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Provisioning ecosystem services supply and demand: The role of landscape management to reinforce supply and promote synergies with other ecosystem services

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ABSTRACT

Currently, trade enables regions to have a higher provisioning ecosystem services (ES) demand than that provided by ecosystems in the same region. This practice leads to a supply and demand provisioning ES scale mismatch, which may affect the provision of other ES. To address such an issue from the sub-national scale, an ES approach implementation step to provide realistic, context-specific pathways toward sustainability is necessary. This paper provides a detailed quantitative assessment of ecosystem services over time in Biscay, Basque Country, Spain. The aim is to identify ways of balancing the local provisioning ecosystem service supply and demand and to enhance sustainable land use. We studied the ecological footprint evolution of the province for 11 years and its relation to ecosystem services. We determined that the replacement of the current forest plantations' monocultures to a multifunctional landscape reinforces food security and enhances biodiversity and essential ES. This place-based ecosystem services assessment, which integrates ecological footprint calculations into an ecosystem service framework, demonstrated that provisioning ES-scale mismatches may be confronted locally by implementing sustainable landscape management strategies, including actions focusing on the supply and demand of ES. The current globalised economy promotes a global reduction in ecosystem integrity and ecosystem services. Reducing the ecological footprint at the local scale would contribute to the reduction of provisioning ecosystem services' demand at the global scale. Thus, maximising a mosaic approach to land use locally would help improve the provision of ecosystem services and therefore also contribute to the global footprint reduction.

Introduction

Ecosystem services (ES) are the conditions and processes by which natural ecosystems and the species that they comprise, sustain and fulfil human life (Daily, 1997). The Millennium Ecosystem Assessment (MA) (2005) explored the link between human well-being and the status of ecosystems and their sustainable use. This assessment focused on how ecosystem changes have affected, are affecting and will affect human well-being. It demonstrated that although the use of ecosystems has led to an increase in human well-being, some advances have been made at the cost of other services that are essential for human well-being (Millennium Ecosystem Assessment (MA), 2005).

The MA preceded many scientific, social and political concern on ES and the relevance of their sustainable use at different scales (e.g., Fisher et al., 2009; Perrings et al., 2011). Despite academic progress, many important issues regarding sustainability need to be further developed for the implementation of ecosystem services assessments, such as the current ES demand and supply scale mismatch (Burkhard et al., 2012) (We use the term mismatch here to explain the imbalance between the supply of resources and the societal demand in industrialised societies). Trade, through imports, enables regions to increase consumption levels without increasing pressure on domestic ecosystem services, but results in impacts elsewhere (Kastner et al., 2014). The scale mismatch occurring in many industrialised regions between the supply and demand of ES is especially important for provisioning ecosystem services (e.g., food, fibre, energy, raw materials), which have been

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historically managed as commodities traded in markets (Viglizzo et al., 2012). In the current globalised economy, trade allows some regions to have a higher provisioning ecosystem services demand than that provided by ecosystems in the same region, promoting a global reduction in ecosystem integrity and ecosystem services. Regulating ecosystem services, on the contrary, with some notable exceptions, such as global climate regulation, are often characterised by physically connected areas of supply and demand (Burkhard et al., 2012). Similarly, cultural ecosystem services are mostly site specific (e.g., Otero-Rozas et al., 2013), even if the interpretation of the cultural ES demand side is more complex because of human perceptions (Kumar and Kumar, 2008) and, for example, the scale mismatch related to the satisfaction obtained from the existing value of cultural ES is not easy to track.

Despite the agreement about the importance of including ecosystem service demand-side issues in ES assessments (McDonald, 2009; Anton et al., 2010), there are few ES assessments (the UK-NEA are exceptions, Weighell, 2011) that incorporate provisioning ecosystem service supply and demand scale mismatches. Additionally, there is a lack of place-based assessments that analyse how confronting the provisioning ES demand locally may influence other local ecosystem services. A place-based approach can help us understand issues regarding natural capital, multi-functionality, and the role of landscape in framing debates concerning ecosystem services and sustainability (Potschin and Haines-Young, 2013). For the recently established Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), studies on synergies and trade-offs between ES at the local scale are required. The research community needs to move toward solution-oriented research to provide realistic, context-specific sustainability pathways (DeFries et al., 2012).

An indicator that analyses the interaction between goods production and consumption and shows the intensity of human impact on them is the ecological footprint. The ecological footprint indicator is an estimation of resource consumption and waste assimilation requirements of a defined human population in terms of corresponding productive land area (Wackernagel and Rees, 1996). Ecological footprint calculations can be directly related to human consumption patterns and, therefore, identify benchmarks of sustainable activities (Jenerettea et al., 2006). In fact, they quantify human–ecosystem relationships by estimating the land area required to sustainably supply the ecosystem services consumed (Wackernagel and Rees, 1996). In other words, the ecological footprint represents the demand for ecosystem products and services in terms of the appropriation of various land use types (Borucke et al., 2013).

These two prominent approaches, the ecosystem services approach and ecological footprint calculations or accounts (which relate the ecological footprint to the bio-capacity), link the production of ecosystem services with their consumption by societies (Jenerettea et al., 2006). The aim shared by these approaches is to promote the sustainable use of goods and products provided by nature or, in other words, ecosystem services. However, the integration of these perspectives rarely has been applied, perhaps because of the different conceptual framework and the distinct units used in the two approaches. The integration of the ecosystem services approach and an ecological footprint analysis into a coherent analysis could help inform sustainable guidelines for a more sustainable management of goods' supply and demand. We combined these two approaches to better understand the variation on demand and supply of ecosystem products or services in relation to land management.

Local policy makers involved in the Millennium Ecosystem Assessment in the Biscay-Basque Country Sub-National Ecosystem Services Assessment, considering local stakeholders' perceptions and in agreement with the Local Agenda 21 action plan, demanded more information on Biscay's recent provisioning ecosystem service supply and demand evolution (Onaindia et al., 2015). The current demand for provisioning ES in the province is high, but arable land covers less than 1% of Biscay and grassland covers 20% (Fig. 1). Accounting for the data requirements of local policy makers, we performed a detailed quantitative assessment of provisioning ecosystem service supply and demand of Biscay for eleven years. Time trends are valuable to document the human use of natural capital, providing effective support in assisting decision makers (Wackernagel et al., 2004a). The aim of this study is threefold: first, to track the interactions of different provisioning ecosystem service supply and demand over time; second, to analyse how actions towards an appropriate balance of the local provisioning ecosystem service supply and demand may influence biodiversity and other ES; and finally, to help sub-national policy makers identify suitable landscape management strategies that favour such a balance and to enhance synergies with biodiversity and other ES. To accomplish these objectives, we studied the ecological footprint evolution of Biscay from 2000 to 2010. This accounting tool enables the analyses of the provisioning ecosystem services consumed by a given population during a concrete period with regards to the productivity available in the same area and period (Borucke et al., 2013). This approach visualises the possible provisioning ecosystem service supply and demand scale mismatches and links local actions to global socio-ecological and sustainability issues (Aall and Norland, 2005; Collins et al., 2006).

