	+
Brachypodium pinnatum		1	1
Cornus sanguinea L. sanguinea		1	
Crataegus monogyna		1	
Euphorbia amygdaloides		1	
Euphorbia dulcis		1	
Fraxinus excelsior		1	
Helleborus viridis		1	
Laurus nobilis		1	
Lonicera periclymenum		1	
Polystichum setiferum		1	
Pteridium aquilinum		1	
Pulmonaria longifolia		1	+
Rubus ulmifolius		1	1
Smilax aspera		1	
Stachys officinalis		1	
Tamus communis		1	
Teucrium scorodonia		1	
Vicia sativa		1	
Asplenium onopteris		+	
Brachypodium sylvaticum		+	
Erica cinerea		+	
Frangula alnus		+	
Poa nemoralis		+	
Prunus avium		+	
Rhamnus alaternus		+	
Rosa canina		+	
Rubia peregrina		+	
Stachys sylvatica		+	
Viola reichenbachiana		+	
Potentilla sterilis			1
Primula acaulis			1
Viola riviniana			1
Ajuga reptans			+
Andryala integrifolia			+
Daucus carota			+
Fragaria vesca			+
Geum urbanum			+
Taraxacum gr. Officinale			+
Vicia hirsuta			+

Relevé	**#**	**4**
Lauro nobilis-Querco ilicis S.	FO	
Sampling Site	PE4*	
Number of species		41

Species	ADI
Eucalyptus globulus	2
Quercus pubescens	2
Quercus robur	1
Quercus faginea	+
Quercus ilex	2
Crataegus monogyna	1
Arbutus unedo	1
Prunus spinosa	1
Ilex aquifolium	+
Viburnum lantana	1
Cornus sanguinea	1
Ligustrum vulgare	+
Phillyrea latifolia	+
Erica vagans	+
Cistus salvifolius	+
Origanum vulgare	1
Smilax aspera	1
Rubia peregrina	1
Rosa sempervirens	1
Tamus communis	1
Hedera helix	1
Clematis vitalba	+
Rubus ulmifolius	1
Ruscus aculeatus	+
Geranium robertianum	1
Asplenium trichomanes	+
Brachypodium sylvaticum	+
Conyza albida	+
Desmazeria rigida	+
Eleusine tristachya	+
Helianthemum nummularium	+
Helleborus foetidus	+
Sedum album	+
Sedum cepaea	+
Sedum dasyphyllum	+
Sedum sediforme	+
Taraxacum gr. Officinale	+
Teucrium pyrenaicum	+
Vincetoxicum hirundinaria	+
Viola riviniana	+
Asphodelus albus	+

Relevé	**#**	**5**	**6**
Lauro nobilis-Querco ilicis S.	FO	(cont. of PE4*)	
Sampling Site	BM22		
Number of species		48	28
Species		ADI	
Quercus ilex L. ilex		2	2
Eucalyptus globulus		2	2
Quercus pubescens		2	2
Quercus robur		1	1
Quercus faginea		+	+
Crataegus monogyna		1	1
Pistacia terebinthus		1	1
Arbutus unedo		1	1
Prunus spinosa		1	1
Ilex aquifolium		+	+
Cornus sanguinea		1	1
Ligustrum vulgare		+	+
Phillyrea latifolia		+	+
Viburnum lantana		1	1
Cistus salvifolius		+	
Origanum vulgare		1	
Rubus ulmifolius		1	1
Clematis vitalba		+	+
Hedera helix		1	1
Rosa sempervirens		1	
Rubia peregrina		1	1
Smilax aspera		1	1
Ruscus aculeatus		+	+
Asphodelus albus		+	1
Asplenium trichomanes		+	+
Brachypodium sylvaticum		+	+
Carex humilis		+	
Carlina vulgaris		+	
Conyza albida		+	
Desmazeria rigida		+	
Eleusine tristachya		+	
Erica vagans		+	+
Erica ciliaris		+	
Galium mollugo		+	
Geranium robertianum		1	1
Helianthemum nummularium		+	
Helleborus foetidus		+	+
Linum catharticum		+	
Lithodora diffusa		+	
Prunella laciniata		1	
Sedum album		+	
Sedum cepaea		+	
Sedum dasyphyllum		+	
Sedum sediforme		+	
Sporobolus indicus		+	
Tamus communis		1	1
Taraxacum gr. Officinale			+
Teucrium pyrenaicum		+	
Vincetoxicum hirundinaria		+	
Viola riviniana			+

Relevé	**#**	**7**
Lauro nobilis-Querco ilicis S.	FO	(Next to BZ54)
Sampling Site	BD3	
Number of species		36

Species	ADI
Quercus ilex	2
Quercus faginea	+
Arbutus unedo	2
Crataegus monogyna	1
Pistacia terebinthus	1
Prunus spinosa	1
Phillyrea latifolia	+
Corylus avellana L.	1
Cornus sanguinea	1
Viburnum lantana	1
Ligustrum vulgare	+
Ilex aquifolium	+
Phillyrea latifolia	1
Erica ciliaris	+
Erica vagans	+
Cistus salvifolius	+
Ulex europaeus	+
Hedera helix	1
Smilax aspera	+
Tamus communis	1
Geranium robertianum	1
Origanum vulgare	1
Rubus ulmifolius	1
Prunella laciniata	1
Carex humilis	+
Helleborus foetidus	+
Hepatica nobilis	+
Linum catharticum	+
Lithodora diffusa	+
Rubia peregrina	+
Ruscus aculeatus	+
Sanicula europaea	+
Sedum album	+
Sedum dasyphyllum	+
Sedum sediforme	+
Teucrium pyrenaicum	+

Riparian Forests

Relevé	**#**	**07/24/2012**	**10/04/2012**	**04/10/2016**
		1		
Hyperico androsaemi-Alno glutinosae geosigmetum	RF			
Sampling Site	RF1			
Number of species		18		

Species	ADI		
Alnus glutinosa	2		
Quercus robur	+		
Castanea sativa	+		
Corylus avellana	+		
Salix atrocinerea	+		
Pinus radiata	+		
Betula celtiberica	1		
Rubus ulmifolius	+		
Pteridium aquilinum	+		
Polystichum setiferum	1		
Hedera helix	+		
Brachypodium sylvaticum	+		
Geum urbanum	+		
Fragaria vesca	+		
Carex pendula	1		
Saxifraga hirsuta	+		
Oxalis acetosella	+		
Viola ribiniana	+		

Relevé	**#**	**2**
Hyperico androsaemi-Alno glutinosae geosigmetum	RF	
Sampling Site	RF2	
Number of species		12

Species	ADI
Alnus glutinosa	1
Quercus robur	1
Fraxinus excelsior	+
Corylus avellana	2
Ligustrum vulgare	+
Pinus radiata	+
Salix atrocinerea	2
Hedera helix	+
Polystichum setiferum	+
Ajuga reptans	+
Geranium robertianum	+
Symphytum tuberosum	1

