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Relevance for decision making of spatially explicit, participatory scenarios for ecosystem services in an area of a high current demand

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ABSTRACT

Participatory ecosystem services scenarios can be used to inform decision making on the sustainable or wise use of biodiversity and ecosystem services (ES). To establish the plausibility and coherency of the recently constructed Biscay participatory scenarios, and to analyze policy options for improving sustainability of land use and the supply of ecosystem services, a spatially explicit analysis of land cover change was carried out. The modelling used an innovative methodology which included feedback from key stakeholders. Our study showed that scenario mapping can be a way of testing the credibility and internal consistency of scenarios, and a methodology for making them more coherent; it was also useful for highlighting land use trade-offs. The sustainability analysis for the ES supply side showed the benefits of promoting two land use/cover trends in the Biscay region: (i) an increase of sustainable arable land in the valley zones to reinforce biocapacity and self-provisioning while preserving agroecosystems' ES flow; and (ii) natural forest regeneration in mountainous and other zones to increase carbon storage and sequestration while enhancing biodiversity and other ES flows. We argue that even if already protected public agro-forest lands may be the best places to start promoting these changes, additional measures are needed to involve private landowners and guarantee changes at a landscape level. Finally, we reflect on the need to make complementary analyses of ES supply and demand as a way of contributing to a broad sustainability agenda.

1. Introduction

Scenarios are descriptions of how the future may plausibly unfold based on a coherent and internally consistent set of assumptions about key driving forces and relationships (MA, 2005a). They explore a range of future changes in ways that recognize and explore uncertainty from the decision-makers' perspective (Vervoort et al., 2014; Henrich et al., 2010). Currently, scenarios are a central component in assessment processes for a range of global issues, including climate change, biodiversity, agriculture and energy (O'Neill and Nakicenovic, 2008). Due to their capability to support the development of proactive management strategies (Wollenberg et al., 2000) and to improve adaptive capacity (Biggs et al., 2007; Vervoort et al., 2014) they have been used in global ecosystem assessments such as the Millennium Ecosystem Assessment (MA) (MA, 2005b), as well as in many Sub-Global Assessments such as the SAFMA assessment (Biggs et al., 2004), the Portugal Assessment (Pereira et al., 2009) or the UK National Ecosystem Assessment and its Follow-on (Haines-Young et al., 2011, 2014). The latter were innovative in terms of creating land use cover maps to illustrate the consequences of the different scenarios.

Scenarios should be plausible, internally consistent and relevant (Henrich et al., 2010; Haines-Young et al., 2014); that is they should be scientifically credible and coherent, and address the kinds of question that stakeholders want to explore. In fact, stakeholders' involvement is crucial to establish both the legitimacy of scenarios, i.e. the degree to which they are based upon our best understanding of what changes are likely and what their effects might be, and their impact, i.e. the degree to which they are found meaningful and are used as a basis for making proactive decisions. This is especially true when they are used to support public decision making (Henrich et al., 2010). In fact,

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the ecosystem approach specifically identifies participation as a means of ensuring the sustainable or wise use of biodiversity and ecosystem services (ES) (Haines-Young and Potschin, 2014). Participatory scenarios within place-based ecosystem approaches may enhance sustainable local or regional planning and facilitate public decision making. Such is the case in the Biscay region, where participatory scenario planning has been carried out as part of the MA in Biscay-Basque Country Sub-Global Assessment (Palacios-Agundez et al., 2013).

In the Biscay Assessment four scenarios were developed: (1) *Oppressed Biscay*, where decisions are made by an authoritarian local government that has a reactive approach to ecosystem management; (2) *Global Delicatessen*, where, although local institutions lose power to global institutions and decisions are made in a reactive way, the region specializes in high-end or 'elitist' agrotourism and local agroecological products; (3) *TechnoFaith*, a consumer society which relies heavily on imported goods and has put its faith in technological solutions, and where multinational corporations have a great deal of power and ecosystems are highly modified; (4) *Cultivating Social Values*, where education, knowledge sharing within society, participation and responsible social actions are key and there is a tendency towards self-provisioning and sustainable production and consumption. Our claim for their relevance is based on the fact that these scenarios were created through a participatory process that involved a representative set of stakeholders (Palacios-Agundez et al., 2013).

The Biscay Scenarios had different developmental paths with regard to indicators of the provision of ES, of human well-being and of biodiversity (Fig. 1). The most favourable scenario for ES and human well-being in Biscay appears to be *Cultivating Social Values*, which seems Pareto efficient with respect to the indicators. However, participants identified major constraints acting against this scenario, given the existing high consumption patterns in the region, as well as land use and population constraints. Moreover, as currently arable land covers less than 1% of the study area, grassland covers 20% and forest plantations cover 44%, self-provisioning alone does not seem wholly feasible and land use trade-offs are likely to occur. During the participatory scenario planning process described in Palacios-Agundez et al. (2013), participants proposed several measures for a more sustainable scenario, focused both on the ES demand side (where behavioural changes were expected to diminish consumption patterns) and on the ES supply side. For the supply side, local stakeholders identified the need for strategic landscape planning and management that would lead to a more sustainable and multifunctional landscape than presently exists (Palacios-Agundez et al., 2013, 2014). Local policy-makers also identified the need to conduct a detailed analysis of supply side ES for sustainable landscape planning. To do so, they asked for further analysis of the Biscay Scenarios' plausibility and coherency with regard to the landscape and to the possible land use trade-offs. The participatory process did not include the use of maps and references to landscape and land use change where therefore descriptive. However, in this paper we analyze the landscape implications of the Biscay Scenarios in a spatially explicit way.

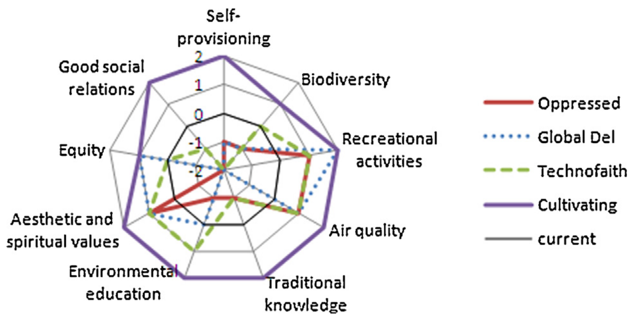

Fig. 1. Evolution of Biscay scenarios for biodiversity, self-provisioning, relevant ES and indicators of human well-being, compared to current conditions (substantial increase = 2; increase = 1; constant or increases in same aspects and decreases in other aspects = 0; decrease = 1; large decrease = 2) (based on Fig. 3 in Palacios-Agundez et al., 2013).

As in other studies (e.g. Thenkabail et al., 2005) we use 'land-use/land-cover' or LULC to refer to mapping of surface cover composed of different categories of land cover (i.e. observed biophysical attributes of the earth's land surface, Lambin et al., 2003) and land use (defined by the purposes for which humans exploit the land cover, Di Gregorio and Jansen, 2000). To enrich the qualitative projections that arose from participatory scenario work, and make them more plausible, coherent and useful for policy-making, we used quantitative projections to model how LULC would change under the different scenarios (cf. Henrich et al., 2010; Vervoort et al., 2014; Haines-Young et al., 2014). This spatial analysis was therefore used to visualize the existing trade-offs in land use while testing the coherency and plausibility of the scenario set.

This paper aims to show how qualitative participatory scenarios can be made relevant to sustainable land use planning, by analysing ES demand and supply and the trade-offs between services. To do this the work sought to: (1) verify the coherency and plausibility of LULC change for each scenario; (2) identify areas likely to experience LULC change; and; (3) analyze the sustainability of scenarios by reference to changes in biocapacity, carbon storage and sequestration. The latter were included because forest management has been identified as a key element for Biscay's future sustainable landscape (Palacios-Agundez et al., 2013, 2014), and because the ecological footprint accounts in Biscay have been shown to be influenced by the carbon footprint in the last eleven years (Palacios-Agundez et al., 2015). To achieve this we used a spatially explicit approach for mapping LULC change and for making the associated ES assessment.

