

Using ecosystem services valuation to measure the economic impacts of land-use changes on the Spanish Mediterranean coast (El Maresme, 1850–2010)

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Abstract Over the last few decades, Mediterranean coastal areas have experienced profound land-use changes due mainly to urban sprawl and reforestation at the expense of former traditional agrarian mosaics and natural resources, such as beach areas or freshwaters streams. These changes have had severe negative consequences on the biodiversity and ecological state (i.e. function) of the territory. The overall objective of this study was to evaluate the economic impacts of these consequences on ecosystem services (ES). By reconstructing the landscape of El Maresme County (Barcelona Province, Spain) for three historical points in time (1850, 1954 and 2010), we were able to assess how these land-use changes have affected the total ecosystem value (TEV) by estimating the ES non-market and market values provided by each land-use through market prices and benefit transfer methods. Results show an important decrease in the value of TEV since the 1950s (23.6 million Euros per year) due to urban sprawl. Despite the major changes occurring between the 1850s and 1950s, non-market values did not alter very much due to the type of agricultural practices. Our results show the

necessity to take into account the value of non-market ES when designing land planning policies, and especially those concerning beaches and coastal systems to fully integrate the contribution on natural systems into decision-making processes.

Keywords Spanish Mediterranean coast · Land-use changes · Ecosystem services valuation · Benefit transfer analysis

Introduction

The goal of this study is to measure the historical impact of land-use changes on the market and non-market economic value of ecosystem services (ES) produced in a typical Mediterranean coastal area, the Catalanian County of El Maresme (Barcelona Province, Spain). Land-use changes in European coastal areas have been faster and more extensive than those observed elsewhere, which has led to the degradation of European coastal ecosystems and of the huge variety of services they supply to people (e.g. food, timber, recreation, and water purification, stabilization of the coastal line, disturbance protection). In Atlantic and northern European regions, coastal economic development is due to the restructuring of the fishing industry and the increasing number of ports and volume of marine transportation (EEA 2006), while in Mediterranean regions, the economic development is attributable to both tourism and a residential construction boom (Garcia and Servera 2003). In recent decades, uncontrolled urban sprawl and the development of tourism and seaport infrastructure have had a direct effect on ecosystems, changing the local identity of coastal areas (Garcia and Servera 2003).

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Over the past two decades, scientific and political considerations have led to the rapid development of the spatially explicit analysis of ES value. Schägner et al. (2013) identified 143 studies on mapping the value of ES published between 1995 and 2012, 60 % of which were published since 2007. Among these, only 13 studies focused on land-use transformation over time to estimate the impacts of urban sprawl (as reviewed by Dupras and Alam 2015) and only one assessed the impacts on coastal systems (Mendoza-González et al. 2012). Here, we use a longer timeframe (more than 150 years) than the study of Mendoza-González et al. (2012) (11 years) to assess the impacts of urban sprawl on Mediterranean coastal systems. By using historical cases from 1850 to 1954 as two temporal references, this spatial approach to economic evaluation will help us clarify the long-term patterns of production of economic values.

The advantage of this approach, when compared to the traditional evaluation of ES specific to a given site, lies in a cartographic production that reveals new information. Values can thus be assessed, spatially visualized, and summarized across multiple spatial scales, for which there is growing institutional demand in public and private sectors (Rosenberg and Loomis 2001; Maes et al. 2012; Schägner et al. 2013). In light of this reality, it becomes relatively simple to extract the values from a database to estimate ES value at any given site. For institutional users (e.g. planners and policy-makers), these maps have explicit strategic advantages, especially because they have potential applications for green accounting, assessment of land-use policies, resource allocation, and design of new policies such as payments for ecosystem services (Schägner et al. 2013).

To demonstrate the impact of land-use changes along the Spanish Mediterranean coast on the value of ES, our three main objectives are: to show the economic valuation of ES provided by Mediterranean coastal ecosystems (we use benefit transfer and market prices methods); to analyse and map the land-use (through the study of El Maresme) and associated ES of the studied region; and to calculate the total ecosystem value, its breakdown by land-use type and historic time points to show the evolution of ES value through time.