Methods

Study area

This study was performed in Biscay (2213 km^2; 1.2 million inhabitants), northern Spain (43°46′–42°92′N, 03°45′–02°40′W), in the Basque Country (Fig. 1). Its high population density, focused in the river estuaries, is a consequence of the heavy industrialisation that Biscay underwent during the nineteenth and early twentieth centuries. Iron-based economic development characterised the social and economic development of the region until the beginning of the 1990s. Biscay then underwent a profound transformation. The industry sector evolved toward a new type of industry in which the service sector was clearly strengthened (e.g., currently covers 72% of the total Gross Domestic Product-GDP, Eustat: Basque Statistics Office, 2013).

The industrialisation period entailed high rural land abandonment after which an important transformation process occurred in the rural sector. To confront the rural crisis, reforestation with exotic tree species was promoted (Groome, 1990, Madariaga et al., 2011). Currently, more than half of the land surface in Biscay (59%) is dominated by forest, predominantly exotic plantations (*Pinus radiata* and *Eucalyptus* sp., 39 and 5% of the area, respectively), but arable land covers less than 1% and grassland covers 20% of the study area (Fig. 1). Typically, logging occurs every 30–35 years for coniferous plantations and every 15 years for *Eucalyptus* sp. The primary natural forest types in Biscay are Cantabrian evergreen-oak forests (*Quercus ilex*), mixed oak forests (*Quercus robur*) and beech forests (*Fagus sylvatica*). These forests represent the potential vegetation of approximately 80% of the region, but they currently only cover 13% of the area (Fig. 1). The current Biscay landscape is dominated by monoculture forest plantations, and the traditional Basque multifunctional countryside mosaic landscape has been severely reduced. These monoculture plantations, with fast-growing exotic tree species and aggressive forms of management, are associated with a series of environmental problems, such as soil erosion, soil compaction, nutrient loss, turbidity and supply of surface water, and biodiversity loss (Amezaga and Onaindia, 1997; Merino et al., 2004; Santos et al., 2006; Leslie et al., 2012).

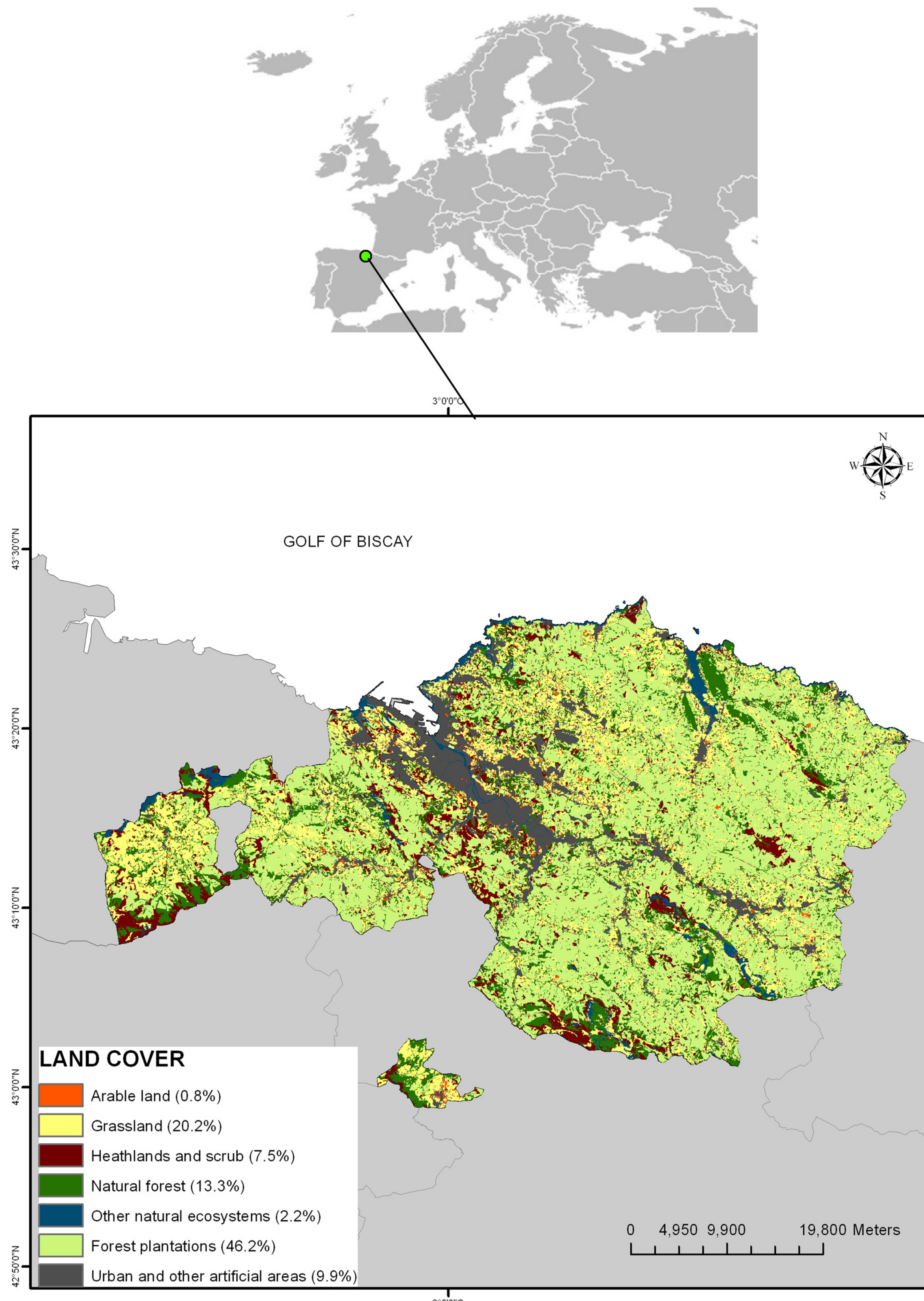

Fig. 1. Location of the study area and land cover percentage.