2. Methodology

2.1. Study area

Biscay is located in the north of the Iberian Peninsula (43° 46′–42° 92′ N, 03° 45′-02° 40′ W), in the Basque Country (Fig. 3a). Its high population density (2213 km^2; 1.2 million inhabitants), especially along estuaries, is a consequence of industrialization during the nineteenth and early twentieth centuries. The region is mountainous (with altitudes up to 1500 m and around half the area having slopes exceeding 20°) and the climate is temperate and humid (average temperature 12.5 °C; average rainfall 1200 mm). More than half of the land surface (56%) is forest, mainly exotic plantations (*Pinus radiata* and *Eucalyptus* sp., 39% and 4% respectively), with arable land covering less than 1% and grassland 20% of the study area. The main natural forest types are mixed oak (*Quercus robur*), Cantabrian evergreen-oak (*Quercus ilex*) and beech (*Fagus sylvatica*). They represent the potential natural vegetation (Loidi and Fernández-González, 2012) of approximately 80% of the region, but currently they only cover 13% (Fig. 3; Table C.1 of Appendix A MC3).

2.2. Mapping land cover for 2050 in each scenario

Descriptions of likely changes under each of the scenarios were arrived at through stakeholder engagement, including the use of a questionnaire (answered by 35 participants) and two participatory workshops (39 participants in total) (described in Palacios-Agundez et al., 2013). These descriptions were used to derive rules for mapping LULC change. However, stakeholders' descriptions were mainly expressed in a qualitative way, with varying levels of detail, and desk-based research was often needed to arrive at a set of quantitative rules for deriving land-cover maps. This allowed us to apply these rules to data layers mapped at a fine resolution in the study area. For example, in the *Cultivating Social Values* scenario, stakeholders expressed the view that scientific and cultural knowledge would be utilized to minimize environmental damage. As Merino et al. (1998) demonstrated negative impacts on soil quality of intense forest harvesting on steep slopes in the study area, in this scenario forest plantations in slopes over 35° are therefore avoided.

The method prioritized differing assumptions about likely and unlikely land cover transitions in each scenario. Therefore, in cases where there was a conflict between different rules for LULC change, the rule which was most closely aligned with the stakeholders' descriptions of the scenario was prioritized. For example, in *cultivating social values* scenario, riverine woodland is likely to recover and organic arable land is expected to increase. As a key characteristic of this scenario is that it is gives importance to ecological processes, we assume that arable land will not compete with riverine woodland, and in the modelling process riverine woodland recovery is therefore prioritized over increases in arable land in places where both are possible. Appendix A lists the order of the transition rules applied in each scenario.

During the mapping process, LULC transition rules were developed iteratively (Fig. 2). This allowed each step of the mapping to be checked, and it also allowed the inclusion of any relevant data or criteria not included before. Moreover, the iterative process was used to apply scientific, social and political filters in the mapping. This was done through two different meetings carried out with key stakeholders. These included four researchers working in Biscay on ecology and on landscape related issues; a politician responsible for policy related to environmental issues in the region; two stakeholders from public regional administration: one specialized in forest management as well as in biodiversity conservation in protected areas of Biscay, and the other in landscape management and in relationships with the private sector; and three representatives of local NGOs. In these meetings the output maps were presented and discussed with the stakeholders. This feedback identified inconsistencies and allowed improvements to the final LULC maps. Examples of such improvements included: (1) a rule that arable land and Peri-urban parks would not be found at higher altitudes than at present; and, (2) a rule that new urban developments would most likely be located next to the Bilbao metropolitan area. The mapping process thus converts qualitative descriptions derived from a stakeholder participatory process into quantitative outputs that are enriched with stakeholder feedback. Further details on how the LULC transitions were produced are given in Appendix A, which shows the final rules derived by the mapping process, including the methods applied, their relationship with the input given by the stakeholders (both in the initial consultation process and in later feedback), together with further explanation when appropriate.

This methodology also allowed the plausibility and coherency of the scenarios described by participants during the initial participatory scenario planning process to be checked with regard to the landscape outcomes (Palacios-Agundez et al., 2013). In some cases, the mapping exercise served to detect inconsistencies or potential trade-offs within the scenarios; thus, some aspects of the scenarios described by stakeholders have therefore been adjusted to ensure plausibility and coherency. For example, in the *Global Delicatessen* scenario, stakeholders stated that ecological restoration to promote ecotourism should be prioritized, but also that geological resources should be exploited until exhausted. Therefore, to maintain the coherency and plausibility of the scenario, the percentage area increase of quarries has been restricted such that no further quarries have been allowed on protected areas, public agro-forest lands and habitats of community interest (Appendix A MC1).

The 1:10,000 habitats, vegetation and land use map of the region (Basque Government, 2009), which uses EUNIS level 4 or beyond (EEA, 2002), was enhanced by adding main roads, rivers and railways (Basque Government, 2013) and reclassified into 26 LULC types, to map present-day cover. These were subsequently aggregated into 13 LULC categories (Fig. 3a; Appendix C Table C1). The geoprocessing required to model future change in LULC was undertaken with ArcGIS 10 software (ESRI, 2013), using gridded 10 m^2 resolution data derived from the following datasets (see Appendix A MC1): (1) Digital Elevation Model (DEM) at 5 m resolution (Basque Government, 2012a); (2) a potential natural vegetation map (Basque Government, 2006; Loidi and Fernández-González, 2012); (3) official maps of public agro-forest lands, and protected areas (Natural Parks, Biosphere Reserves, habitats of community interest, Natura 2000 network); (4) air photos of the study area at 1:5000 (Basque Government, 2012b); and, (5) topographical data such as roads, railways, watercourses and boundaries of municipalities (Basque Government, 2013).

2.3. Analyzing the main LULC changes

Once LULC for 2050 had been mapped, LULC changes were analyzed. First, we examined the major LULC changes in each scenario compared to the present, identifying which areas are expected to change, and how. This analysis provided a general understanding of the main landscape transitions occurring in each scenario, and so allowed us to look at its coherency and plausibility using existing scientific studies and other complementary knowledge of the area (see Table 1). To identify the zones most

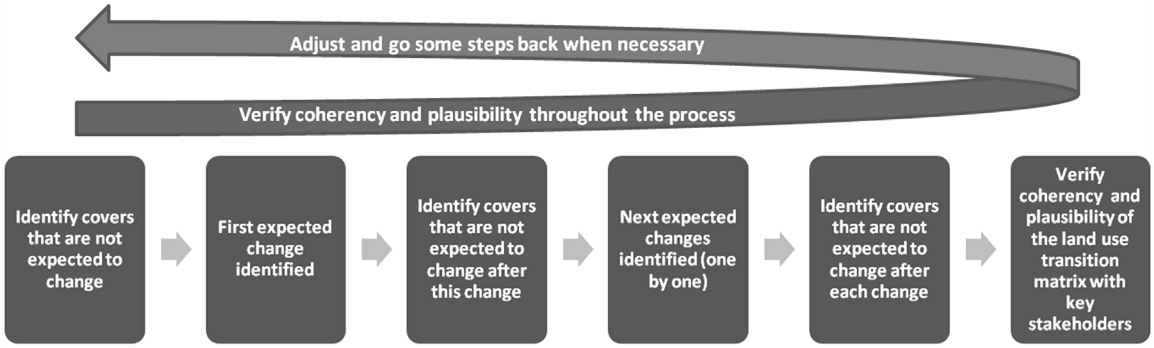

Fig. 2. Summary of the methodological process applied for mapping LULC for the year 2050 in the four Biscay scenarios.