Relevé	**#**	**3**
Hyperico androsaemi-Alno glutinosae geosigmetum	RF	
Sampling Site	RF3	
Number of species		12

Species	ADI
Alnus glutinosa	3
Fraxinus excelsior	+
Corylus avellana	+
Betula celtiberica	+
Rubus ulmifolius	1
Pteridium aquilinum	1
Mentha aquatica	+
Carex pendula	+
Ligustrum vulgare	+
Geranium robertianum	+
Carex divulsa	+
Geum urbanum	+

Coniferous plantations

Relevé	#	Date: 07/24/2012	Date: 10/04/2012	Date: 04/10/2016
			1	2
P. menziesii plantation	PP			
Sampling Site	PP47			
Number of species			3	3
Species			ADI	
Pseudotsuga menziesii			5	5
Rubus ulmifolius			+	+
Pteridium aquilinum			+	+

Relevé	#	07/24/2012	10/04/2012	04/10/2016
			3	
P. radiata plantation for water protection	PP			
Sampling Site	PP68			
Number of species			5	
Species			ADI	
Pinus radiata			5	
Rubus ulmifolius			2	
Pteridium aquilinum			+	
Brachypodium pinnatum			1	
Agrostis curtisii			+	

Relevé	#	07/24/2012	10/04/2012	04/10/2016
			4	5
P. radiata plantation	PP			
Sampling Site	PP81			
Number of species			4	4
Species			ADI	
Pinus radiata			5	5
Rubus ulmifolius			+	+
Pteridium aquilinum			+	+
Brachypodium pinnatum			+	+

***Eucalyptus* plantations**

		Date		
		07/24/2012	**10/04/2012**	**04/10/2016**
Relevé	**#**			**1**
Eucalyptus plantations	EP			
Sampling Site	PE4			
Number of species				6
Species			ADI	
Eucalyptus globulus				4
Smilax aspera				1
Rubus ulmifolius				1
Geranium robertianum				+
Viola riviniana				+
Taraxacum gr. Officinale				+
Relevé	**#**	**2**		**3**
Eucalyptus plantations	EP			
Sampling Site	PE14			
Number of species		4		8
Species			ADI	
Eucalyptus globulus		4		4
Pteridium aquilinum		2		+
Smilax aspera		+		+
Arbutus unedo		+		+
Rubus ulmifolius				+
Brachypodium pinnatum				1
Geranium robertianum				+
Conyza bonariensis				+
Relevé	**#**	**4**		**5**
Eucalyptus plantations	EP			
Sampling Site	PF39			
Number of species		6		6
Species			ADI	
Eucalyptus globulus		5		5
Pteridium aquilinum		3		3
Smilax aspera		1		1
Arbutus unedo		+		
Rubus ulmifolius		1		1
Hedera helix		+		+
Lonicera sp.				+

Broadleaved plantations

		Date		
		07/24/2012	**10/04/2012**	**04/10/2016**
Relevé	**#**			**1**
Q. rubra plantation	BP			
Sampling Site	PF24			
Number of species				5

Species	ADI
Quercus rubra	5
Rubus ulmifolius	1
Hypericum pulchrum	+
Viola riviniana	+
Scilla verna	+

Relevé	**#**	**2**
Q. rubra w/ *F. sylvatica* plantation	BP	
Sampling Site	PF38	
Number of species		11

Species	ADI
Quercus rubra	4
Fagus sylvatica	2
Ranunculus nemorosus	+
Asphodelus albus	+
Viola riviniana	+
Oxalis acetosella	+
Vaccinium myrtillus	+
Anemone nemorosa	+
Erythronium dens-canis	+
Hedera helix	+
Blechnum spicant	+

Relevé	**#**	**3**
Prunus sp. plantation	BP	
Sampling Site	PF44	
Number of species		5

Species	ADI
Prunus sp.	4
Brachypodium pinnatum	+
Viola riviniana	+
Hedera helix	+
Bellis perennis	+

Relevé	**#**	**4**
Pinus sp. w/ *Q. pyrenaica* plantation	BP	
Sampling Site	PF3	
Number of species		13

Species	ADI
Pinus pinaster	4
Pinus radiata	4
Quercus pyrenaica x Q. robur	1
Erica cinerea	+
Ulex europaeus	1
Pteridium aquilinum	2
Salix atrocinerea	+
Arbutus unedo	+
Daboecia cantabrica	+
Crataegus monogyna	+
Rubus ulmifolius	1
Frangula alnus	+
Sorbus aria	+