The Basques have historically been linked to the land and its services. Currently, both socially and culturally, these links are still highly valued and preferences for the traditional multifunctional countryside landscape have been acknowledged (Casado-Arzuaga et al., 2013a,b). However, the primary economic sector (i.e., agriculture, livestock, forestry and fishing) (Fig. 1) is facing a challenging economic situation and only covers a small portion, less than 1%, of the total GDP (Eustat: Basque Statistics Office, 2013). Because of the globalisation of the timber market and other factors, forest plantations in the area are no longer as profitable as they once were. The value of timber production fell by 80% between 2005 and 2011 (Basque Government, 2013), and current Basque forestry depends heavily on public subsidies (Rodríguez-Loinaz et al., 2013). Therefore, strategic planning to create sustainable landscapes and opportunities to discuss a new rural–urban relationship are needed.

Assessing supply and demand of goods and services

We used ecological footprint accounts as a tool to conduct a regional provisioning ecosystem service supply and demand assessment. Through ecological footprint and bio-capacity calculations it is possible to analyse the provisioning ecosystem services consumed with regard to the productivity actually available (Borucke et al., 2013). For this comparison, the provisioning ecosystem service demand is calculated in the same unit as the supply (global hectare per person and year). Even if we focus on provisioning ecosystem services, it must be noted that the ecological footprint also considers carbon regulation and habitat ecosystem services (Borucke et al., 2013).

The ecological footprint represents the demand for provisioning ecosystem goods and services in terms of the appropriation of five main land use types that respond to six demand categories (Borucke et al., 2013): arable land for the provision of plant-based food and fibre products; grazing land and arable land for animal products; forest land for timber and other forest products; fishing grounds for fish products; carbon footprint; and built-up land for shelter and other infrastructure. Note that the carbon footprint corresponds to the forest area needed to absorb anthropogenic carbon dioxide emissions from the production and consumption of energy and materials, as well as from waste generation. Recycling rates are used to reduce the total carbon dioxide emissions coming from waste generation. The list of categories included in the ecological footprint accounts of Biscay in relation to the six land demand categories is presented in Table 1.

The bio-capacity, defined as the capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans (GFN (Global Footprint Network), 2012), represents the productivity available to serve each use included in the ecological footprint (Borucke et al., 2013). The capacity of an area to provide essential ecosystem services can be estimated in part through the calculation of its bio-capacity. However, the calculation of the bio-capacity does not imply an automatic estimation of the ecosystem service supply. The production of food, wood and other commodities can easily be expressed in terms of hectares to measure the ecological footprint and the bio-capacity of land. The needed land for shelter and other infrastructure is also expressed in hectares. The expression in hectares of other goods such as electricity, fossil fuels (gas, liquid, and solid) or waste generation is expressed through the carbon footprint, which at first glance is less intuitive.

For a given region, each of the land demand categories included in the ecological footprint for fulfilling the actual provisioning ecosystem services consumption is represented as an area in hectares, expressing the land needed to serve such demand. This allows a homogeneous indicator to be used for the different provisioning ecosystem services demand types and expresses the often delocalised ecosystem service consumption (e.g., Gómez-Baggethun and Barton, 2013) as visual parameters or units. For the metrics to be globally comparable, the Global Footprint Network provides equivalence factors for each land demand category for which they are multiplied to obtain the ecological footprint in global hectares (Monfreda et al., 2004). In this study, the yield factors (YF) and the equivalence factors (EQF) coefficients needed to obtain this standardised unit of measure (Monfreda et al., 2004; Borucke et al., 2013) were obtained from the 2014 Edition of the National Footprint accounts (GFN (Global Footprint Network), 2014). The sum of the total number of area types equals the total ecological footprint EF (Wackernagel et al., 2005):

$$\text{EF}\,(\text{gha}) = \sum \text{area}\,(\text{ha}) \times \text{equivalence factor}\,\left(\text{gha/ha}\right) \tag{1}$$

The extension of each land demand category area required to sustain consumption is obtained by dividing the consumption for each land demand category by the specific production coefficients or yield factors. The consumption for each land demand category is calculated by adding imports to and subtracting exports from the domestic production (Wackernagel et al., 2005; Borucke et al., 2013). For the case of the carbon footprint, the extension needed to absorb anthropogenic carbon dioxide emissions is obtained dividing the total direct and indirect energy consumption (including that associated to the production and distribution of consumed food and materials) by the capacity of the forest system to sequester CO_2.

Bio-capacity represents the provisioning ecosystem service supply side and is expressed in units of productive area annually available to cater for the demand for provisioning ES of a given population (Wackernagel and Rees, 1996; Borucke et al., 2013). It is the sum of a region's biologically productive areas: arable land, grazing land, forest land, and fishing grounds. The bio-capacity (BC) of a region, which is expressed in global hectares (gha), is calculated by multiplying the actual area by the appropriate equivalence factor and yield factor specific to that region (Wackernagel et al., 2005):

$$\text{BC}\,(\text{gha}) = \sum \text{area}\,(\text{ha}) \times \text{equivalence factor}\,\left(\text{gha/ha}\right) \times \text{yield factor} \tag{2}$$

The ecological footprint accounts' analysis over time, with an adequate degree of desegregation, allows for an insightful reading of the final data that reveals the positive tendencies towards sustainability and shows where improvements are needed (Wackernagel et al., 2004a,b; Bagliani et al., 2008). In this study, we calculated the Biscay ecological footprint accounts for the period 2000 to 2010.

The accuracy of ecological footprint accounts depends on the accuracy of the source data (Kitzes et al., 2009). Therefore, we used the most detailed and accurate source data available. We first consulted the official data available, which are consistent for our region. Next, we contacted and collaborated personally with key council officers and representatives for different socio-economic activities (fishing, forestry, recycling industries and consumer association) to guarantee the accuracy and correct use of the data. Table 2 shows the main data sources used to calculate the ecological footprint and bio-capacity of Biscay.

Results

Biscay's ecological footprint accounts show an ecological deficit during the studied time period. The ecological footprint presents higher values than the bio-capacity, signifying there is a higher local provisioning ecosystem service annual consumption than what the local ecosystems are annually providing. During the analysed period, however, there is a trend to reduce this deficit, starting with an ecological deficit of 4.1 gha/capita in 2000 and decreasing to 2.4 gha/capita in 2010 (Table 3). The ecological footprint had a decreasing trend for the studied 11-year period, beginning at over 5 gha/capita in 2000 and decreasing to 3.5 gha/capita in 2010. Bio-capacity, which calculates the area of the ecologically productive land, had a relatively constant trend during the studied time period, varying from a high of 1.08 gha/capita in 2001 to a low of 1.05 in 2010 gha/capita (Table 3).