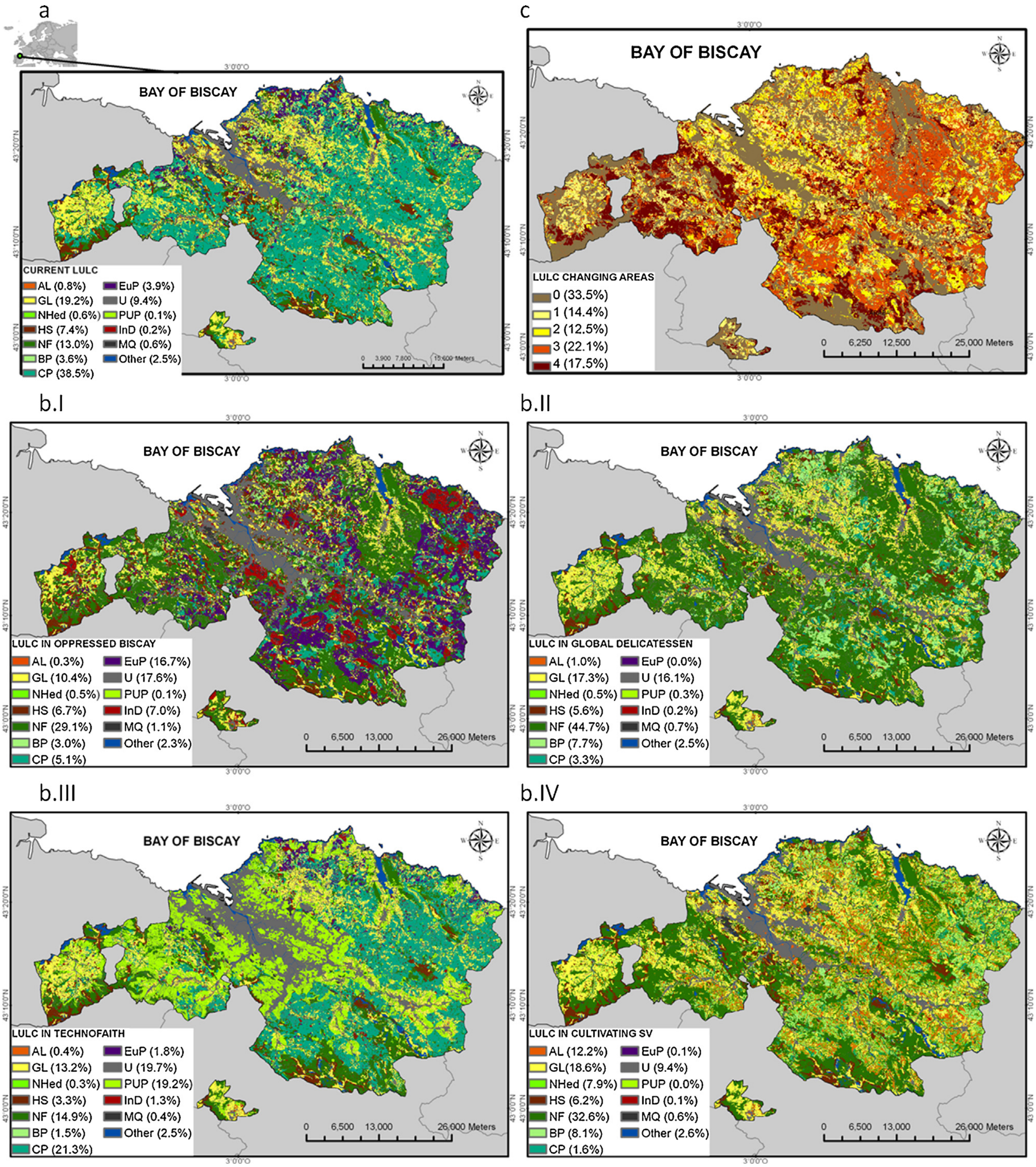

Fig. 3. (a) Location of the study area and current LULC map; (b) LULC map for each of the four scenarios: (b.I) *Oppressed Biscay*; (b.II) *Global Delicatessen*; (b.III) *Technofaith*; (b.IV) *Cultivating social values*; (c) change in LULC under the four scenarios. Name codes: AL = Arable Land; GL = Grassland; NHed = Native hedgerows; HS = heathlands and scrub: NF = natural forest; BP = broadleaved deciduous plantations; CP = coniferous plantation; EuP = *Eucalyptus* plantation; U = urban; PUP = Peri-urban parks; InD = invasive species or degraded land; MQ = mines and quarries. LULC changes codes: 0 = it does not change under any of the four scenarios; 1 = changes under one scenario; 2 = changes under two scenarios; 3 = changes under three scenarios; 4 = changes under all four scenarios.

likely to experience change, spatial concordance between the areas of change in each scenario was analyzed by calculating the number of overlapping changing cells among the four scenarios. Thereafter, the total distribution of the resulting changing categories (from those grid cells that do not change under any scenario to those that change in every scenario) was analyzed by current LULC type. In addition, changes in the distribution of LULC was analyzed in Natural Parks and on public agro-forest lands.

2.4. Analyzing the ES supply side: biocapacity and carbon storage and sequestration

‘Biocapacity’ represents the supply side of an area’s Ecological Footprint Accounts (Borucke et al., 2013), that measures the evolution towards or away from sustainability for a region (Wackernagel et al., 2004). It represents the productivity available to cater for the demand for provisioning ecosystem services

Table 1
Plausibility and coherency of the mayor land cover changes in each scenario.

	Major land cover changes	% of the total change	Plausibility	Coherency
Oppressed Biscay scenario				
1.	From coniferous plantation, grassland, heathlands and scrub and eucalyptus plantation to natural forest	35.64	It is a plausible change because natural forests are the potential natural vegetation of these land cover types (Basque Government, 2006) and natural succession usually proceeds towards woodland (Prach et al., 2014). In addition, plantations in the study area provide optimal conditions for regenerating native forests although some management actions must be undertaken to bring about regeneration (Onaindia et al., 2013a).	Following a productivity crisis and land abandonment, the primary sector declines in favour of growth in tourism dependent on protected and relatively wild natural areas. Therefore, in protected public areas native forest regeneration is expected.
2.	From Coniferous plantation to Eucalyptus plantation	28.29	This results from a forestry management decision that many land owners have already taken in order to maximize profit.	In this scenario differing tendencies are shown with regard to landscape planning and forest management. While in publicly protected areas natural forests regeneration is encouraged, the private sector prioritizes more intensive high rate growth plantations for energy production.
3.	From various cover types to urban	16.44	This is a plausible anthropogenic conversion that has historically occurred in the region, having had a significant impact over the last 50 years.	In this authoritarian scenario, where rich people live in heavily protected houses with gardens outside the cities, an increase in urban areas, especially around the development of new large-scale transport infrastructure, is expected.
4.	From grassland, heathlands and scrub, arable land and other cover types to invasive species or degraded land	13.84	With land abandonment, widespread use of invasive species and transgenic organisms, and various unsustainable activities having severe environmental impacts, many land cover types are likely to became degraded.	The heterogeneous landscape of this scenario includes heavily damaged areas and abandoned rural areas. In addition, expansion of areas dominated by invasive species and genetically-modified plants present a challenge to an already impoverished native biodiversity. All of this results in the conversion of many cover types to invasive species or degraded land.
5.	From grassland to heathlands and scrub	4.78	Due to land abandonment, many grasslands became scrubland and heathlands by natural succession. After land abandonment, natural succession has been seen to follow a broadly predictable pathway (Prevosto et al., 2011).	It is coherent with this scenario where land abandonment is expected.
6.	From a variety of cover types to mines and quarries	1.02	The territory is rich in limestone, much of which has not been yet exploited due to high negative trade-offs with other uses.	Linked to unsustainable consumption of resources and the development of large-scale infrastructure projects in this scenario, a dramatic increase in the number of quarries is expected in this authoritarian scenario, which is not influenced much by social or environmental issues.
Global delicatessen scenario				
1.	From coniferous plantations (56% of changes in cover), exotic forest plantations, heathlands and scrubland, grassland and other cover types, to natural forests	69.49	This is a plausible change because all of these cover types may convert to natural forest, which is the potential natural vegetation of these areas (Basque Government, 2006). 40 years will allow time for at least the early stages of native forest regeneration, especially with active management (Onaindia et al., 2013a).	It is coherent with the scenario because growth of natural forests is promoted in order to encourage ecotourism, which is as an important economic activity in the scenario.
2.	From rapid growth and fast turnover plantations, to slow turnover broadleaved deciduous plantations	12.71	This conversion in forestry from rapidly growing to slower growing but higher quality species is a plausible change, although it currently occurs only occasionally, as it is not widely promoted.	In this scenario, in order to increase landscape quality, forestry is reoriented towards higher quality, mainly native, species and more sustainable management.
3.	From coniferous plantations to heathlands and scrub	1.74	After clear-cutting a coniferous plantation, heathlands and scrublands predominate in the early stages of succession, unless interventions are put in place to prevent this.	Not all forest plantations are expected to be clear-cut at the same time and interventions to prevent the development of heathland or scrub is not expected at all locations.
4.	From various cover types to urban	14.41	This is a plausible anthropogenic change that historically has often occurred in the region, having had a dramatic impact over the last 50 years.	In this scenario, where the global market is a key driver of change and consumption patterns are not sustainable, an increase in urban areas due to infrastructure development is expected.
Technofaith scenario				
1.	From forest plantations, grasslands, heathlands and scrub, natural forests and other cover types to Periurban parks	53.87	When urban population increases, there is likely to be a greater demand for periurban parks with more and more man-made features and infrastructure to service them.	Population density in urban areas increases in this scenario and outlying areas are converted to large periurban parks. Many rural areas are therefore converted into locations for leisure activities for city dwellers.
2.	From various cover types to urban	29.79	With an increase in urban population and higher levels of demand, for housing land, service industries etc., the urban area is likely to increase.	This scenario is the most urban and most disconnected from the natural world. In this consumption-driven and highly technological society urban areas are expected to increase.