UV	UTM	Localidad/Barrio	Altitud	Orientación	EUNIS t	Habitat (descripc)	Fecha	Autor	Notas
PA25	30TWN0084685670	Zamaia	558	NNE	E1.73	Pastos silÍceos	10-abr-16	Orrantia, Balentzia	
PA18	30TWN0093385704	Zamaia	553	N	E1.73	Pastos silÍceos	10-abr-16	Orrantia, Balentzia	
PA98	30TWN9980788318	Zamund_Irauregi	168	S	E2.11	Prado de siega	24-jul-12	Balentzia, Patino, Orrantia	
PA4	30TWN0061688326	La Llan_Iraureg	39	E	E2.21	Prado de siega	24-jul-12	Balentzia, Patino, Orrantia	
PA55	30TVN9979388313	Zamundi	167	S	E2.21	Prado de diente y siega	24-jul-12	Balentzia, Patino, Orrantia	Muy seco, poco suelo, elevada pendiente, poca cobertura vegetal
PA55_2	30TVN9971588290	Zamundi	165	SE	E2.21	Prado de diente y siega	01-abr-16	Orrantia, Balentzia	
PA111	30TWN0059088628	Irauregi	72	E	E2.21	Pasto abandonado en elevada pedt, poco suelo	24-jul-12	Balentzia, Patino, Orrantia	
PA75	30TVN9879088560	Peñas Blancas	339	E	E2.11	Plantación de pino/sauce	24-jul-12	Balentzia, Patino, Orrantia	por debajo pista es sauce, por encima pino
PA85	30TVN9980088313	Zamundi	155	SW-SE	E5.31(x)	Prado de diente y frutales	24-jul-12	Balentzia, Patino, Orrantia	
BZ19	30TWN0135784699	Miregana	550	NNW	F4.23(X)	Brezal desbrozado (LAT) y con ganado	10-abr-16	Orrantia, Balentzia	
BZ33	30TWN0279084620	Parkotxa	500	NNW	F4.237	Argomal	4-oct-12	Orrantia	
BZ33_2	30TWN0279084621	Parkotxa	501	NNW	F4.237	Argomal desbrozado (LAT) y con ganado	10-abr-16	Orrantia, Balentzia	
BZ54	30TVN9920388608	Zamundi	280	SE	F3.11(X)	Bortal	24-jul-12	Balentzia, Patino, Orrantia	más pobre que BM22 pero una cont d éste
BZ3	30TVN9887788655	Zamundi	335	S	F4.23(X)	Espinar en karst	24-jul-12	Balentzia, Patino, Orrantia	
BZ5	30TVN9895588653	Zamundi	330	S	F5.21(Y)	Encinar muy degradado en karst	24-jul-12	Balentzia, Patino, Orrantia	Junto con BM3, mancha única
BM32	30TWN0051688319	Irauregi	81	SE	G1.86	Bosque degradado, ctra	24-jul-12	Balentzia, Patino, Orrantia	
BD36	30TWN0060988691	Irauregi	72	ENE	G5.61	Robledal ca barranco y encinar en solana. Pdt.Gand	24-jul-12	Balentzia, Patino, Orrantia	
BD36_2	30TWN0060988691	Irauregi	72	ENE	G5.61	Robledal ca barranco y encinar en solana. Pdt.Gand	10-abr-16	Orrantia, Balentzia	
PE4*	30TVN9931888511	Zamundi	238	S	G2.81	Encinar con eucaliptal	24-jul-12	Balentzia, Patino, Orrantia	En zonas con suelo hay planta de eucalipto
BM22	30TVN9916588602	Zamundi	281	S	G1.71	Encinar	24-jul-12	Balentzia, Patino, Orrantia	Continuación de PE4, en mejor estado conservación. Q. pubescens
BM22_2	30TVN9916588602	Zamundi	281	S	G1.71	Encinar	10-abr-16	Orrantia, Balentzia	
BD3	30TVN9969988644	Zamundi	290	E	G5.61	Encinar	24-jul-12	Balentzia, Patino, Orrantia	más fresco
PE14	30TVN9986088295	Zamundi	175	S	G2.81	Eucaliptal joven	24-jul-12	Balentzia, Patino, Orrantia	
PE14_2	30TVN9987088261	Zamundi	175	S	G2.81	Eucaliptal	01-abr-16	Orrantia, Balentzia	
PE4	30TVN9931888511	Zamundi	238	S	G2.81	Encinar con eucaliptal	24-jul-12	Balentzia, Patino, Orrantia	En zonas con suelo hay planta de eucalipto
PF2	30TVN9942888514	Zamundi	220	SE	G1.D(X)	zona rural	24-jul-12	Balentzia, Patino, Orrantia	sobre karst
PF24	30TWN0041586504	Kobatxu	320	NNE	G5.72	Plantación de frondosas, Q. rubra	01-abr-16	Orrantia, Balentzia	
PF3	30TVN9892088435	Apuko	330	NE	G5.72	Plantación Pino	24-jul-12	Balentzia, Patino, Orrantia	Parte inf radiata, sup pinaster
PF38	30TWN0192884442	Parkotxa	520	N	G5.72	Plantación Q. rubra	01-abr-16	Orrantia, Balentzia	
PF39	30TVN9985188288	Zamundi	180	S	G5.73	Eucaliptal joven	24-jul-12	Balentzia, Patino, Orrantia	
PF39_2	30TVN9984688320	Zamundi	180	S	G5.73	Eucaliptal joven	01-abr-16	Orrantia, Balentzia	
PF44	30TWN0066886624	Kobatxu	305	NE	G5.72	Plantación de frondosas	01-abr-16	Orrantia, Balentzia	

Annex 5. Contributions

- 5.1 “**Fragmentation pattern of an extinguishing lowland temperate forest**”. VII Congreso de Biología de la Conservación de Plantas. SEBICOP. Vitoria, 2015. Coauthor

- 5.2 “**Analyzing topsoil characteristics associated to vegetation types in Atlantic Iberian Peninsula: soil resistance to desiccation as related to organic matter**”. Global soil biodiversity initiative. Dijon, Francia. 2014. Coauthor

- 5.3 “**Interés de conservación del brezal y la pradera en la Reserva de la Biosfera de Urdaibai**”. IV Congreso de Biodiversidad. Bilbao 2013. Coauthor

FRAGMENTATION PATTERN OF AN EXTINGUISHING TEMPERATE ATLANTIC FOREST

Universidad del País Vasco / Euskal Herriko Unibertsitatea

LANDAREEN KONTSERBAZIO BIOLOGIAREN VII. BILTZARRA
VII CONGRESO DE BIOLOGÍA DE LA CONSERVACIÓN DE PLANTAS
2015eko irailaren 30etik urriaren 2ra - Del 30 de septiembre al 2 de octubre del 2015

SOCIEDAD DE CIENCIAS NATURALES DE SESTAO
SESTAOKO NATUR ZIENTZIEN ELKARTEA

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INTRODUCTION

The complexity of forest habitats encountered at the Cantabrian and Basque sector results on a controversial integration of the Spanish mixed oak forest ecosystems into the European Nature Information System (EUNIS) and the Habitat Directive. At lowland and colline levels of Bizkaia and Gipuzkoa provinces there are two main climatophilous forests, not included into the HD, which have *Quercus robur* as one of its main species: the acidophilous *Q. robur* oak forests of *Hyperico pulchri-Quercetum roboris* and the mesophytic oak-ash mixed forest of *Polysticho setiferi-Fraxinetum excelsioris* (EUNIS codes G1.86 and G1.A1) .

Despite their ecological importance, silviculture and urbanization threaten *Quercus robur* woodlands of the Basque lowlands. Up to now most research has been performed at local sites but there is a lack of knowledge of fragmentation patterns of both habitats from a regional perspective.

Our main goals had been:

(1) to describe on a regional level ***Q. robur* forest -QRF-** spatial configuration, isolation patterns and habitat risk; and

(2) to analyze QRF presence at protected and at public managed sites.

GIS METHODOLOGY

We studied *Quercus robur* forests (G1.86 and G1.A1) located at (1) Bizkaia and Gipuzkoa provinces as a whole, (2) only those QRF at the Atlantic region and (3) at the fourteen Atlantic watersheds (b1-b14).

We used potential (Fig. 2a) and real (Fig.2b) vegetation maps and cartographic information to analyze QRF presence at protected sites -Bizkaia and Gipuzkoa- (Fig.2b) and public mountains –Bizkaia- (Fig. 2c).