Table 1
List of categories included in the ecological footprint accounts of Biscay in relation to the six land demand categories (a semicolon divides subcategories).

1. Arable land
a. Plant food products: cereals; vegetables: potatoes, legumes, vegetables; food preparations; fruit trees; sugar; Cofe and tea; cacao; oilseeds; other fats and oils; products of the milling industry; drinks and vinegar
(b) Other plant products: live plants; tobacco; gums, resins and other vegetable saps and extracts; plaiting materials; manufactures of esparto or basket making; cotton; fabrics and clothes; other textile fibres and products
2. Grazing land
a. Animal food products: live animals; meat; milk, eggs and honey
b. Other animal products: wool; leather; shoes; others
c. Plant food for animals
3. Forest land
Wood products: wood and articles of wood; wood charcoal; cork and articles of cork; pulp of wood or of other fibrous cellulosic material; paper and paperboard; articles of paper pulp; newspapers and other products of the printing industry
4. Fishing ground
Animal food products: fish, crustacean and mollusc
5. Carbon footprint
5.1. Production and consumption of materials
a. Quimic products: inorganic quimic products; organic quimic products; pharmaceutical products; fertilizer; tanning and dyeing extracts, paints; essential oils and resinoids, perfumery and cosmetic; wax, detergents and soaps; albuminoidal substances; explosives and gunpowder, inflammable materials; photographic or cinematographic products; rubber and articles thereof; human-made fibres; plastics and articles thereof
b. Non-metallic minerals and articles thereof: salt, sulphur, soil and stones, plastering materials, lime and cement; metallic ores, slag and ash; ceramic products; glass and glassware
c. base metals and articles thereof: smelting, steel and iron, and articles thereof; copper and articles thereof; nickel and articles thereof; aluminium and articles thereof; lead and articles thereof; zinc and articles thereof; tin and articles thereof; tools, implements and cutlery of base metal; other base metals and articles thereof
d. Non-electrical machinery: Nuclear reactors, boilers and mechanical appliances
e. Electrical machinery: electrical machinery and equipment
f. Transport equipment: railway locomotives and materials thereof; motor vehicles, tractors, moped and others; aircraft or spacecraft; marine and river navigation
g. Optical, photographic or measuring instruments and apparatus; clocks and watches and parts thereof; music instruments
h. Other products: pearls, precious stones, precious metals, jewellery; arms and ammunition; furniture (all types); toys, games and sports requisites; works of art, collectors' pieces and antiques
5.2. Energy production and consumption
a. Solid fuel: soft coal and anthracite, metallurgical coke, petroleum coke
b. Liquid fossil fuel: fuel oil, diesel fuels, petrol
c. Gaseous fossil fuels: total LPG, natural gas
d. The incorporated energy in the net imports
e. Electricity produced from natural gas
f. Imported electricity (unknown origin)
5.3. Waste generation and recycling rates
General waste; batteries and accumulators; bulky rubbish; paper and paperboard; glass; plastic; metals; packaging; pruning and gardening; wood; clothes; electrical and electronic equipment; fluorescent lamps
6. Built-up land
a. Built up land for: urban residential area; urban economic activities; general infrastructures (railways, airports, ports, trains and others); extractive activities; rural settlements
b. Land occupied for the generation of electricity by hydropower, wind power and solar power*

* To avoid double counting, some energy components were included in other land use types, such as solar power in built up land or biomass energy in arable land.

Analysing the Biscay ecological footprint and bio-capacity disaggregated according to ecologically productive land categories or land demand categories, and examining the waste and energy components, enables a more detailed and insightful interpretation of these trends. The carbon footprint is by far the category that most influenced the ecological footprint in the province during the 11 years (Fig. 2). Its percentage distribution over time on Biscay's ecological footprint increased from 47% in 2000 to 60% in 2010, with a peak of 68% in 2007 (Fig. 3). The carbon footprint land demand category analyses the direct and indirect energy uses, as well as the impact of waste generation and treatment. The incorporated energy in the net imports is the ecological footprint energy component that most influences the energy demand, followed by liquid fossil fuel consumption and imported electricity of unknown origin (Fig. 4).

Overall, the demand placed on each of the ecologically productive land categories decreased or remained relatively constant during the 11-year study period (Fig. 2). During this time, arable land demand decreased (Table 3 and Fig. 2) along with its percentage distribution on Biscay's ecological footprint (Fig. 3). This

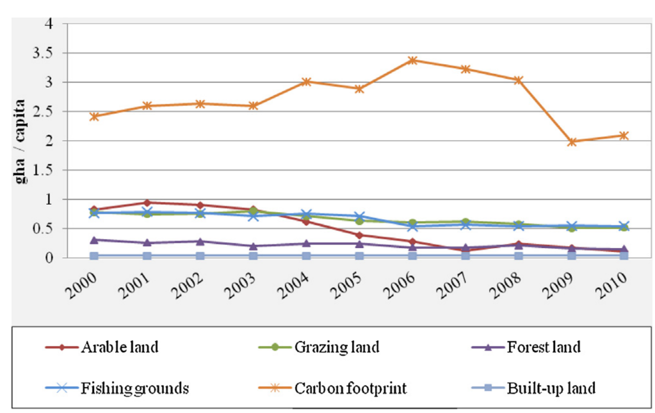

Fig. 2. Ecological footprint per capita evolution disaggregated into land demand categories (2000–2010).

Table 2
The main data sources used to calculate the ecological footprint and the bio-capacity of Biscay.