Table 1 (*Continued*)

	Major land cover changes	% of the total change	Plausibility	Coherency
3.	From coniferous plantations to natural forest	12.06	Pine plantations in the study area provide optimal conditions for regenerating native forests (Onaindia et al., 2013a).	Even though this scenario is the most urban and most disconnected from the natural world, and its ecosystems are highly modified, some natural forest recovery occurs, such as in riverine woodland.
4.	Form heathlands and scrub to invasive or degraded land	3.48	The generalized use of genetically modified organisms in the region would bring about a change from heathlands and scrub to land dominated by invasive species or degraded land.	In this scenario the use of genetically modified organisms is common, and there are high levels of biological pollution.
Cultivating social values scenario				
1.	From exotic forest plantations (mainly pine) to natural forest	41.96	Plantations in the study area provide optimal conditions for regenerating native forests because within approximately 20 years they are able to foster the regeneration of most species of native trees and ferns as well as some herb species typical of native woodland (Onaindia et al., 2013a), although some management initiatives must be undertaken to encourage this regeneration.	In this scenario management is undertaken to preserve, improve and regenerate natural ecosystems and recovery of natural forests is actively promoted
2.	From rapid growth and fast turnover plantations (e.g. *Pinus radiata*), as well as from heathlands and scrubland, to arable land with native hedgerows surrounding it	41.91	In the 1950s, industrialization in the region initiated a crisis in the agricultural areas that resulted in farm abandonment and the spread of rapid growth and fast turnover plantations in many places suitable for agriculture.	Under this scenario there is an aim to reduce dependency of ES from outside the region, and increase self sufficiency and sustainability. It promotes mosaic landscapes and diversified, organic and sustainable arable land. Furthermore, the ecological and economic value of some ES can be maintained and enhanced on arable farm land by adopting sustainable practices such as organic farming (Sandhu et al., 2010). In addition, hedgerows of native species are an important element of multi-functional landscapes that contribute to the maintenance of biodiversity and ES, providing resources of economic and social interest (Otero and Onaindia, 2009, Morandin and Kremen, 2013).
3.	From fast growing exotic tree species to broadleaved native plantations	13.52	This conversion in forestry from rapidly growing to slower growing but higher quality species is a plausible change, although it currently occurs only occasionally, as it is not widely promoted.	In this scenario, a more diversified and sustainable forestry sector is encouraged, with a tendency towards slower growing, mainly native, species, where timber quality is higher.
4.	From other land cover types such as grassland, arable land, heathland and scrub to natural forests (especially riparian)	2.24	Natural succession usually proceeds towards woodland (Prach et al., 2014), which in this scenario is expected to be encouraged by active management to encourage regeneration of native forest.	In this scenarios key ecosystems such as riverine woodland are regenerated, because conservation of healthy riparian habitats is crucial for maintaining many important ecological functions (Naiman et al., 2005), including many services provided to society (Hruby, 2009).

(Borucke et al., 2013), and is expressed in units of productive area annually available for a given population. It can be thought of as the sum of a region's biologically productive areas: arable land for the provision of plant-based food and fibre products; grazing land for animal products; forest land for timber and other forest products; fishing grounds. For this study fishing grounds were not included because the LULC mapping did not include marine areas. The biocapacity of a region is calculated by multiplying the actual physical area by a yield factor specific to that region (Wackernagel et al., 2005). Regional yields have been assumed to be constant over time. For the regional yield estimates there was insufficient data to distinguish between different type of arable land management or between different types of forest. Therefore, we used regional average yield factors for the basic land use categories (arable land, grazing land and forest land).

To estimate the amount of carbon (C) stored at present and in future scenarios, as well as to estimate the amount of carbon sequestered over time, we used the widely used Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) carbon storage and sequestration model, version 2.5.6 (Tallis et al., 2013; Kareiva et al., 2011). Input data were obtained mainly from local studies (Appendix A MC2). Limitations of the model include an assumed linear change in carbon sequestration over time (Tallis et al., 2013).

3. Results

3.1. LULC for the year 2050 in each scenario

Arable land currently occupies less than 1% of the territory. Under *Cultivating Social Values*, this increased to 12% (Fig. 3; Appendix A MC3 Table C.1). This scenario presents a landscape mosaic where native productivity and biodiversity are promoted, with a substantial increase in native hedgerows and natural forests (covering 8% and 33%, respectively). In contrast, for *Technofaith*, there is an increase in artificial surfaces, with substantial increases in urban areas and peri-urban parks (together covering 39%) (Fig. 3b.III). Similarly, in *Oppressed Biscay*, invasive and degraded lands increase to 7% of the study area, and urban areas to 18% (Fig. 3b.I). This scenario presents a heterogeneous landscape with damaged areas and isolated patches of protected natural areas. It shows two distinct tendencies in forest management: higher growth-rate *Eucalyptus* plantations on private land, and recovery of natural forest in public and protected areas. The greatest increase in natural forest occurs in *Global Delicatessen* (up by 45%), largely to meet the demands of 'elitist' ecotourism. In this scenario, where consumption increases and environmental awareness is not high, cover of urban areas and quarries increases (Fig. 3b.II; Appendix A MC3 Table C.1.).

Table 2
Distribution of changing categories (CC) by current LULC type in the total study area (a), as well as in natural parks (b) and in public agro-forest lands (c). The percentage of each LULC type per changing category is indicated (CC%), as well as the percentage in that category of the total LULC type (%LULC). LULC changes codes (CC): 0 = it does not change under any of the four scenarios; 1 = changes under one scenario; 2 = changes under two scenarios; 3 = changes under three scenarios; 4 = changes under all four scenarios.