RESULTS

QRF presence at protected sites and public mountains

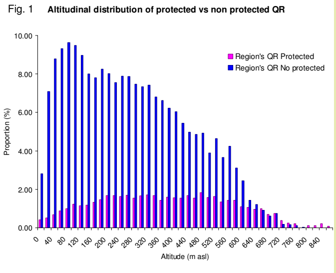

Table 1. Vegetation types in public mountains of Bizkaia

Vegetation type	Distribution (%)	Altitude (masl) mean	±	SD
Acuatic veg.	0.09	331.51	±	99.75
Coastal veg.	0.04	28.89	±	38.82
Pastures and meadows	12.37	544.98	±	273.69
Heaths	14.87	648.48	±	267.55
Forests	16.52	512.46	±	257.53
QRF	3.81	373.40	±	156.80
Total plantations	51.68			
Conifer plantations	41.78	448.37	±	158.06
Eucalyptus plantat.	5.79	289.44	±	118.56
Broadleaved plantat.	4.10	413.54	±	177.40
Anthropic veg.	1.32	285.79	±	132.35
Rural areas	0.26	352.43	±	129.55
Urban areas	2.82	727.94	±	225.40
NA	0.03			

Table 2. Altitude of *Quercus robur* forests

	Altitude (masl) mean	±	SD
Bizkaia and Gipuzkoa			
Protected sites	314.91	±	149.92
Non protected sites	243.02	±	166.41
Bizkaia			
Public lands	373.40	±	156.80
Private lands	151.67	±	19.66

Fig.2a)

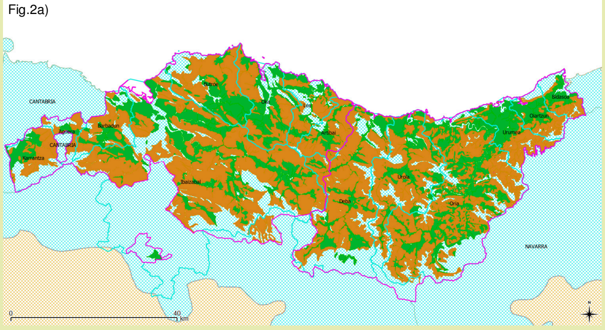

Fig.2b)

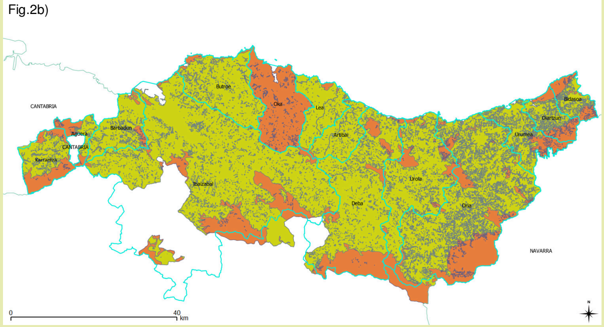

Fig.2c)

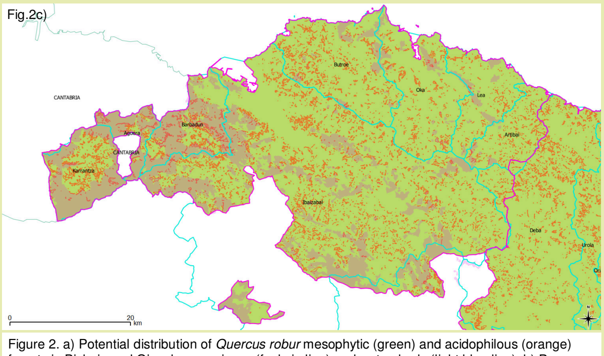

Figure 2. a) Potential distribution of *Quercus robur* mesophytic (green) and acidophilous (orange) forests in Bizkaia and Gipuzkoa provinces (fuchsia line) and watersheds (light blue line). b) Presence of pedunculate *Quercus robur* forests -both gathered in one group- (grey) in/out protected sites (orange/lime) (Natura 2000 sites, Biosphere Reserve, Regional Natural Protected Sites. c) *Q. robur* forests and their relationship with Mountains of Public Utility and Patrimonial Mountains that belong to local/regional governments and are managed by Bizkaia Provincial Council

FRAGMENTATION ANALISYS METHODOLOGY

We transformed vegetation vectorial layers onto valid rasters (geotif) to be used in FRAGSTAT software to obtain fragmentation indexes.

• No-data value had to be defined and differentiated from background value (999 -rest of the basin-), so we edited with gdal to apply to no-data areas a value of one. We rasterized at high resolution (20x20 m, 0.04 ha) and search radios of 300 m were used.

Among the metrics provided by Fragstat, we used a set of **standard landscape metrics** already used at regional studies to:

• Quantify forest patches' **spatial configuration** and

• Obtain **isolation and dispersion indices**.

RESULTS

Spatial configuration

Table 1 shows the results for the analysis of spatial configuration of Atlantic Basque pedunculate oak forests (*Q. robur*). A ranking of the results at watershed level was done (values are colored green-blue-yellow-orange-red)

Tb 3. Spatial configuration

Region		QRFA (ha)	R (%)	NPV (%)	R/NPV	NP	PD (no/100 ha)	LPI	ED (m/ha)	PS (ha) MN	±	SD	PS (ha) AM	QRF Altitude (m asl) MN	±	SD
BiGi		31152.6	7.43	78.60	0.09	12564	3.00	0.09	33.09	2.48	±	8.86	34.14	255.14	±	155.17
BiGi ATL		30948.8	7.58	71.75	0.11	12514	3.07	0.11	33.70	2.47	±	9.16	36.38	253.06	±	153.36
BiGi ATL	Site protected	5211.48	5.17	40.41	0.13	1906	1.89	0.26	18.25	2.73	±	12.69	61.61	314.91	±	149.92
BiGi ATL	Site not prot.	25742.04	8.09	83.07	0.10	11742	3.69	0.07	38.24	2.19	±	6.53	21.65	243.02	±	166.41
Watershed																
b1	Karrantza	1032.12	7.49	62.06	0.12	379	2.75	0.71	34.63	2.72	±	7.13	21.39	351.14	±	116.50
b2	Aguera	513.36	10.57	59.81	0.18	136	2.80	4.15	31.92	3.77	±	18.01	89.73	404.37	±	121.69
b3	Barbadun	1013.48	7.63	72.95	0.10	408	3.07	0.29	36.66	2.48	±	5.07	12.84	253.40	±	136.01
b4	Ibaizabal	4810.08	4.31	65.99	0.07	3058	2.74	0.06	22.88	1.57	±	3.49	9.30	222.17	±	141.59
b5	Butroe	1304.44	5.51	80.84	0.07	570	2.41	0.24	26.62	2.29	±	4.64	11.69	102.84	±	75.89
b6	Oka	849.32	3.92	82.58	0.05	334	1.54	0.18	17.72	2.54	±	4.68	11.15	181.13	±	103.07
b7	Lea	300.12	2.34	72.68	0.03	229	1.79	0.11	15.11	1.31	±	1.93	4.16	182.32	±	118.53
b8	Artibai	428.84	3.89	88.45	0.04	333	3.02	0.13	24.46	1.29	±	2.00	4.38	238.50	±	124.14
b9	Deba	2364.04	4.52	70.11	0.06	1290	2.47	0.23	22.59	1.83	±	5.02	15.57	306.76	±	141.17
b10	Urola	2682.48	7.67	74.35	0.10	1071	3.06	0.58	32.41	2.50	±	8.84	33.70	305.72	±	147.39
b11	Oria	10360.08	13.27	72.39	0.18	3119	3.99	0.30	54.01	3.32	±	10.16	34.38	303.61	±	154.07
b12	Urumea	2610.64	18.84	81.16	0.23	632	4.56	1.83	66.72	4.13	±	17.08	74.77	159.49	±	104.25
b13	Oiartzun	1270	13.59	71.88	0.19	659	7.05	0.88	65.89	1.93	±	5.99	20.56	144.19	±	93.70
b14	Bidasoa	1313.8	17.41	62.96	0.28	283	3.75	2.89	68.26	4.64	±	18.01	74.54	140.51	±	105.09
Maximum value's color																