Data	Year/s	Source	Website	Specific data link
General import and export data	2000–2010	Eustat-Basque Statistics Institute	http://www.eustat.es	http://www.eustat.es/bancopx/Dialog/varval.sp?ma=PX_2817_ar03&ti=Comercio%20exterior%20por%20flujo,%20territorio,%20%E1rea,%20cap%EDtulo%20arancelario%20y%20unidad&path=./spanish/tablas/&lang=1&idTema=TEMA_374#axzz2HHzyRpFp
Imports and exports of fish	2000–2010	Eustat-Basque Statistics Institute	http://www.eustat.es	http://www.eustat.es/bancopx/Dialog/varval.asp?ma=PX_2817_ar19&ti=Comercio%20exterior%20por%20flujo,%20territorio,%20%E1rea,%20rama%20de%20actividad%20A86%20y%20unidad&path=./spanish/tablas/&lang=1&idTema=TEMA_374#axzz2CwFZP2cb
Live animals	2000–2009	Department of Economic Development and Competitiveness of the Basque Government	http://www.nasdap.ejgv.euskadi.net	http://www.nasdap.ejgv.euskadi.net/r50-774/es/contenidos/estadistica/estadistica_rapida/es_dapa/estadistica_rapida.html
Meat production	2000–2009	Department of Economic Development and Competitiveness of the Basque Government	http://www.nasdap.ejgv.euskadi.net	http://www.nasdap.ejgv.euskadi.net/r50-774/es/contenidos/estadistica/sacrificio_gan_bizkaia/es_dapa/sacrificio_gan_bizkaia.html
Milk, eggs and honey production	2000–2010	Department of Economic Development and Competitiveness of the Basque Government	http://www.nasdap.ejgv.euskadi.net	http://www.nasdap.ejgv.euskadi.net/r50-774/es/contenidos/estadistica/estadistica_rapida/es_dapa/estadistica_rapida.html
Production of fish, crustacean and mollusc	2000–2010	Eustat-Basque Statistics Office	http://www.eustat.es	http://www.eustat.es/bancopx/Dialog/varval.asp?ma=PX_2817_ar19&ti=Comercio%20exterior%20por%20flujo,%20territorio,%20%E1rea,%20rama%20de%20actividad%20A86%20y%20unidad&path=./spanish/tablas/&lang=1&idTema=TEMA_374#axzz2CkaXhLhv
Wool production	2003–2010	HAZI-Basque Government Corporation for rural and marine development	http://www.hazi.es	Obtained after express request to the statistical body of the Environmental and Landscape Policy Department of the Basque Government
Plant food products production	2000–2010	Department of Economic Development and Competitiveness of the Basque Government	http://www.nasdap.ejgv.euskadi.net	http://www.nasdap.ejgv.euskadi.net/r50-774/es/contenidos/estadistica/superf_prod_bizkaia/es_dapa/superf_prod_bizkaia.html
Fruit trees and drinks Production	2000–2010	Department of Economic Development and Competitiveness of the Basque Government	http://www.nasdap.ejgv.euskadi.net	http://www.nasdap.ejgv.euskadi.net/r50-774/es/contenidos/estadistica/estadistica_rapida/es_dapa/estadistica_rapida.html
Wood production	2000–2010	Forestry Section of the Agriculture Department of the County Council of Biscay	http://www.bizkaia.net	Carlos Uriagereka Larrazabal, Head of the Forestry Section of the Agriculture Department. Lehendakari Agirre 9, 2° Izda 48014 Bilbao
Energy production	2000–2010	EVE-Ente Vasco de la Energía (Basque Energy Body)	http://www.eve.es	Data provided by the personal from the Basque Energy Body, EVE. Alameda de Urquijo 36, 48011 Bilbao Tel: (+34) 944 035 663
Waste production	2000–2010	County Council of Biscay	http://www.bizkaia.net	http://www.bizkaia.net/home2/Temas/DetalleTema.asp?Tem_Codigo=7710&idioma=CA&dpto_biz=9&codpath_biz=9|351|7709|7710
Waste recycling: Plastics, metals and paper	2005–2010	Ecoembes	http://www.ecoembes.com	https://sistemas.ecoembes.com/Ecoembes.SGR.InformeACiudadanos.WebUI/Informe.aspx?InfId=ISEL
Packaging waste recycling	2007–2010	Bizkaiko Zabor Berziklategia-Separation and sorting plant for urban and industrial packaging and packaging waste	http://www.bzb.es/	Unai Urrutia Azkue, Director of the Bizkaiko Zabor Berziklategia
Glass waste recycling	2000–2010	Waste Management Service of the Environmental and Landscape Policy Department of the Basque Government	http://www.ingurumena.ejgv.euskadi.net/r49-579/es/	Joseba González Artaza. Service of waste treatment of the Basque Government
Pasture, Forest and arable land surface	2000–2010	Forest Inventory of the Basque Country 2005 in 1:10,000 scale-Basque Government	www.geo.euskadi.net	http://www.nasdap.ejgv.euskadi.net/r50-15135/es/contenidos/informacion/inventario_forestal_index/es_dapa/inventario_forestal_index.html
Built-up land surface	2000–2010	UDALPLAN-Environmental and Landscape Policy Department of the Basque Government	http://www.geo.euskadi.net/udalplan/visor/viewer.htm	Al data series available at: ftp://ftp.geo.euskadi.net/cartografia/Planeamiento/Udalplan/Historico_Udalplan/
Sea surface		Azti-Tecnalia, marine research center	http://www.azti.es/	Iñaki Artetxe Irueta. Azti-Tecnalia, marine research center. Isla de Txatxaramendi s/n 48395 Sukarrieta
Population	2000–2010	Eustat-Basque Statistics Office	http://www.eustat.es	http://www.eustat.es/elementos/ele0000600/ti_Poblacion_estimada_de_la_CA_de_Euskadi_a_31_de_diciembre_1975-2010/tbl0000660_c.html#axzz2CkaXhLhv

Table 3
Per capita values of the ecological footprint (disaggregated according to the six land demand categories) of the bio-capacity and ecological deficit of Biscay for 2000–2010. All data are in gha per person.

	Ecological footprint by ecologically productive land categories						Total Ecological Footprint	Bio-capacity	Ecological deficit
	Arable land	Grazing land	Forest land	Fishing grounds	Carbon footprint	Built-up land			
2000	0.83	0.79	0.31	0.77	2.42	0.04	5.16	1.07	4.09
2001	0.95	0.75	0.26	0.79	2.60	0.04	5.39	1.08	4.31
2002	0.90	0.76	0.28	0.76	2.64	0.04	5.38	1.08	4.30
2003	0.83	0.80	0.20	0.71	2.60	0.04	5.19	1.07	4.12
2004	0.62	0.72	0.25	0.76	3.01	0.04	5.40	1.07	4.33
2005	0.39	0.63	0.24	0.71	2.89	0.04	4.91	1.07	3.84
2006	0.28	0.61	0.18	0.54	3.38	0.04	5.03	1.07	3.96
2007	0.12	0.62	0.18	0.56	3.23	0.04	4.75	1.06	3.69
2008	0.24	0.58	0.22	0.55	3.04	0.04	4.66	1.05	3.61
2009	0.17	0.51	0.16	0.55	1.99	0.04	3.42	1.05	2.37
2010	0.11	0.52	0.15	0.54	2.10	0.04	3.47	1.05	2.42