Materials and methods

In this study, a method combining land-use changes analysis and ES valuation is used. This has been generalized by Troy and Wilson (2006) and is provided in this way:

1. Spatial selection and description of the study area;
2. Creation of a typology of land cover classes, which predict significant differences in the flow and value of ES;
3. Analysis of the ES valuation literature and data to connect coefficients per unit area to the types of coverage available;
4. Analysis and mapping of land-uses and flows of associated ES;
5. Calculation of the total value and breakdown by land cover classes;
6. Historical analysis of land-use to give a temporal dimension to the spatial analysis.

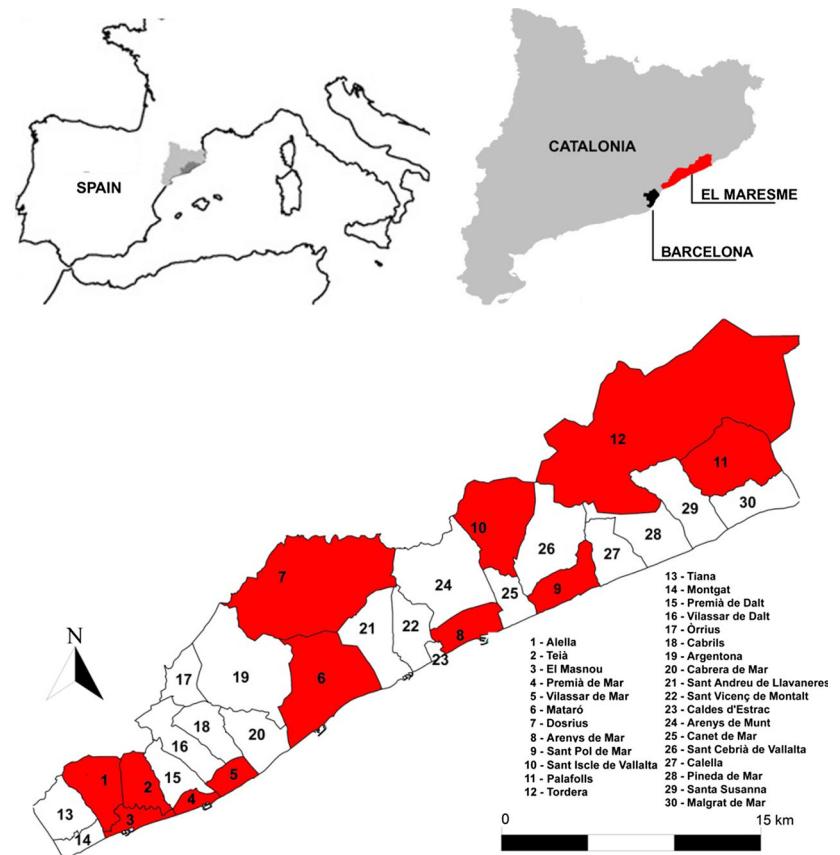
The study area and its historical land-use change

El Maresme County is located in the Spanish Mediterranean region, north east of Barcelona along the coastline. Municipalities on the mountain range are connected to those near the sea via irregular water creeks and local roads (Fig. 1). Despite a multitude of seasonal water creeks, the only important permanent river in the county is Tordera River, in the north, which irrigates an important crop area across the river's delta area. However, throughout most of the year, there is an abundance of water from aquifers tempered by sea water level.