	CC	Total %	Land cover %																									
			AL		GL		NHed		H&S		NF		BP		CP		EuP		Urban		PUP		InD		MQ		Other	
			CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC	CC %	% LULC
A. Total area	0	33.5	0.4	16.5	23.3	40.5	0.9	45.2	7.2	32.7	28.3	73.1	3.2	30.0	0.1	0.1	0.0	0.0	28.2	100	0.0	0.0	0.2	30.1	1.3	72.4	6.9	91.2
	1	14.4	2.2	39.4	51.7	38.7	1.6	36.8	10.6	20.5	17.5	19.3	5.4	21.6	7.0	2.6	0.8	2.8	0.0	0.0	0.5	73.9	0.5	28.3	0.9	21.5	1.4	7.9
	2	12.5	1.9	30.3	17.7	11.5	0.3	5.0	12.5	21.0	3.1	3.0	1.5	5.1	48.2	15.6	13.9	44.9	0.0	0.0	0.2	21.3	0.4	21.8	0.1	2.1	0.2	0.8
	3	22.1	0.4	11.8	7.2	8.3	0.4	12.2	5.6	16.8	2.7	4.6	6.1	37.2	73.2	42.1	4.2	23.7	0.0	0.0	0.0	4.8	0.2	17.9	0.1	3.9	0.0	0.0
	4	17.5	0.1	1.9	1.2	1.1	0.0	0.7	3.8	9.0	0.0	0.0	1.3	6.2	87.2	39.6	6.4	28.6	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
B. Natural parks	0	59.9	0.0	87.9	18.4	82.7	0.1	26.1	22.7	71.6	39.6	98.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	100	0.0	0.0	0.0	0.0	0.4	91.7	18.5	99.4
	1	2.6	0.0	0.0	69.0	13.3	4.7	59.4	18.9	2.6	6.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	82.1	0.1	1.1	0.8	0.2
	2	3.8	0.0	0.0	1.9	0.5	0.0	0.7	96.8	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.4
	3	4.4	0.0	12.1	10.1	3.3	0.6	13.6	27.6	6.4	7.1	1.3	51.4	91.3	0.0	0.0	2.7	12.7	0.0	0.0	0.0	0.0	0.0	0.0	0.4	7.3	0.0	0.0
	4	29.3	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.2	0.0	0.0	0.7	8.7	96.4	100	2.8	87.3	0.0	0.0	0.0	0.0	0.0	17.9	0.0	0.0	0.0	0.0
C. Public utility lands	0	36.3	0.0	8.6	18.5	54.7	0.1	13.2	24.8	64.4	42.5	92.7	0.0	0.0	0.0	0.0	0.0	0.0	2.3	100	0.0	0.0	0.0	10.3	1.4	66.2	10.3	98.7
	1	7.3	0.5	65.6	64.7	38.2	3.5	73.5	20.1	10.4	7.9	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	79.4	0.5	25.2	2.4	22.9	0.3	0.6
	2	1.4	0.5	13.2	10.2	1.1	0.5	1.9	81.7	8.0	1.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.9	9.0	2.5	4.4	1.9	0.7
	3	8.2	0.1	12.2	8.8	5.9	0.5	11.0	19.3	11.3	7.4	3.7	62.3	84.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.8	0.8	51.8	0.6	6.4	0.0	0.0
	4	46.8	0.0	0.3	0.0	0.1	0.0	0.4	1.7	5.8	0.0	0.0	2.0	15.8	87.6	100	8.6	100	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0

3.2. Main LULC changes

3.2.1. Major LULC changes in each scenario compared to the present

In *Global Delicatessen*, 54% of the area does not experience any change from the present, whereas 26% changes from coniferous plantations to natural forest by 2050 (Fig. C.2.a of Appendix A MC3). In *Oppressed Biscay*, the percentage unchanged is 51%. In this scenario 14% of the territory changes from coniferous plantations to *Eucalyptus* whereas 13% changes from coniferous plantations to natural forest (Fig. C.2.b of Appendix A MC3). This results from a forest management strategy which is different on private lands compared to public protected areas. *Technofaith* is the scenario with the highest percentage unchanged (65%). Here, coniferous plantations are converted to peri-urban parks (9% of the area) as well as to urban areas (4%) (Fig. C.2.c of Appendix A MC3). There is also a conversion from other LULC types to peri-urban parks, and especially those located in metropolitan Bilbao (C.2.c and Table C.3.c of Appendix A MC3). *Cultivating Social Values* shows unchanged LULC across 58% of the study area. The major changes under this scenario are from coniferous plantations to natural forest (16%) as well as to arable (9%) (C.2.d and Table C.3.d of Appendix A MC3). Table 1 summarizes the plausibility and coherency analysis of each scenario.

3.2.2. Areas of change amongst the four scenarios

The analysis of expected LULC change shows 34% of the study area does not change under any of the four scenarios, whereas roughly 18% changes under all of them (Fig. 3c). None of the areas which are currently urban will change into another LULC type under any of the four scenarios, which does not imply that areas with a presently different LULC type will not change into urban. Urban areas represent 28% of total land cover remaining the same for all four scenarios, which also comprises natural forest (also 28%), grassland (23%), headlands and shrubs (7%) and other natural ecosystems (7%) (Table 2a). Among those areas that change under all four scenarios, 95% are currently forest plantations (mainly coniferous). From amongst current coniferous plantations, 40% changes under all four scenarios, 42% changes under three scenarios and 15% changes under two scenarios. Similarly, 29% of current *Eucalyptus* plantations change under all four scenarios, 24% change under three scenarios and 45% change under two scenarios. In contrast, among current natural forests, 73% does not change under any of the four scenarios, 19% changes under one scenario, 3% under two scenarios, 5% under three scenarios and none under all four scenarios (Table 2a).

We have observed that in Natural Parks and on public agro-forest lands, the majority of the study area either does not change LULC type under any of the four scenarios or changes under all four scenarios (89% in natural parks and 83% in public lands) (Table 2b and c). Among those areas that do not change under any of the four scenarios, the majority consist of natural or semi-natural ecosystems (100% in natural parks and 96% in public lands), whereas those changing in all four scenarios are mainly forest plantations (100% and 98% respectively). Considering the changes in Natural Parks and in public agro-forest lands by LULC type, we observe that 100% of the coniferous plantations changes in all four scenario (Table 2b and c). In the majority of the cases they change to natural forest, and in some cases they also change to urban or peri-urban parks. In contrast, 98% of natural forest and 99% of other natural ecosystem do not change under any of the four scenarios in natural parks (Table 2b) (94% and 100% respectively in public agro-forest lands, Table 2c). In contrast, on private non-protected agro-forest lands, only 20% of the area does not change under any scenario; the changes observed vary depending on the scenario.

Table 3
Percentage of change comparing to present of biocapacity and carbon storage.

	Oppressed	Global del	Technofaith	Cultivating
Biocapacity (total biologically productive land)	−10.80	−4.90	−31.61	13.82
Biologically productive forest land	−8.41	−5.62	−32.89	−28.09
Biologically productive arable land	33.88	128.25	46.75	1524.04
Biologically productive grassland	−35.33	−13.40	31.63	19.20
Carbon storage	1.69	3.41	−32.45	−12.64

3.3. ES supply side: biocapacity and carbon storage

Compared to the present, the only scenario that increases productivity available to meet the demand for provisioning ES is *Cultivating Social Values*, with a 14% increase (Table 3). *Technofaith*, in contrast, is the scenario that shows the greatest decreases in biocapacity and carbon storage (−32%) (Table 3). The increase in biocapacity for *Cultivating Social Values* is explained mainly by the increase in biologically productive arable land, which currently is only 3% of the total biologically productive land. Biologically productive forest land decreases in every scenario even though carbon storage and carbon sequestration increases in two of them (Table 3, Fig. C.4 of Appendix A MC3). This may be because there is a decrease in total forest area and an increase in natural forest (Appendix A MC3 – Table C.1). It should be noted that current levels of stored carbon are relatively high, with the highest values concentrated in natural forest areas (Fig. C.4. of Appendix A MC3). *Global Delicatessen* presents the highest values among all scenarios in total carbon storage (26,890,500 tC) and carbon sequestration (22,144 tC per year). In the case of the *Cultivating Social Values* scenario, even though there is an increase in natural forest and forest plantations improve in quality, there is a decrease both in biologically productive forest land and in carbon storage. This reflects an evident trade-off between fast growing monoculture plantations, (which tend to decrease in this scenario) and arable land (which increase significantly in this scenario). Therefore, in the *Cultivating Social Values* scenario, there is a reversal of the current predominance of forest plantations, produced as a consequence of rural land abandonment.

4. Discussion

4.1. Scenarios consistency and plausibility

Modelling how land cover would change under the different scenarios has served to enrich the qualitative projections that arose from the participatory scenario work. By linking directly to the existing storylines, and using the scenario assumptions to make quantitative projections, such models can establish their plausibility, credibility and saliency (cf. Haines-Young et al., 2014). Quantification helped to detect inconsistencies within scenarios as well as to highlight land use trade-offs.

The few ecosystem assessments that involve participatory scenarios and spatially explicit tools usually first create the model and then work on it with stakeholders (e.g. Pettit et al., 2011; Bacic et al., 2006). In some cases stakeholders even work on the model directly (e.g. Arciniegas and Janssen, 2012). However, the use of spatially explicit models in participatory workshops without previous free interaction may hinder thinking in terms of multifunctional space and the search for innovative and integrative solutions (Barnaud et al., 2013). For this reason, we first worked directly with stakeholders without using maps (Palacios-Agundez et al., 2013) and then complemented the participatory outputs with the quantitative projections presented in this paper. These projections were strengthened by stakeholder feedback, which improved the mapping outcome by pointing out important aspects to be considered such as the appropriateness of avoiding peri-urban parks at high altitudes where accessibility is poor.