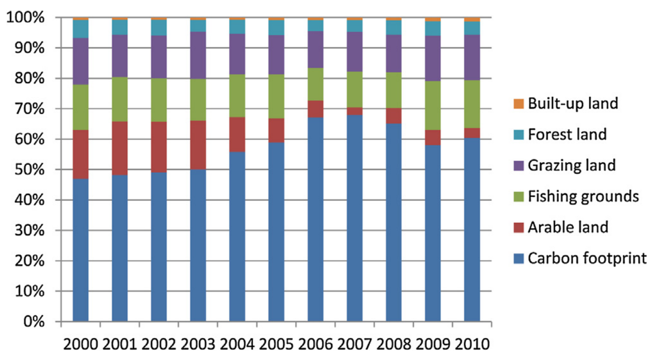

Fig. 3. Percentage distribution over time of the Biscay ecological footprint according to the six land demand categories (2000–2010).

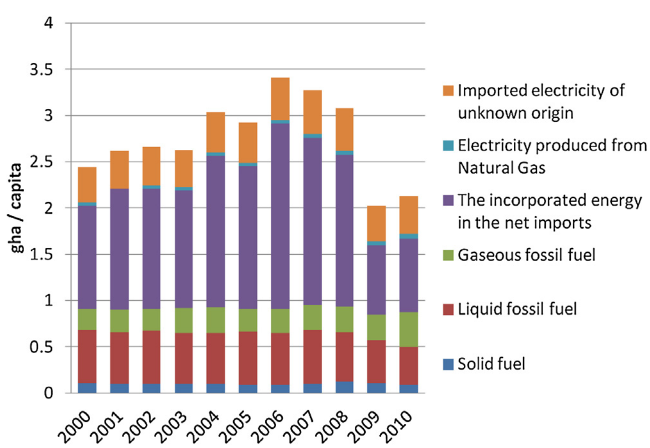

Fig. 4. Ecological footprint energy component of Biscay for the examined period.

decrease in arable land demand is related to a decrease in imported food, especially associated with a decrease in oilseed imports (Fig. 5). In the most recent years, the carbon footprint of the ecological footprint decreased, peaking at 3.4 gha/capita in 2006 and decreasing to 2.1 gha/capita in 2010 (Table 3, Fig. 2). The disaggregated analysis of the ecological footprint revealed the incorporated energy in the net imports was the main aspect responsible for the decrease in the carbon footprint after 2006, which decreased from a peak of 2.0 gha/capita in 2006 to 0.8 gha/capita in 2010 (Fig. 4).

Several positive trends are observed for waste generation and treatment. There was an increase in the selective waste collection for recycling (from 160,005 t in 2000 to 210,876 t in 2010) and a steady decrease in the general waste collection (from 492,869 t in 2000 to 404,060 t in 2010) (Fig. 6). The total waste collection, a sum of the selective waste collection and general waste, peaks in 2007 with a maximum of 669,508 tones and then decreases to 11.7% to 614,936 t in 2010 (Fig. 6). The ecological footprint waste-recycling component increases during the study period (Fig. 7). This leads to a slight decrease in the carbon footprint evolution and in the overall ecological footprint of the province.

Discussion

Waste recycling and control of demand

During the studied 11-year period, the ecological footprint decreases but the bio-capacity remains relatively constant. There is a notable reduction in the ecological deficit of Biscay. This could indicate that there is a trend toward greater sustainability in the region as a consequence of sustainability policies and programs performed in recent years linked to the Local Agenda 21 action plans of Basque institutions, such as the Biscay 21 action plan (www.bizkaia21.net). However, the current economic crisis may have influenced such results, signifying that caution is needed when interpreting the observed provisioning ES demand reduction. This decrease of the ecological deficit in the final years of the studied period is explained primarily as a result of the reduction of the energy component within the carbon footprint. The incorporated energy in the net imports, which most influences the energy demand, decreases during this period (probably because imports are arriving from shorter distances), certainly a result of the impact of the global economic crisis visibly affecting the study area.

In any case, our results indicate the effectiveness of local policies and environmental programs focused on promoting recycling and reducing waste generation. These measures include offering better recycling facilities for citizens by creating selective waste collection points (known as *Garbigune*) and improving the accessibility of inhabitants to public recycling bins. In fact, the appropriate management of the end-of-life of a product strongly depends on efficient waste collection to start the subsequent recycling process (Toso and Alem, 2014). During the studied period, there was a notable increase in the number of public recycling bins distributed throughout the municipalities of the province, such as glass bins (72%), paper and paperboard bins (69%) and light packaging bins (31%). This increase has led to a considerable decrease in the ratio of inhabitants per public recycling bin (up to 40%, 41% and 23%, respectively). The current value is less than 300 (e.g., 225 inhabitants per light packaging recycling bin) (DFB: Regional Government of Biscay, 2013). Additionally, the use of other more specific and less common public recycling bins, such as those for vegetable oil recycling or organic matter collection for compost, is increasing and expanded in the study area. All of these are important, successful sustainability policies that need to be highlighted, even if waste treatment represents a small fraction of Biscay's total footprint, as