BiGi, Bizkaia and Gipuzkoa provinces. BiGi ATL, Atlantic watersheds of Bizkaia and Gipuzkoa. ED, edge density -the sum of the lenght of all QR patches' edges divided by the total landscape area-. LPI, Largest patch index -% of landscape comprised by the largest patch- . NPV, percentage of QR natural potential vegetation. PD, patch density -no. of patches per 100 ha-. PS_MN & SD, Mean and standard deviation of QRF patch size. PS_AM, Patch area weighted mean -PS/QRFarea-. QRFA, Quercus robur forests' total area. R, real QRF distribution. R/NPV, cocient of real to potential vegetation. Source: Mcgarigal & Ene (2013)

Isolation patterns

Table 2 gives connectivity indices of Atlantic Basque pedunculate oak forests (*Q. robur*). Same ranking as T.1 except PROX that follows an increasing ranking.

Table 4. Isolation patterns

Region		LSI	SHAPE	±	SD	PROX	±	SD	ENN (m)	±	SD	Rc
BiGi		196.35	1.73	±	0.80	29.18	±	103.58	109.44	±	115.25	0.21
BiGi ATL		195.36	1.72	±	0.80	31.84	±	129.96	108.64	±	112.69	0.21
BiGi ATL	Site protected	63.76	1.60	±	0.71	18.45	±	77.62	168.48	±	325.15	0.20
BiGi ATL	Site not prot.	189.57	1.71	±	0.78	24.71	±	76.15	107.04	±	110.11	0.25
Watershed												
b1	Karrantza	37.07	1.81	±	0.87	37.95	±	93.65	99.69	±	109.04	0.17
b2	Aguera	17.07	1.68	±	0.70	14.76	±	22.76	88.91	±	77.70	0.16
b3	Barbadun	38.15	1.83	±	0.81	25.69	±	43.33	109.85	±	126.22	0.21
b4	Ibaizabal	91.96	1.66	±	0.65	8.63	±	25.66	124.34	±	133.77	0.22
b5	Butroe	43.51	1.76	±	0.75	12.04	±	33.59	147.59	±	150.64	0.23
b6	Oka	32.91	1.76	±	0.75	10.32	±	24.24	177.06	±	178.11	0.17
b7	Lea	27.80	1.73	±	0.72	5.91	±	12.18	194.70	±	198.58	0.22
b8	Artibai	32.39	1.69	±	0.70	3.81	±	8.90	152.59	±	134.08	0.29
b9	Deba	60.68	1.66	±	0.67	10.19	±	42.12	129.28	±	133.00	0.20
b10	Urola	54.74	1.71	±	0.71	19.04	±	62.73	115.23	±	110.57	0.22
b11	Oria	103.59	1.78	±	0.92	45.29	±	93.82	82.26	±	64.31	0.21
b12	Urumea	45.23	1.81	±	0.93	66.11	±	178.83	79.91	±	62.98	0.23
b13	Oiartzun	43.11	1.62	±	0.85	39.32	±	83.84	71.15	±	95.72	0.32
b14	Bidasoa	35.49	1.93	±	1.27	126.53	±	245.31	71.19	±	58.93	0.17
Maximum value's color												

BiGi, Bizkaia and Gipuzkoa provinces. BiGi ATL, Atlantic watersheds of Bizkaia and Gipuzkoa. ENN, Euclidean nearest-neighbor distance -based on the shortest edge to edge distance; ENN~0 as the distance to the nearest QRF decreases-. LSI, Landscape shape index -a measure of TE or ED that adjust to the size of the landscape-. PROX, Proximity index -it considers the size and proximity of all patches whose edges are within a specified search radius of the focal patch; Prox=0 when there are no QRF around (search radius 300m). SHAPE,Shape index -the patch perimeter divided by the square root of patch area adjusted for a square standard; Shape=1 when squared-. SD, standard deviation. Rc, index of dispersion -based on the mean of the same class ENN and fragment density. Source: Mcgarigal & Ene (2013) and Forman 1995.

CONCLUSIONS

• Those watersheds located in Bizkaia (b1-b8) have a more fragmented and isolated pattern that in Gipuzkoa (b9-b14). Karrantza (b1) and Agüera (b2) smooth somehow that strong fragmentation tendency in Bizkaia (Tb3).

• In the middle area of QRF potential distribution Oka, Lea and Artibai watersheds (b6-b8) exhibit QRF extinction rates (R/NPV 0.04) (Tb3). Legal protection of the Oka basin (b6, Biosphere Reserve since 1984 and Natura 2000 site) contrasts with the fragmented and isolated configuration of QRF patches found within (Tb4).

• Urumea and Bidasoa (b12, b14) are the only watersheds whose QRFs are approaching the minimum "fragmentation threshold" of QRF distribution=20%, below which habitat fragmentation may affect population persistence. Meanwhile, QRFs at Oka, Lea and Artibai (b6-b8) are below the minimum value considered as "extinction threshold" (4%) for a population to go extinct (Fahrig 2001) (Tb3).

• Taking into account that lowland QRFs are underprotected (insufficiently included in protected areas –Fig1-) a compensation policy should be implemented. Public lands are half covered by plantations, but should offer an opportunity in QRF restoration (Tb1&2).