Maresme, meaning “marshland” in Catalan, was named for the important salt marshlands found in the area. Beaches in Maresme were historically very large, and sand was abundant, but they have now been transformed into urban land-uses and have been isolated from the creeks and the mountain range, which provided necessary sediments for their maintenance. Currently, more than 50 % of its territory (21,000 hectares) is covered by forests, after the large reforestation due to agricultural abandonment since the 1950s. The most common forest species are the holm oak (*Quercus ilex*) and the stone pine (*Pinus pinea*). These forests have a direct, positive effect on the quality of life of the local population: they purify the air, regulate temperatures year-round, and avoid flooding problems during heavy rains (MEA 2005; Garcia-Nieto et al. 2013). Moreover, forests supply local inhabitants with large amounts of primary resources, such as mushrooms, cork, pine nuts, and medicinal plants.

Very high population densities, especially in the coastal towns closer to Barcelona, have been a constant characteristic in the county. In the mid-nineteenth century, almost all municipalities exceeded the threshold of 65 inhabitants per square km, considered by Boserup (1981) as the upper limit an organic-based agricultural economy could support. In fact, some municipalities reached densities of over 600 inhabitants per square km, which were comparable to industrialized and urban societies. These high densities can

Fig. 1 Map of the 12 municipalities studied in El Maresme. *Source:* Parcerisas (2012)



be attributed in part to the early establishment of commercial and industrial activities in the area, thanks to the connection with Barcelona by sea and then from 1848 onwards by railway.

Until the arrival of Francisco Franco's dictatorship regime in 1939, agrarian activity, driven by a large group of small peasants (Parcerisas 2014), increased the value of the territory by preventing speculative real-estate operations. There has been a big housing boom in the area since Franco's regime and since the post-1978 new democratic period (Naredo 1996). The progressive improvement of the railway network and the opening of the motorway in the 1960s incorporated the county very quickly into Barcelona's metropolitan dynamics (Lleonart 2007), which also led to the exponential growth of the county's population density. Tourism and construction have been the economic driving forces of the county, replacing the traditional agrarian and industrial sectors. Relatively cheap housing (compared to Barcelona) has encouraged many foreign workers to take residence in El Maresme, turning the county into a series of bedroom communities.

Historically, livestock has been largely absent in the county and has not been important in its agricultural sector, especially in the coastal municipalities and those closer to Barcelona. In general, circa 1850 all livestock statistics

were below the average of livestock in the province of Barcelona, both in terms of share of livestock and in terms number of heads of livestock per unit of land area (Moreno-Ramírez 1858). The Lower Maresme (south portion of the county) was the area with less land dedicated to grazing land, which accounted for only 7 % of its surface, even less than the city of Barcelona and its surroundings, with 10 % (Moreno-Ramírez 1858). Livestock in El Maresme remains an unimportant activity to this day. El Maresme has not participated in the cattle-feeding boom experienced in other regions. Cows, pigs, lambs, and chickens are only present in a few municipalities of El Maresme; they account for only a very small percentage of these animals in the province of Barcelona. For instance, in 2009, the cows of all Maresme only accounted for 2 % of the cows in the province, sheep accounted for less than 2 %, goats for less than 4 %, and pigs for <1 % (Idescat 2009).

Land-use change analysis

We based our land-use analysis on two previous studies (Parcerisas 2012; Parcerisas et al. 2012) where historical land-use maps of El Maresme from the 1850s, 1954, and 2010 were produced using MiraMon GIS software. Despite the fact that El Maresme County is made up of 30

municipalities, we focus on only twelve of them (Fig. 1). Data were not available for the rest of the municipalities in 1850, so their landscape from 1850 could not be reconstructed. The available cadastral maps, with a scale ranging from 1:5,000 to 1:25,000, and the books which accompany them provide detailed information about land-use at the patch scale and also allow for the different land-uses to be mapped spatially.