Our methodological approach and the high resolution data available meant that the mapping was sufficiently detailed to be useful in land use planning (Arciniegas and Janssen, 2012). It should be noted that the innovative methodology we have used for modelling land use change is more precise than that used for other recent LULC scenario studies; for example, Haines-Young et al. (2011) and Mancosu et al. (2014) have worked at a one km scale. The resolution at which these other studies work is too broad for the study area, which is very heterogeneous, and so the results would not be useful for local decision-makers. Even if we assume that uncertainty is inherent in our use of scenarios, our aim is to produce representations of the scenarios which are plausible and coherent, rather than accurate forecasts. We believe it is preferable to accurately map features such as roads and riverine habitats, rather than to map them at a coarser scale, which would severely distort the relationship between the area that they cover in reality and the area that they cover on the maps.

The iterative mapping methodology also allows the inclusion of any given data set or criteria not included before in a straightforward and transparent way, which is important for good stakeholder-engagement (Carcamo et al., 2014). Furthermore, it generates many intermediate outputs that can be used to check the plausibility and coherency of the scenarios. In addition, the scientific, social and political filters applied in the mapping allowed improvements to the final LULC maps. This stakeholder feedback has made the resulting scenarios more realistic and useful for landscape planning and local decision making. In fact, the feedback exercise with key stakeholders not only improved the mapping outcome, but also showed the importance of scenario mapping for detecting trade-offs among different uses and demands. For example, visualization of scenario landscape models allowed stakeholders to observe that an increase in arable land to improve self-provisioning would occur mainly by reducing current forest plantations and could even limit the potential for natural forest recovery. Stakeholders also found a potential trade-off between urban development and conservation of natural ecosystems.

4.2. Likely changes and target areas

The scenario mapping showed forest plantations to be the land cover types more likely to vary between scenarios (Table 2). They are expected to change considerably under every scenario and, depending on the response options in each scenario, the direction of these changes will vary. In fact, forest plantations may change to urban areas, peri-urban parks, arable lands, and, when forestry activities are maintained, they may shift to higher growth alien species or to slower growth more adaptive ones. They could also regenerate and reconvert to natural forests (Fig C.2 and Table C.3 of Appendix A MC3). These findings indicate an important role for the management of forest lands because decisions here are going to determinate the future landscape of the study area; this was also highlighted by stakeholders (Palacios-Agundez et al., 2013).

Forest areas offer a great opportunity to address global and local sustainability challenges such as climate change mitigation and adaptation, biodiversity conservation, and soil or freshwater protection, with special emphasis on the conservation and restoration of natural ecosystems (e.g. Macdonald et al., 2011; Burch et al., 2014). In the study area, where natural forests are fragmented and sparse, the suitability of promoting, where possible and appropriate, the restoration of natural forest ecosystems has been supported both by stakeholders and scientific knowledge (Palacios-Agundez et al., 2014). Protected and public agro-forest lands may be the best places to start making these changes. In fact, our results show that change is likely to occur in a different way in public or protected agro-forest lands, where it is relatively straightforward to bring about change towards regeneration of natural ecosystems, and private non protected ones, where the future appears to be more variable and uncertain (Table 2b and c in comparison to a). Moreover, Biosphere Reserves are expected to be used as models of land management and of approaches to sustainable management (UNESCO, 1996), and so could be used in other protected areas and in public agro-forest lands. Similarly, previous studies have identified examples of nature conservation, forest recovery and climate change mitigation and adaption in protected areas or public lands (e.g. Macdonald et al., 2011). Even if protected and public agro-forest lands offer a great opportunity to promote sustainable changes, additional measures are needed to involve private landowners and guarantee changes at a landscape level. Our results show that the most likely places to suffer change, and to positively or negatively influence landscape multifunctionality, biodiversity and ecosystem services in the study area are private non protected agro-forest lands (Fig. 3c and Table 2). This chimes with other studies that highlight the need to promote change on private lands (e.g. Rittenhouse and Rissman, 2012; Hendee and Flint, 2013).

4.3. Response options towards a more sustainable scenario

Our supply side analysis showed trade-offs regarding land use. The greatest increase in biocapacity and therefore in provisioning ES supply comes with an increase in arable land, whereas increases in carbon storage and sequestration are seen in the scenario with greatest natural forest recovery. In regions like Biscay with high provisioning ES demand (Palacios-Agundez et al., 2015), self-provisioning should be strengthened given the objective of increasing sustainability and diminishing the region's dependency on external sources. This becomes especially important if competition for scarce land increases at a global scale (Smith et al., 2013). In *Cultivating Social Values* the typical Basque Atlantic countryside is enhanced; the result is a biodiverse mosaic landscape of multifunctional uses that depend on sustainable practices such as organic agriculture (cf. Sandhu et al., 2010).

The scenario that exhibited the greatest recovery of natural forest was shown to store and to sequester the highest amount of carbon. Combining climate change prevention strategies with other policy agendas such as biodiversity conservation or freshwater resource protection, through the conservation and regeneration of natural forests, seems to be an important opportunity in Biscay. In fact, recent studies have shown that conservation of biodiversity and restoration of natural habitats would ensure the provision of many important ecosystem services (Onaindia et al., 2013b; Palacios-Agundez et al., 2014).

Our results highlight two interesting trends, from the land use and ES supply side, towards a more sustainable scenario. One is the conservation and regeneration of natural ecosystems, which would be of special importance for mixed Atlantic broadleaved deciduous forests that currently occur in small, widely scattered and fragmented remnants (Rodríguez-Loinaz et al., 2011). The other is the increase in organic and other sustainable arable land, which would lead to an increase in self-provisioning while preserving agroecosystems' capacity to provide a diverse flow of ES (Morandin and Kremen, 2013; Gómez Sal and González García, 2007). From a landscape planning perspective, this place-based approach provides the opportunity to apply concrete measures from the ES supply side that would help improve the sustainability of the region.

This study has shown that improvements could be made in land use management to achieve sustainability. Our results have demonstrated that even if carbon sequestration were to increase, this will not offset Biscay's annual emissions unless the demand side is also managed; the scenario with highest expected carbon sequestration showed a maximum total carbon sequestration of 22,144 tC per year, which is only around 1% of Biscay's current annual emissions (IHOBE, 2010). Similarly, even if there is scope for improvement in self-sufficiency, current food demand cannot be met locally, especially if a diverse flow of local ES is required (Palacios-Agundez et al., 2015). This result shows that in regions like Biscay with high current ES demand, it is important to apply policy measures on the ES supply side, and implement ES demand side measures to find a balance that has an acceptable and equitable ecosystem service footprint (Burkhard et al., 2012).

5. Conclusions

The use of spatially explicit quantitative models has improved the plausibility of the qualitative storylines previously developed by participatory methods during the Biscay Assessment. Our study showed that scenario mapping can be a way of testing the credibility and internal consistency of participatory scenarios, and a methodology for making them more coherent and consistent. Furthermore, applied qualitative modelling was also useful for highlighting land use trade-offs and for analysing response options. In fact, the innovative methodology reported here ensured both that stakeholders were kept informed and that we were able to analyze a diverse set of response options for landscape planning and decision making. The results therefore have general relevance outside the Biscay Study.

The sustainability analysis described here helped improve management strategies for land use and the supply of ES, and highlighted the benefits of promoting two land use/cover trends in the Biscay region: (i) an increase of sustainable arable land in the valley zones, to reinforce biocapacity and self-provisioning while preserving agroecosystems' ES flow and (ii) natural forest regeneration in mountainous and other zones, to increase carbon storage and sequestration while enhancing biodiversity and other ecosystem service flows. Areas which are currently protected or designated as public agro-forest lands may be the best places to start promoting these changes, through specific actions such as reorienting public land management towards restoration of natural forest ecosystems. However, additional measures are needed, such as using incentives to encourage the involvement of private landowners, to guarantee an overall change towards sustainability.