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Analyzing topsoil characteristics associated to vegetation types in Atlantic Iberian Peninsula:

soil resistance to desiccation as related to organic matter

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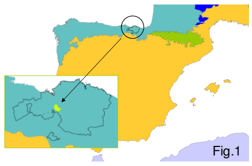
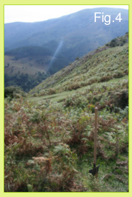


Introduction

A topsoil characterization involving collection of 66 samples from a variety of land covers was undertaken in Alonsotegi municipality (Basque Country, Spain, 30TWN0088)



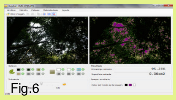
Site description

• East Atlantic Iberian Peninsula, within the Cantabroatlantic sector of the Atlantic European biogeographic province (Fig. 1) (1)

• Altitude gap goes from 20 m to 999 m a.s.l.
• Slope average ~26% (maximum ~ 54%) (Fig. 2)
• Lithology appears homogenous (quartz sandstone)

Sampling took place at the beginning of October 2012 after an extremely dry and hot summer (total summer rainfall represented 70% of precipitation registered along the severe hot spell of 2003, temperatures being slightly lower), providing a **baseline for maximum drought conditions**

Fig.1. Location map (Atlantic European biogeographic province) (1)
Fig. 2. Aereal view of the SE study area (Red circle for Fig. 3 and 4) Google Earth 2009
Fig. 3 and 4 Soil sampling at Meadow unit
Fig. 5. GIS analysis (gvSIG) (3)
Fig. 6. Sun exposure determination by CobCAL
Fig. 7. Soil organic matter determination by LOI method (2)



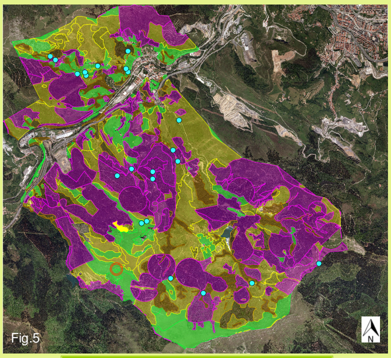


Fig.5. gvSIG view (GIS)
Polygons after EUNIS vegetation map over Aerial photographs (3). Red circle for Fig. 3 and 4. For colours see legend (no colours for rural, urban areas, rivers, damms or rock vegetation). Blue circles for sampling sites.

Methodology

We surveyed topsoil from seven main vegetation units: **meadows, heaths, hygrophilous forest, climatophilous broadleaved deciduous forests, coniferous, eucalypt and deciduous plantations**

- Vegetation analysis followed phytosociological criteria which allowed us to assemble several vegetation associations under a broader category so called Vegetation Unit (VU) (Fig. 5). EUNIS vegetation maps (3) were used under gvSIG computer program (GIS)
- Soil sampling took place at 22 different sites all around the municipality (3 samples per place, at least 3 places per VU) (Fig. 2-5)
- Volume of earth collected in cores (13x8x8 cm^3) was homogeneous: 869.06 ml ±70.30 (ANOVA $p = 0.16$)
- Field measurements taken were humidity, topsoil and air temperatures, ph, luminosity and canopy cover (pictures treated with COBCAL, Fig. 6)
- Laboratory determinations were pH, field capacity, field water content, and dry and organic matter (Fig. 7) using gravimetric and volumetric direct measurements for soil water content (4,5) and loss on ignition (LOI) method for SOM determination (2)

Results

Top soil temperature variation is analyzed by ANCOVA being related to cover (factor: sunny, mixed or shaded categorized after Cobcal evaluation) and air temperature as covariate (p< 0.05 for the two predictors and their interaction) showing no difference at sun exposures below 50%. It is followed by Tukey/Kramer multiple comparisons test of vegetation units soil temperatures (Table 1). No significant differences appear between meadows (TsoilºC = 23.6 ± 2.9) as fully exposed vegetation units and eucalypt plantations (TsoilºC = 22.9 ± 1.5) with 33% exposure.

Table 1. Tukey/Kramer analysis for top soil temperature means (± SD) within vegetation units

Soil Temp (ºC)	Meadows	Eucalypt Plantt.	Climatophilous forest	Deciduous Plantt.	Heathland	Coniferous Plant.	Hygrophilous forest
Mean	23.60	22.86	20.44	18.11	17.94	16.78	16.67
SD	2.92	1.55	0.98	1.45	1.47	0.67	1.80
Tukey/Kramer	23.40 (S.D. 2.6)		20.44 (SD 0.98)	17.4 (SD 1.5)			

A common water field capacity (FC) of 30.3 ± 6.8 % (vol %) appears but wide differences associated to vegetation profile are evident in regard to actual field water content (FW): between 8.0 and 45.1% (weight %) (Table 2, Fig. 8).

Table 2. Tukey/Kramer analysis for field water content means (± SD) within vegetation units

FW (weight)	Eucalypt Plantt.	Coniferous Plant.	Climatophilous forest	Meadows	Deciduous Plantt.	Hygrophilous forest	Heathland
Mean	0.13	0.14	0.15	0.17	0.19	0.23	0.28
SD	0.039	0.033	0.028	0.032	0.071	0.096	0.083
Tukey/Kramer	(1) 0.13 ±0.007		(2) 0.15 ±0.017	(3) 0.17 ±0.020	(4) 0.21 ±0.028		(5) 0.28 ±0.083

Organic matter content (SOM, % dry weight) ranks from lowest for hygrophilous forest (5.0 ±2.3 %) to highest for heath (15.9% ± 5.1 %) indicating increased density in flooding areas (Table 3). SOM determines FC (Fig. 9).

Table 3. Tukey/Kramer analysis for SOM means (± SD) within vegetation units

SOM (g/g)	Hygrophilous forest	Meadows	Eucalypt Plantt.	Deciduous Plantt.	Climatophilous forest	Coniferous Plant.	Heathland
Mean	0.05	0.10	0.11	0.12	0.13	0.14	0.16
SD	0.023	0.027	0.04	0.034	0.047	0.082	0.051
Tukey/Kramer	(1) 0.09 ±0.037		(2) 0.12 ±0.053		(3) 0.14 ±0.009		

Fig. 8. Field water (FW by weight) retained at maximum drought
$FW = 0.037e^{(5.312FC)}$
R^2=0.64; p-value<0.0001; n=57 (no riparian forest)

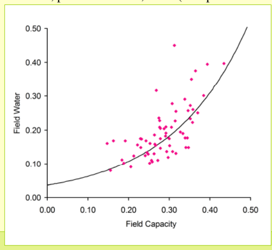


Fig. 9. Field capacity (FC) for water retention is related to SOM
$FC = 0.577SOM^{0.309}$
R^2=0.62; p-value<0.0001; n=61

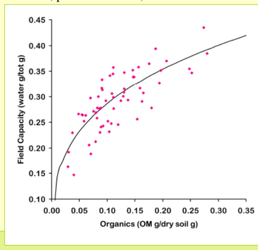
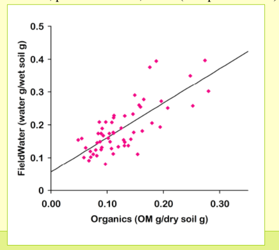


Fig. 10. Soil's water content depends upon SOM
$FW = 0.056 + 1.051SOM$
R^2=0.57; p-value<0.0001; n= 57 (no riparian forest)