Ecosystem service valuation

To assess the value of non-market ES, we used a benefit transfer approach. The method aims to assess the value of ES of our study area using the results from previous empirical valuation studies on ES conducted in other study sites. The benefit transfer method involves transferring the results of the monetary estimates of ES in a specific context and applying them to another one, assuming that there exists a high degree of similarity between the selected areas in terms of the socio-economic context and the characteristics of the natural environment (Rosenberg and Loomis 2001). In this study, we used the database of Brenner et al. (2010), who assessed the economic value of the ES provided by the Catalan coast. This study included the non-market economic value of ES on the Catalan coast, including El Maresme County. The results found by Brenner et al. (2010) were based on an exhaustive analysis of the scientific literature from the 1980s to 2005, after which they used the benefit transfer method to value 14 non-market ES, ranging from regulating services such as disturbance and water regulation, habitat services (i.e. habitat for biodiversity), provisioning services, and cultural services such as aesthetics and recreation services (see Table 4).

We reviewed the database of Brenner et al. (2010) and deleted values that were not relevant for the study of El Maresme County. For example, we did not include values for saltwater wetlands, seagrass beds or burned forests because these ecosystems are not present in our study area. Moreover, we decided to focus exclusively on values published in peer-reviewed primary studies as a way to minimize transfer biases (Wilson and Hoehn 2006; Johnston and Rosenberg 2010; Dupras et al. 2015).

In order to increase the robustness of this assessment, we conducted an additional literature search and integrated more valuation studies to update the database. We followed the benefit transfer methodology described in Dupras et al. (2015), where the valuation studies used in the transfer are selected according to socio-economic and ecological criteria in order to minimize the methodological bias. The socio-economic criteria are assessed by analysing and cross-matching the living conditions of people in the countries where the studies were conducted and the local

conditions in the study area. Accordingly, we screened only studies performed in countries with high income, according to the gross national income per capita classification of countries by the World Bank (Wilson and Hoehn 2006). The ecological criteria are also used to maximize the similarities between the target site (El Maresme) and the site analysed in the primary studies. Therefore, only studies based on study areas with similar ecological characteristics to the Mediterranean coastal system were selected. These similarities were based on an analysis of ecosystem type (e.g. coastal wetlands, temperate forests, beaches), ecosystem quality (e.g. size, facilities, level of degradation), and ecosystem scarcity based on the number of available substitutes (e.g. number of inland wetlands in a given region). In sum, we based the benefit transfer on original peer-reviewed studies focusing on natural and semi-natural ecosystems similar to El Maresme from Western Europe and North America.

To harmonize the ES value estimates, we normalized them using gross domestic product (GDP) deflators and purchasing power parity (PPP) conversion factors relative to the year World Bank (2013). The literature on the economics of ES shows that values can be expressed in several units, such as Euros/household, Euros/hectare or Euros/year, and that they are also dependent on currency and the year in which the value was estimated (Dupras et al. 2015). This variability in monetary units makes the comparison difficult and values need to be standardized in order to report average values and perform calculations. Consequently, the economic values for ES were standardized and expressed in 2013 Euros per hectare per year, allowing an easier and comprehensible transfer to cartographic tools and land cover data expressed in hectares. The standardization was performed by adjusting the values presented in the original studies using the exchange rates, GDP deflators of each country and PPP conversion factors relative to the year 2013 based on World Development Indicators (World Bank 2013). This allowed us to minimize economic differences arising from non-Spanish studies and to correct values for inflation in order to present results in 2013 Euros.

To measure the value of the market ES, we calculate an economic rent for the relevant sectors. The valuation of the market ES from agrarian lands was consequently divided into four parts: crop production, cattle production, forest production, and agro-tourism. The objective was to obtain the total incomes by multiplying the physical production of each one by the corresponding market prices of 2013. Production costs were then deduced to obtain the net economic benefit. Market values and production costs were gathered from official sources and statistics available from the websites of the Catalanian and Spanish Agriculture Department (XCAC 2010a, b; Idescat).

Historical and current cadastral land-use maps provide spatial information on coarse land-use categories (e.g. cereal, horticulture, vineyard, orange trees, pasture, forest, urban, river), but, for cereals, horticulture, and most fruit trees they do not specify the type of cereal, vegetable, or fruit cultivated nor the crop rotation followed. We obtained approximate crop rotations per hectare from other sources (www.idescat.cat) that detail the area of each crop at El Maresme. The value of cattle production was calculated based on the cattle census of 2010 (www.idescat.cat) and was based on their market prices and average production costs (XCAC 2010a). Values were then indexed in 2013 Euros using a GDP deflator.