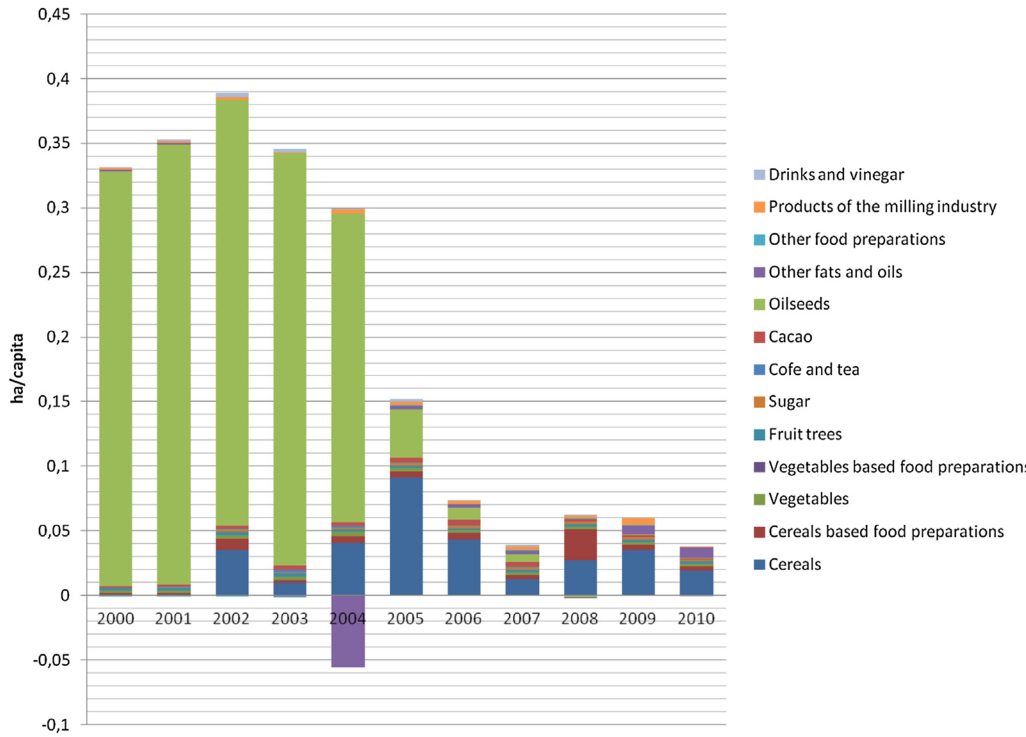

Fig. 5. Plant food products provisioning ES demand evolution during the study period (2000–2010).

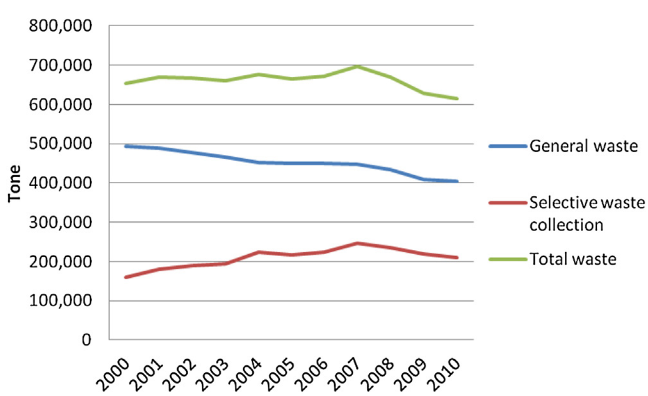

Fig. 6. Waste generation evolution disaggregated in selective waste collection for recycling and general waste, the sum of which equals the total waste.

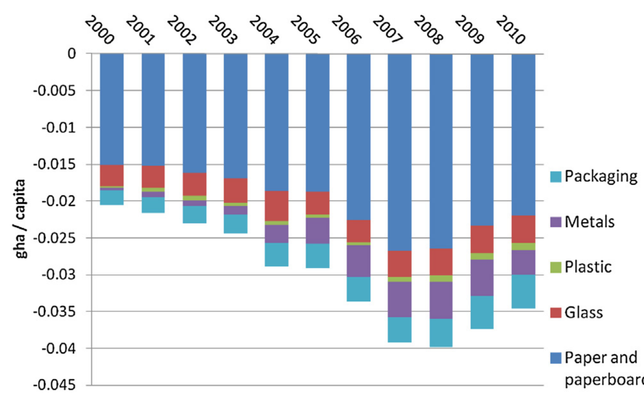

Fig. 7. Ecological footprint waste recycling component of Biscay for the examined period. Data are expressed in negative gha/capita as the recycling component discounts from the total provisioning ecosystem service demand.

occurs in other high consumption regions such as Oslo (Aall and Norland, 2005).

Even if there is a reduction of the ecological footprint in the final years of the study, our results show that Biscay had an ecological deficit during the entire 11-year period, confirming Biscay is dependent on other region's provisioning ecosystem services. The analysed territory is unable to meet its inhabitants' demands for provisioning ecosystem services when only using local ecosystems. The lifestyle of Biscay's inhabitants is characterised by an elevated demand on provisioning ecosystem services, which are "embedded" in market products. Biscay is highly dependent on imported food, energy and other provisioning ecosystem services. This happens to be a common trend in high-income regions, which have a higher demand for biologically productive land per capita than low-income areas (Jorgenson and Burns, 2007; Weinzettel et al., 2013).

To contribute to a broad sustainability agenda from our subnational scale, it is important to apply policy strategies and actions on the ES demand side, which could decrease the current demand. This is in agreement with those authors that defend the need of consumption contraction in medium- and high-income regions to reverse the increasing global resource demand trend (e.g., Weinzettel et al., 2013). We found it necessary to reduce the import of food and materials that currently is too high. This seems to be a common trend in Europe, whose import rates are high, especially for food (Kastner et al., 2014). In the UK, for instance, food has been identified as a key future driver (Weighell, 2011). In the coming decades, a crucial global challenge will be meeting future food demands without undermining the integrity of the Earth's environmental systems (Mueller et al., 2012). One aspect that has not already been established on the political agenda of most local authorities is the need to reduce the consumption of intensive land-demanding food (Aall and Norland, 2005), such as food from distant sources (Carlsson-Kanyama and González, 2009). From a local authority perspective, it is important to continue to decrease the demand for imported products by promoting local and more sustainable consumption. Another relevant area for reducing demand on provisioning ecosystem services in Biscay is reducing energy consumption. Our data shows that the incorporated energy in the net imports strongly influences the energy demand, suggesting a reduction in imported food and materials would decrease the energy demand. Reducing fossil fuel and electricity consumption is key to reducing the energy demand in Biscay. We observed a decrease in the demand for liquid fossil fuel since 2007, but its consumption, primarily related to private transport, is still high.

To reinforce this decreasing trend and actively promote the reduction of energy consumption, the Regional Government of Biscay recently approved *the sustainability energy strategy for Biscay–EESB 2020* (www.bizkaia21.net). This strategy includes several actions and measures to reduce fossil fuel consumption, reinforce the use of renewable energy and diminish electricity consumption. However, no specific actions for reducing the incorporated energy in the net imports are included in this strategy, which indicates that Biscay's dependence on other region's provisioning ecosystem services is not perceived as local energy consumption. The results presented in this paper could be used to raise social and political awareness on the relevance for local sustainability of diminishing import rates. Diminishing the demand for imported food and other provisioning ES would have a decreasing effect on energy demand, reducing the water consumption associated with imported foods (e.g., Winter et al., 2014) and diminishing the potential environmental and social impacts elsewhere (e.g., Seppelt et al., 2011; Weinzettel et al., 2013).