Conclusions

1. Eucalypt plantations' soil temperature is similar to that of fully exposed meadows

2. In drought conditions, top soil organic matter (SOM) determines water retention ability (FW): a linear regression equation between field water content (g/g) and organic content (g/g) indicates an isometric relation (Fig. 10)

$$FW = 0.056 + 1.051SOM$$

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Interés de conservación del brezal y la pradera en Urdaibai (RBU)

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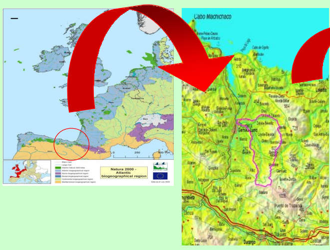
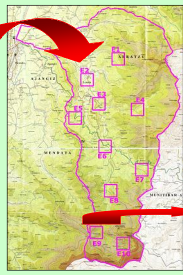
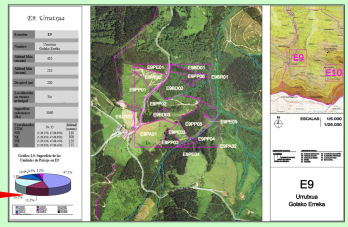
Resumen

El paisaje rural vasco se transforma y pierde su heterogeneidad al sustituirse en los ambientes montanos y colinos los bosques, pastos y brezales/helechales por plantaciones. En los valles son las áreas destinadas a usos agrarios tradicionales las que dan paso a plantaciones forestales y urbanizaciones. Así, desaparecen unidades de vegetación unidas al caserío, un conjunto complejo de pastos, prados, setos, cultivos, formaciones boscosas de galería a lo largo de cauces y caminos y bosquetes de frondosas, que conforman el agrosistema.

En este contexto, estimamos de utilidad abordar la evaluación del grado de calidad natural de distintas unidades de vegetación del territorio mediante criterios científicos y con un método repetible y que proporcione resultados numéricos, de modo que se pueda medir la contribución de las áreas naturales razonablemente bien conservadas a la preservación de la calidad de vida de las poblaciones humanas.







Objetivo

Evaluar la calidad del estado de conservación de las unidades de vegetación **pradera** y **brezal** mediante el uso del Índice de Interés de Conservación (IC).

Ajustar IC de ambas unidades a la situación ecológica actual, por su importancia en la conservación de áreas naturales de cierto valor ecológico y la evolución observada durante los últimos 15 años.

Palabras clave

Valoración de servicios del ecosistema, interés de conservación, agrosistema, pastizal, brezal.

Metodología

1. Estudio de la evolución del paisaje de la cuenca del Golako (1999-2013). Seleccionamos 10 estaciones (25 ha/estación) y mapeamos en SIG, creando polígonos de vegetación para ortofotos de diferentes años y contrastando con visita a campo (Orrantia, 2004; Orrantia et al. 2008). Analizamos resultados para pradera (MD) y brezal (HT) en cuanto a modificación en la superficie ocupada, altitud y distancia a caserío y a núcleo urbano.
2. Aplicación de IC. Aplicamos la herramienta siguiendo la definición original (Orrantia et al, 2008) y ajustamos tanto el valor biológico (B), como las funciones de retención de Carbono, protección del suelo (S) y de recursos hídricos (H) a las nuevas necesidades detectadas para estas unidades, tanto a nivel de UV como para las categorías EUNIS.

Resultados

Se evidencia una presión antrópica sobre los pastizales del fondo del valle originada por la urbanización y las plantaciones forestales, y de aquellos situados en un ambiente colino/montano de menor accesibilidad.

El aumento de los valores de IC no responde a una mejora en el estado ecológico del territorio sino a un nuevo calibrado con el objetivo de proteger de las áreas naturales, entre las que incluimos, además de las áreas boscosas, los prados fuertemente amenazados por la artificialización y ampliación de los núcleos rurales y por la ampliación de las áreas destinadas a aprovechamiento forestal (que ya ocupa un 75% de la superficie arbolada de la RBU) en los lugares más alejados de los núcleos, y los brezales, por tratarse de un estadio pre-bosque, unidad altamente amenazada.

Metodología 2

Interés de Conservación (IC)

IC = (N+P+A+F+R) x Rc x S x H x E

IC = B x RC x S x H x E

B	**Valor Biológico**	Definido por características sintaxonómicas de cada unidad de vegetación
N	**Naturalidad**	Grado de influencia humana en la unidad de vegetación; distancia a la clímax
P	**Reemplazabilidad**	Estima de la capacidad para recuperarse tras una perturbación
A	**Amenaza**	En función de las circunstancias socioeconómicas.
F	**Valor florístico-fitocenótico**	Mide el valor biológico intrínseco: biodiversidad en sentido amplio, estructura, etc.
R	**Rareza**	Representa la distancia media entre los lugares donde aparece
RC	**Retención de Carbono**	Sumidero de materia orgánica de las unidades de vegetación
S	**Protección del suelo**	Capacidad de retención del suelo por parte de las raíces; edafogénesis.
H	**Función Hídrica del suelo**	Capacidad de almacenamiento de agua de la unidad de vegetación
E	**Coeficiente de necesidad territorial para la protección del ecosistema**	Dependiente de la densidad de población (hab/km^2).

Utilizamos un índice agregado, **Interés de Conservación** (IC), compuesto por cinco indicadores que evalúan funciones y servicios ecológicos potenciales desarrollados por cada unidad de vegetación. En trabajos anteriores (ver referencias) esta herramienta ha resultado eficaz principalmente para evaluar la unidad de bosque, por lo que en este trabajo nos proponemos su adecuación a otras dos unidades, el brezal y el agrosistema que, tras el bosque, son los sistemas más afectados.

El **valor biológico** (B) está definido por las características sintaxonómicas de cada unidad de vegetación, teniendo en cuenta factores como **naturalidad, rareza, amenaza, valor florístico y reemplazabilidad**.

A su vez, la valoración de las funciones que realizan cada unidad de vegetación respecto de la **conservación del suelo** (S), los **recursos hídricos** (H) y la **retención de carbono** (RC) se basa en un estudio comparado de los suelos asociados a las principales unidades de vegetación (en estados de conservación variable) de la vertiente atlántica del País Vasco. Los resultados muestran un gradiente de valor creciente donde brezales y agrosistemas ocupan un lugar intermedio entre las plantaciones forestales (eucaliptales y coníferas) y el bosque en sus distintos estados (degradados y maduros).

Por último, creamos una **pasarela entre la sintaxonomía y el sistema EUNIS** que permita utilizar IC en sistemas de información geográfica (SIG) que utilizan la clasificación EUNIS (EEA) y faciliten el seguimiento y valoración del estado ecológico del territorio.