Forest production data were obtained from the Department of Agriculture and Environment of the Generalitat of Catalonia specifying the average incomes and costs of forest exploitation per hectare (XCAC 2010b). Yearly income from forest production was 126 Euros per hectare and expenses accounted for 37 Euros, giving a net benefit of 89 Euros per hectare.

The economic value per hectare of each section was also applied to the land-uses of 1954 and 1850 to estimate the economic value of agro-forest production for these years.

Results

Land-use changes

In the mid-nineteenth century, El Maresme County was predominantly agrarian. For the 12 municipalities studied, the total cultivated area represented around 53 % of the total area (Table 1), while forests accounted for 40.3 %. Only 2.5 % of the land was urbanized. There was a predominance of vineyards in the coastal plains and the initial slopes. Woodlands were located higher up the mountain range, with many rain-fed cereal plots scattered throughout the area, especially along the valley of the Tordera River, which crosses the county from north to south (Fig. 2).

The main change observed between the 1850s and 1950s was a significant expansion of irrigated orchards in the coastal plains with the pumping of underground water (Table 2). The woodlands in the higher inland area also increased slightly. After the Phylloxera plague, an epidemic pest which attacked and destroyed European vineyards since 1860s, both irrigated land and woodland expanded at the expense of vineyards (Badia-Miró et al. 2010). Cereal crops remained scattered in rain-fed plots either in the plains or on the slopes. The urban area doubled during this period. However, although land-uses diverged along the slope line started to reduce the land-use diversity, agricultural mosaics remained in place and the biodiversity was not very affected (Parcerisas et al. 2012).

From the 1950s onward, there were many land-use changes. Land-use changes matrices are a tool to understand the direction of these permutations between two time periods (Tables 1, 2). Values of the matrix diagonal represent that land which has remained unaltered, while the values in the rest of the cells represent the hectares permuted between two land-uses, lost by one and absorbed by the other during the time period.

First, accelerated urban sprawl due to rapid urbanization triggered by private urban developers in the absence of any appropriate or enforced land-use planning produced continuous conurbation along the coast as well as causing the conversion of a number of upland areas (Fig. 2; Table 2). In 2010, urban land-uses already represented 23 % of the total area in these 12 municipalities, 27 % in the entire county (Parcerisas 2012). Secondly, agrarian activities declined, affecting around 14 % of the land in 2010. Only high-intensity irrigated agriculture, mostly horticulture, flower-growing, and some irrigated cereal cropping in Tordera could persist despite the advance of urbanisation due to real-estate speculation. Consequently, agricultural abandonment caused the reforestation of large areas in the mountain municipalities (in 2010, forest land covered 56 % in the 12 municipalities, and around 52 % in the entire county), which nowadays are characterised by low-density residential areas, highways, and other linear infrastructures, such as railroad tracks. The overall result has been a severe loss of ecological connectivity, a process which has also taken place in the entire province of Barcelona (Parcerisas et al. 2012; Marull et al. 2010).