Enhancing local provisioning ES supply: Synergies and trade-offs with biodiversity and other ES

Policy actions in favour of reducing demand and promoting sustainable local consumption would enhance sustainable local production and reinforce self-provisioning. Additionally, to tackle sustainability, solution-oriented policy strategies and management actions that link and promote local sustainable agricultural production and consumption are needed (Davies, 2014). This would reconnect consumers to the source ecosystems of their food provision and help re-establish physical connections between decision-making processes and the territory (e.g., Gómez-Baggethun and de Groot, 2010; Redman, 1999). To accomplish this, provisioning ecosystem service management should be integrated into landscape management and should account for biodiversity and cultural and regulating ES. Unfortunately, provisioning ES are often considered separate from other ecosystems and services (Poppy et al., 2014) and result in ecosystem disservices (Millennium Ecosystem Assessment (MA), 2005; Viglizzo et al., 2012). However, many trade-offs between agricultural production and various ecosystem services are not inevitable and 'win–win' scenarios are possible (Power, 2010). To maintain a diverse flow of ES and guarantee the viability of rural areas in Europe, investments should enhance multifunctional sustainable agriculture, which ensures ecological integrity and ecological coherence (Gómez Sal and González García, 2007). Multifunctional, sustainable agriculture could be an appropriate response for Biscay to enhance landscape multifunctionality, increase self-provisioning, recover natural ecosystems and maintain biodiversity and a diverse flow of ES (e.g., Palacios-Agundez et al., 2014; Casado-Arzuaga et al., 2013a). This would lead to the maintenance and reinforcement of the traditional multifunctional landscape, which includes forest, pastureland and arable land, and also to reduce the current dominant forest monoculture plantations.

Synergies related to this possible landscape transformation are likely to occur with biodiversity, regulating ecosystem services and cultural ES. Regarding cultural ecosystem services, this increase in arable practices could enhance local ecological knowledge, regarded as relevant for natural resource management (Gómez-Baggethun et al., 2010). Additionally, maintaining countryside landscapes with active agricultural activity increases the aesthetic value of the landscape in the study area (Casado-Arzuaga et al., 2013a). This landscape transformation recovers natural ecosystems, especially natural forest, for which high levels of biodiversity have been acknowledged compared to the monoculture plantations in the region (Onaindia et al., 2013; Palacios-Agundez et al., 2014). Additionally, multifunctional mosaic landscapes may enhance biodiversity by combining different elements, such as live fences (Otero and Onaindia, 2009). Because the management techniques of the current forest monoculture plantations are quite aggressive (Merino et al., 2004), the expected reduction in forest monoculture plantations would diminish the disservices associated with current forest plantations (e.g., soil erosion). Therefore, many regulating services would be enhanced. Forest management strategies could be improved in the maintained forest plantations to reinforce biodiversity (Johansson et al., 2013). Therefore, recovering multifunctional landscapes would create synergies between food production, biodiversity and ecosystem services.

Trade-offs in this case would potentially be related to reducing the current area of *Pinus* and *Eucalyptus* forest monoculture plantations. Primarily, this would reduce wood production ecosystem service. Considering that this economic activity is not currently very profitable in the area without public subsidies (Rodríguez-Loinaz et al., 2013), this economic sector could be easily reoriented, and more focus could be placed on environmentally friendly high wood quality products for the remaining forest plantations. Additionally, a reduction in carbon sequestration caused by the reduction in forested area would likely occur. Even if carbon sequestration is reduced, the overall carbon sequestration or storage ecosystem service would not be substantially reduced because the logging periods are short for *Pinus* and *Eucalyptus* plantations and the derived products have a short life (e.g., paper) (Rodríguez-Loinaz et al., 2013).

Scale concerns and implications for management

The need to focus on site-specific solutions has been acknowledged in solution-oriented research (DeFries et al., 2012), for which precise data are needed. In a multi-level governance of sustainable development, sub-national governments are important to begin sustainable development practices, as they are generally competent in specific domains related to sustainability (Happaerts, 2012) such as agriculture, forestry or landscape planning. Therefore, our results should be useful to assist Biscay society and its sub-national governments to proactively focus on specific solutions toward a more sustainable scenario. This science is relevant when the scale of analysis matches the scale of decision-making (DeFries et al., 2012).

The results show that Biscay struggles to cope with the current provisioning ES demand. At the regional scale, two primary management strategies should be adopted given the objective to increase sustainability and diminish the ES dependency from outside the region: demand control and a sustainably strengthened food supply. All of the efforts to reduce demand result in win–win solutions towards a more sustainable scenario (Smith et al., 2013). However, supply measures may cause trade-offs with other land uses and ecosystem services. Therefore, holistic, site-specific sustainable land management strategies are needed. The current context provides regional policy-makers with the opportunity to manage a transition towards more sustainable land use through specific actions, some of which could be based on creating appropriate incentives for agents (Lambin and Meyfroidt, 2011).

Integrating ecological footprints into the ecosystem service framework and confronting the existing provisioning ES scale mismatch locally would contribute to global sustainability. This type of site-specific implementation could serve as a model to encourage other medium- and high-income regions to go a step further toward a more sustainable scenario both locally and globally.

Conclusions

Efforts toward a more balanced local ES supply and demand would lead to significant transformations in the Biscay socio-ecological system that could maximise synergies and minimise trade-offs with biodiversity and other ES through sustainable land management strategies. We found that shifting from the current forest plantations' monoculture landscape to a multifunctional traditional mosaic landscape (by promoting the recovery of natural ecosystems and sustainable agricultural and forestry practices) would increase food security; reduce energy consumption in food transport; maximise synergies with biodiversity, cultural ecosystem services and relevant regulating ES, such as erosion control; and minimise trade-offs. This site-specific ecosystem approach, which integrates the ecological footprint into the ecosystem service framework, proved that the provisioning ES scale mismatches may be confronted locally by implementing comprehensive sustainable landscape management strategies, including focusing on reducing the demand of energy intensive products, increasing sustainable supply and enhancing biodiversity and other ES.

The current globalised economy promotes a global reduction in ecosystem integrity and ecosystem services. Reducing ecological footprints at the local scale would contribute to the reduction of ES overconsumption at the global scale. Therefore, maximising a mosaic approach to land use locally would improve ES provision in the studied region, and thus, would also help in reducing the human global footprint.

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