Cod.	EUNIS	Clasificación fitosociológica	UV	IC 2004	IC 2012
E2.11	Prados pastados y pastos no manipulados	Cynosurion cristati	MD	18.0	193.2
E2.21	Prados de siega atlánticos, no pastoreados	Arrhenatherion elatioris	MD	40.0	210.0
FA.3	Seto de especies autóctonas		MD	310.0	235.5
E5.31(X)	Helechales atlánticos y subatlánticos colinos	Calluno vulgaris-Ulicetea minoris	HT	93.0	360.0
F4.23(X)	Brezal atlántico dominado por Ulex sp.	Calluno vulgaris-Ulicetea minoris	HT	93.0	360.0
F7.44(Y)	Brezal calcícola con genistas, atlántico	Calluno vulgaris-Ulicetea minoris	HT	93.0	360.0
F3.11(Y)	Zarzal calcícola (Rubus ulmifolius)	Rhamno catharticii-Prunetea spinosae	HT	148.5	486.0
E3.41	Prados-juncales basófilos atlánticos	Caricetalia nigrae	MD	18.0	780.0

Metodología 1

Evolución del paisaje rural en la RBU (1999-2013)

Transformaciones del prado (MD)

Entre los hábitat de MD presentes en la RBU están los prados de siega, de diente y aquellos de zonas encharcadas (prados-juncales).

Tras el análisis de la modificación del paisaje desde 1999 hasta la fecha, observamos una pérdida de 11.07% y una ganancia de 5.06% de superficie destinada a prados y pastizales.

La pérdida de prados es debida principalmente a un proceso de casitización del núcleo rural (66.26%), seguida de un aumento del aprovechamiento forestal (23.98% más de plantaciones de coníferas) y un 9.75% de emboscamiento.

Es importante destacar que las nuevas edificaciones transforman completamente su entorno más cercano, urbanizando grandes calles y zonas de aparcamiento y jardines con especies alóctonas y eliminando los antiguos prados de diente, huertas y frutales del agrosistema.

Los prados de siega y los frutales, ambas entidades localizadas claramente más alejadas de los núcleos rurales, están en gran medida afectados por las plantaciones de coníferas.

El emboscamiento de prados se localiza también en zonas de elevada altitud y a una distancia de más de 2 km (20 minutos de conducción) por carretera del núcleo más cercano.

Las ganancias de prados son principalmente a costa de plantaciones de coníferas (PP 46.2%), seguido de antiguas huertas (RA 37.5%) y bosquetes (DF 16.4%). Se trata en su mayoría de desbroces (PP y DF) en el entorno de aquel caserío que no se localiza junto a un núcleo urbano para crear zonas ajardinadas; y desbroces en caseríos cercanos a núcleos urbanos para crear nuevas (aunque menores) áreas de pasto que sustituyen a las ocupadas por las nuevas urbanizaciones.

De las 16 manchas sin cambios observados 31,25% son pastos de diente cercanos al caserío (40 m) y en baja altitud (< 80 msnm); y 68.75% son pastos de siega situados en general cerca del caserío que los mantiene (60 m de camino) pero alejados de los núcleos rurales (400 m).

Pérdida de MD a favor de:

%	RA	PP	DF	%
E2.21	66.26	2.95		69.21
E3.41		9.98		9.98
E2.11			9.75	9.75
I1.2		11.05		11.05
	66.26	23.98	9.75	100.00

Ganancia de MD a favor de:

(%)	RA	PP	DF	%
E2.21	17.25	24.79	16.40	58.44
E2.11	20.20	21.36		41.56
	37.45	46.15	16.40	100.00

MD sin cambio	ha	%
E2.21	7.45	31.66
E2.11	16.08	68.33
	23.53	100.00

Transformación del brezal (HT)

A pesar de tener pocos datos para hacer una generalización, observamos que el brezal, alejado de núcleos rurales a más de 1.5 km y a 450 msnm, es una unidad de paisaje que está ganando terreno a costa del abandono de PP.

Transformación del entorno rural (RA)

Se ha observado un cambio en el 14.17% del uso del suelo rural (suelo destinado a viviendas de baja densidad, huertas, invernaderos y/o frutales).

Principalmente se observa un aumento de la superficie destinada a nuevas urbanizaciones a costa de prados de diente (93.59%).

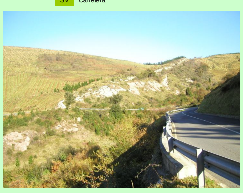
Hay una pequeña pérdida de zonas ajardinadas y frutales relacionados con el caserío que son transformadas en:

(a) PP (20.97%) situados a mayor altitud y/o con distancias relativamente largas (>2km, 20 minutos de coche) a núcleos de población (NR);

(b) MD (79.03%) situadas en el entorno inmediato de un caserío que pertenece a un núcleo rural

P2. Barrio Loiola (10 msnm). Cuenca Golako

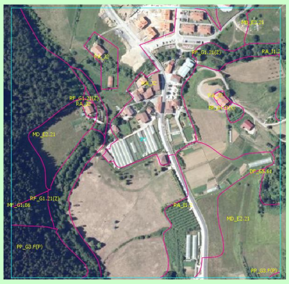
UV	Unidades de Vegetación
MD	Prado de siega, de diente, juncal
HT	Brezal, argomal, helechal
BD	Bosque de frondosas
BR	Bosque de ribera
PP	Plantación de coníferas
PE	Plantación de eucalipto
PF	Plantación de frondosas
RA	Zona rural (casa, huerta, frutal)
SV	Carretera



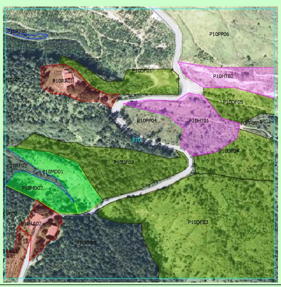
P10. Erenostegi Errota (330-495 msnm). Cuenca Golako

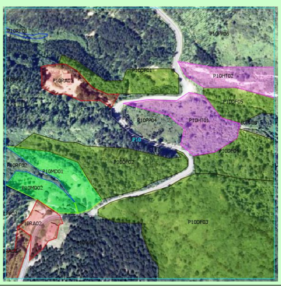
Polígonos de vegetación de 1999 sobre 0rtofoto de 2004

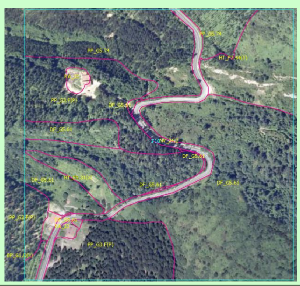
Polígono de vegetación de 1999 sobre 0rtofoto de 2011



Polígonos de Mapa Vegetación EUNIS (CAPV) de 2009 sobre 0rtofoto de 2011. Fuente www.geoeuskadi.net







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