The economic value of ecosystem services

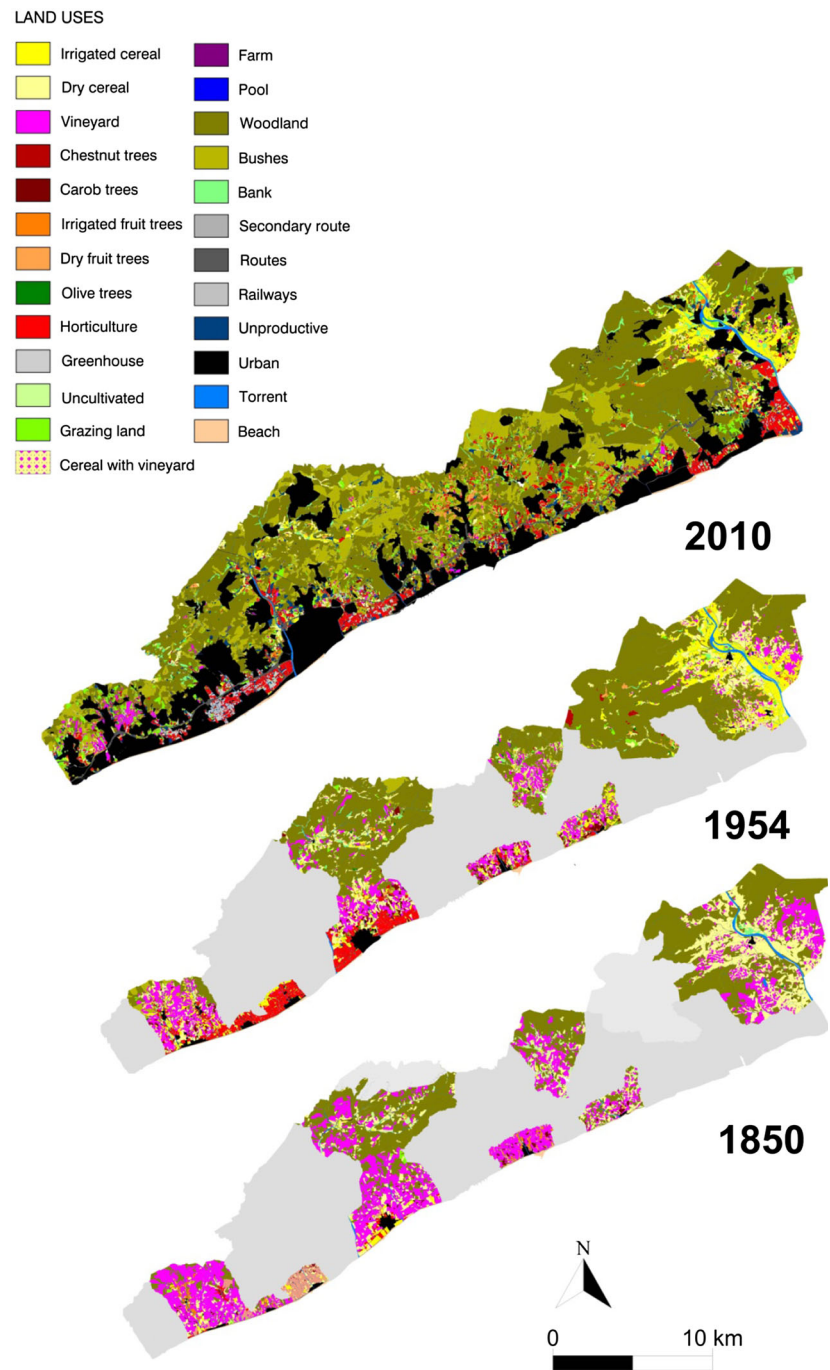
For the market ES value, as expected, irrigated crops are those with higher benefits, especially horticulture and flower cultivation (Table 3). The latter was introduced in the county in the 1920s and since then has become one of the most important crops, turning El Maresme into one of the largest flower and plant exporters in Spain. Certainly, the introduction of irrigation by small farmers during the first decades of the twentieth century altered the landscape as well as the economy of the county, while contributing to improve the economic situation of smallholders formerly facing high rates of poverty (Parcerisas 2014). For example, in 1937 around 90 % of Vilassar de Mar's land was irrigated compared to only 4 % in 1850, this despite the high costs of transformation and horticultural practices. The income per unit of land was ten times higher than production costs (Llovet-Montros and Peladella 1937). This fact explains why agricultural production from 1850 is much less than that of 1954 and 2010 (Table 6). However, a larger amount of land was cultivated in 1850 than in 2010.