We conclude that participatory ecosystem services scenarios, supported by spatially explicit models, are a useful approach to regional decision making. They may help ensure the sustainable or wise use of biodiversity and ecosystem services together with a comprehensive ecosystem approach that deals with the supply and the demand side of ES.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.envsci.2015.07.002.

References

Arciniegas, G., Janssen, R., 2012. Spatial decision support for collaborative land use planning workshops. Landsc. Urban Plan. 107, 332–342.

Bacic, I.L.Z., Rossiter, D.G., Bregt, A.K., 2006. Using spatial information to improve collective understanding of shared environmental problems at watershed level. Landsc. Urban Plan. 77, 54–66, http://dx.doi.org/10.1016/j.landurbplan.2005.01.005.

Barnaud, C., Le Page, C., Dumrongrojwatthana, P., Trebuil, G., 2013. Spatial representations are not neutral: lessons from a participatory agent-based modelling process in a land-use conflict. Environ. Model. Softw. 45, 150–159, http://dx.doi.org/10.1016/j.envsoft.2011.11.016.

Basque Government, 2013. Base topográfica armonizada a escala 1:5.000. Environmental and Landscape Policy Department of the Basque Government, Vitoria-Gasteiz. http://www.geo.euskadi.net (March 2014).

Basque Government, 2012a. Digital Elevation Model in 5 m resolution. Environmental and Landscape Policy Department of the Basque Government, Vitoia-Gasteiz. http://www.geo.euskadi.net (April 2014).

Basque Government, 2012b. Aerophotographs of the Basque Country in the Year 2012: 0.25 × 0.25 m. Scale: 1:5.000. http://www.geo.euskadi.net (April 2014).

Basque Government, 2009. Habitats, Current Vegetation and Land use Map of the Basque Country in a Scale of 1:10,000. Environmental and Landscape Policy Department of the Basque Government, Vitoria-Gasteiz. http://www.geo.euskadi.net (April 2014).

Basque Government, 2006. Potential Vegetation of the Basque Country. Environmental and Landscape Policy Department of the Basque Government, Vitoria-Gasteiz. http://www.geo.euskadi.net (April 2014).

Biggs, R., Raudsepp-Hearne, C., Atkinson-Palombo, C., Bohensky, E., Boyd, E., Cundill, G., Fox, H., Ingram, S., Kok, K., Spehat, S., Tengö, M., Timmer, D., Zurek, M., 2007. Linking futures across scales: a dialogue on multiscale scenarios. Ecol. Soc. 12 (1), 17. http://www.ecologyandsociety.org/vol12/iss1/art17/

Biggs, R., Bohensky, E., Desanker, P.V., Fabricius, C., Lynam, T., Misslehorn, A.A., Musvoto, C., Mutale, M., Reyers, B., Scholes, R.J., Shikongo, S., van Jaarsveld, A.S., 2004. Nature supporting people: the Southern African millennium ecosystem assessment. In: Council for Scientific and Industrial Research. Pretoria, South Africa. http://www.unep.org/maweb/documents_sga/safma_integrated_report.pdf.

Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., Larson, J., Lazarus, E., Morales, J.C., Wackernagel, M., Galli, A., 2013. Accounting for demand and supply of the biosphere's regenerative capacity: the National Footprint Accounts' underlying methodology and framework. Ecol. Indic. 24, 518–533.

Burch, S., Berry, P., Sanders, M., 2014. Embedding climate change adaptation in biodiversity conservation: a case study of England. Environ. Sci. Policy 37, 79–90.

Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping ecosystem service supply, demand and budgets. Ecol. Indic. 21, 17–29.

Carcamo, P.F., Garay-Flühmann, R., Squeo, F.A., Gaymer, C.F., 2014. Using stakeholders' perspective of ecosystem services and biodiversity features to plan a marine protected area. Environ. Sci. Policy, http://dx.doi.org/10.1016/j.envsci.2014.03.003.

Di Gregorio, A., Jansen, L.J.M., 2000. Land Cover Classification System: Classification Concepts and User Manual. FAO, Rome.

EEA, European Environmental Agency, 2002. EUNIS Habitat Classification Web Application. http://eunis.eea.europa.eu/ (accessed March 2014).

ESRI, 2013. ArcGIS 10. Environmental Systems Research Institute, Redlands, California, USA. http://www.esri.com/software/arcgis.

Gómez Sal, A., González García, A., 2007. A comprehensive assessment of multifunctional agricultural land-use systems in Spain using a multi-dimensional evaluative model. Agric. Ecosyst. Environ. 120, 82–91.

Haines-Young, R., Tratalos, J., Birkinshaw, S., Butler, S., Gosling, S., Hull, S., Kass, G., Lewis, E., Lum, R., Norris, K., Potschin, M., Walmsley, S., 2014. UK National Ecosystem Assessment Follow-on. Work package report 7: operationalising scenarios in the UK National Ecosystem Assessment Follow-on. In: The UK National Ecosystem Assessment Technical ReportUK National Ecosystem Assessment, UNEP-WCMC, Cambridge.

Haines-Young, R., Potschin, M., 2014. The ecosystem approach as a framework for understanding knowledge utilisation. Environ. Plan. C: Gov. Policy 32 (2), 301–319.

Haines-Young, R., Paterson, J., Potschin, M., Wilson, A., Kass, G., 2011. The UK NEA scenarios: development of storylines and analysis of outcomes. In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment. United Nations Environment Programme/World Conservation Monitoring Centre, Cambridge, UK, pp. 1195–1264. http://www.nottingham.ac.uk/cem/pdf/NEA_Ch25_Scenarios_Haines-Young_et%20al%20_2011.pdf (accessed August 2014).

Hendee, J.T., Flint, C.G., 2013. Managing private forestlands along the public–private interface of Southern Illinois: landowner forestry decisions in a multi-jurisdictional landscape. Forest Policy Econ. 34, 47–55.

Henrich, T., Zurek, M., Eickhout, B., Kok, K., Raudsepp- Hearne, C., Ribeiro, T., van Vuuren, D., Volkery, A., 2010. Scenario development and analysis for forward-looking ecosystem assessments. In: Ash, N., Blanco, H., Brown, C., Garcia, K., Henrichs, T., Lucas, N., Raudsepp- Hearne, C., Simpson, R.D., Scholes, R., Tomich, T., Vira, B., Zurek, M. (Eds.), Ecosystems and Human Well-being: A Manual for Assessment Practitioners, Island, Washington, DC, USA. pp. 151–220.

Hruby, T., 2009. Developing rapid methods for analyzing upland riparian functions and values. Environ. Manage. 43 (6), 1219–1243.

IHOBE, 2010. GHG inventory of the Basque Country 2009. Environmental and Landscape Policy Department of the Basque Government, Vitoria-Gasteiz http://www.ihobe.net/Publicaciones/Ficha.aspx?IdMenu=750e07f4-11a4-40da-840c-0590b91bc032&Cod={468DBD9A-F22D-445D-8713-0123F40366D6} (accessed August 2014).

Kareiva, P., Tallis, H., Ricketts, T.H., Daily, G.C., Polasky, S. (Eds.), 2011. Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford, UK.

Lambin, E.F., Geist, H.J., Lepers, E., 2003. Dynamics of land-use and land-cover change in tropical regions. Annu. Rev. Environ. Resour. 28, 205–241.

Loidi, J., Fernández-González, F., 2012. Potential natural vegetation: reburying or reboring? J. Veg. Sci. 23, 596–604, http://dx.doi.org/10.1111/j.1654-1103.2012.01387.x.

Macdonald, E.A., Collins, M., Johnson, P.J., Clayton, L., Malhi, Y., Fisher, J.B., Milner-Gulland, E.J., Macdonald, D.W., 2011. Wildlife conservation and reduced emissions from deforestation in a case study of Nantu National Park, Sulawesi: 1. The effectiveness of forest protection—many measures, one goal. Environ. Sci. Policy 14, 697–708.

Mancosu, E., Gago-Silva, A., Barbosa, A., de Bono, A., Ivanov, E., Lehmann, A., Fons, J., 2014. Future land-use change scenarios for the Black Sea catchment. Environ. Sci. Policy, http://dx.doi.org/10.1016/j.envsci.2014.02.008.

Merino, A., Edeso, J.M., González, M.J., Marauri, P., 1998. Soil properties in a hilly area following different harvesting managements. For. Ecol. Manage. 103, 235–246.

Millennium Ecosystem Assessment (MA), 2005a. Ecosystems and Human Well-being: Scenarios. Island Press, Washington, D.C., USA. http://www.maweb.org/en/Scenarios.aspx (accessed August 2014).

Millennium Ecosystem Assessment (MA), 2005b. Ecosystems and Human Well-being: A Synthesis Report. Island Press, Washington, DC.

Morandin, L.A., Kremen, C., 2013. Hedgerow restoration promotes pollinator populations and exports native bees to adjacent fields. Ecol. Appl. 23, 829–839.

Naiman, R.J., Décamps, H., McClain, M., 2005. Riparia: Ecology, Conservation, and Management of Streamside Communities. Elsevier Academic Press, London.

Onaindia, M., Ametzaga-Arregi, I., San Sebastián, M., Mitxelena, A., Rodríguez-Loinaz, G., Peña, L., Alday, J.G., 2013a. Can understorey native woodland plant species regenerate under exotic pine plantations using natural succession? Forest Ecol. Manage. 308, 136–144.

Onaindia, M., Fernández de Manuel, B., Madariaga, I., Rodríguez-Loinaz, G., 2013b. Co-benefits and trade-offs between biodiversity, the carbon storage and water flow regulations. Forest Ecol. Manage. 289, 1–9.

O'Neill, B., Nakicenovic, N., 2008. Learning from global emissions scenarios. Environ. Res. Lett. 3 (4) .

Otero, J., Onaindia, M., 2009. Landscape structure and live fences in Andes Colombian agrosystems: upper basin of the Cane-Iguaque river. Rev. Biol. Trop. 57 (4), 1183–1192.

Palacios-Agundez, I., Onaindia, M., Barraqueta, P., Madariaga, I., 2015. Provisioning ecosystem services supply and demand: the role of landscape management to reinforce supply and promote synergies with other ecosystem services. Land Use Policy 47, 145–155.

Palacios-Agundez, I., Fernández de Manuel, B., Rodríguez-Loinaz, G., Peña, L., Ametzaga-Arregi, I., Alday, G., Casado-Arzuaga, J., Madariaga, I., Arana, X., Onaindia, M.I., 2014. Integrating stakeholders' demands and scientific knowledge for the inclusion of ecosystem services in landscape planning. Landsc. Ecol. 29 (8), 1423–1433. http://link.springer.com/article/10.1007/s10980-014-9994-1 (accessed April 2014).

Palacios-Agundez, I., Casado-Arzuaga, I., Madariaga, I., Onaindia, M., 2013. The relevance of local participatory scenario planning for ecosystem management policies in the Basque Country, northern Spain. Ecol. Soc. 18 (3), 7. http://www.ecologyandsociety.org/vol18/iss3/art7/ (accessed April 2014).

Pereira, H.M., Domingos, T., Marta-Pedroso, C., Proença1, V., Rodrigues, P., Ferreira, M., Teixeira, R., Mota, R., Nogal, A., 2009. Uma avaliação dos serviços dos ecossistemas em Portugal: cenários. In: Pereira, H.M., Domingos, T., Vicente, L., Proença1, V. (Eds.), Ecossistemas e bem-estar humano: resultados da avaliação para Portugal do millennium ecosystem assessment. Escolar Editora, Lisboa, Portugal, IC, pp. 709–711.

Pettit, C.J., Raymond, C.M., Bryan, B.A., Lewis, H., 2011. Identifying strengths and weaknesses of landscape visualisation for effective communication of future alternatives. Landsc. Urban Plan. 100, 231–241, http://dx.doi.org/10.1016/j.landurbplan.2011.01.001.

Prach, K., Rehounkova, K., Lencova, K., Jirova, A., Konvalinkova, P., Mudrak, O., Student, V., Vanecek, Z., Tichy, L., Petrik, P., Smilauer, P., Pysek, P., 2014. Vegetation succession in restoration of disturbed sites in Central Europe: the direction of succession and species richness across 19 seres. Appl. Veg. Sci. 17 (2), 193–200, http://dx.doi.org/10.1111/avsc.12064.

Prevosto, B., Kuiters, L., Bernhardt-Romermann, M., Dolle, M., Schmidt, W., Hoffmann, M., Van Uytvanck, J., Bohner, A., Kreiner, D., Stadler, J., Klotz, S., Brandl, R., 2011. Impacts of land abandonment on vegetation: successional pathways in European habitats. Folia Geobot. 46 (4), 303–325, http://dx.doi.org/10.1007/s12224-010-9096-z.

Rittenhouse, C.D., Rissman, A.R., 2012. Forest cover, carbon sequestration, and wildlife habitat: policy review and modeling of tradeoffs among land-use change scenarios. Environ. Sci. Policy 21, 94–105.

Rodríguez-Loinaz, G., Amezaga, I., Onaindia, M., 2011. Efficacy of management policies on protection and recovery of natural ecosystems in the Urdaibai Biosphere Reserve. Nat. Areas J. 31, 358–367.

Sandhu, H.S., Wratten, S.D., Cullen, R.S., 2010. Organic agriculture and ecosystem services. Environ. Sci. Policy 13, 1–7.

Smith, P., Haberl, H., Popp, A., Erb, K., Lauk, C., Harper, R., Tubiello, F.N., De Siqueira Pinto, A., Jafari, M., Sohi, S., Masera, O., Böttcher, H., Berndes, G., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E.A., Mbow, C., Ravindranath, N., Rice, C.W., Abad, C.R., Romanovskaya, A., Sperling, F., Herrero, M., House, J., Rose, S., 2013. How much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals? Global Change Biol. 19, 2285–2302, http://dx.doi.org/10.1111/gcb.12160.

Tallis, H.T., Ricketts, T., Guerry, A.D., Wood, S.A., Sharp, R., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Arkema, K., Lonsdorf, E., Kennedy, C., Verutes, G., Kim, C.K., Guannel, G., Papenfus, M., Toft, J., Marsik, M., Bernhardt, J., Griffin, R., Glowinski, K., Chaumont, N., Perelman, A., Lacayo, M., 2013. InVEST 2.5.6 User's Guide. The Natural Capital Project, Stanford.

Thenkabail, P.S., Schull, M., Turral, H., 2005. Ganges and Indus river basin land use/land cover (LULC) and irrigated area mapping using continuous streams of MODIS data. Remote Sens. Environ. 95 (3), 317–341, http://dx.doi.org/10.1016/j.rse.2004.12.018.

UNESCO, 1996. Biosphere Reserves: The Seville Strategy and the Statutory Framework of the World Network. UNESCO, Paris. http://unesdoc.unesco.org/images/0010/001038/103849Eb.pdf.

Vervoort, J., Thornton, P.K., Kristjanson, P., Forch, W., Erickson, P.J., Kok, K., Ingram, J.S.I., Herrero, M., Palazzo, A., Helfgott, A.E.S., Wilkinson, A., Havlik, P., Mason-D'Croz, D., Jost, C., 2014. Challenges to scenario-guided adaptive action on food security under climate change. Global Environ. Change, http://dx.doi.org/10.1016/j.gloenvcha.2014.03.001.

Wackernagel, M., Monfreda, C., Moran, D., Wermer, P., Goldfinger, D., Deumling, D., Murray, M., 2005. National Footprint and Biocapacity Accounts 2005: The Underlying Calculation Method. Global Footprint Network, Oakland.

Wackernagel, M., Monfreda, C., Schulz, N.B., Erb, K.H., Haberl, H., Krausmann, F., 2004. Calculating national and global ecological footprint time series: resolving conceptual challenges. Land Use Policy 21 (3), 271–278.

Wollenberg, E., Edmunds, D., Buck, L., 2000. Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests. Landsc. Urban Plan. 47, 65–77, http://dx.doi.org/10.1016/S0169-2046(99)00071-7.