Table 1 Land-use changes matrix between 1850 and 1954 in 12 municipalities of El Maresme

	Rain-fed cereal	Irrigated cereal	Cereal with vineyard	Horticulture	Horticulture	Carob trees	Dry fruit trees	Irrigated fruit trees	Uncultivated	Unproductive	Forest	Urban area	Total 2010	
													ha	%
Rain-fed cereal	955.5	25.9	747.2	20.4	4.6	16.2	0.9	15.7	47.1	0.0	390.9	11.2	2247.3	12.4
Irrigated cereal	1191.1	46.1	365.5	54.8	5.7	12.3	2.3	39.3	22.4	0.0	295.5	7.2	2048.5	11.3
Vineyard	295.8	10.7	1502.1	36.9	2.2	25.2	2.0	11.3	51.2	0.0	379.4	4.0	2326.7	12.8
Cereal with vineyard	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
Horticulture	170.0	84.5	409.3	237.9	44.2	22.7	1.4	58.3	14.6	0.1	47.5	3.9	1097.1	6.0
Carob trees	42.9	1.5	175.2	6.6	0.7	63.4	0.9	4.0	4.4	0.0	44.8	0.3	345.4	1.9
Dry fruit trees	23.7	1.3	71.8	0.0	0.4	1.7	4.6	1.4	8.0	0.0	27.4	0.2	140.6	0.8
Irrigated fruit trees	25.4	0.4	14.9	1.6	1.2	0.0	1.8	6.3	1.5	0.0	12.9	0.5	66.9	0.4
Uncultivated	85.7	6.8	103.1	10.1	3.6	3.6	0.3	6.0	35.2	0.1	72.9	3.4	333.8	1.8
Unproductive	1.3	0.0	2.1	0.4	0.0	0.0	0.0	0.4	0.0	0.3	0.0	0.3	4.8	0.0
Forest	482.8	11.0	1541.6	11.9	0.5	6.0	2.1	6.1	120.4	0.4	5906.1	22.3	8155.2	44.9
Urban area	116.2	48.2	128.4	31.8	31.8	4.3	0.8	21.0	12.3	0.8	97.7	383.0	914.4	5.0
Other	18.4	1.8	11.8	5.1	1.2	0.8	0.0	1.6	1.9	0.0	31.6	10.1	467.5	2.6
Total	3408.8	238.2	5073.0	417.5	96.1	156.2	17.1	171.4	319.0	1.7	7306.7	446.4	18,148.2	100.0
1850	18.8	1.3	28.0	2.3	0.5	0.9	0.1	0.9	1.8	0.0	40.3	2.5	2.7	100.0

Source Parceterisas (2012). The missing areas of Tordera and Dosrius in the historical map of 1850 have not been taken into account for 1954

Fig. 2 Land-use maps of El Maresme, 1850–1954–2010. *Source:* Parcerisas (2012). In the 1850's maps of Dosrius and Tordera, some missing areas do not appear in the original document. *Note* Large grey areas in 1954 and 1850's maps correspond to the municipalities not included in our study



Despite the loss of almost a thousand hectares of cultivated land between 1850 and 1954, the value of agro-forestry tripled due to the intensification of production rendered possible by the massive increase in irrigated land. The real consequence of land-use changes on agro-forest market values can be evaluated by comparing 1954–2010. As the land-use matrix of change shows, the reduction of 64 % of cultivated land (from 8633 to 3144 ha)—land

which was basically reforested or converted into urban uses—caused a 38 % decrease in agricultural and forestry production value. The high-intensive agricultural practices of today, regardless of their marginal extension of land, still hold greater market value than the traditional rain-fed agriculture of the 1850s. On the other hand, the relative unimportance of livestock explains the low production value of cattle (eggs, milk, and meat production) in the

Table 2 Land-use changes matrix between 1954 and 2010 in 12 municipalities of El Maresme

	Rain-fed cereal	Irrigated cereal	Vineyard	Horticulture	Green house	Carob trees	Dry fruit trees	Irrigated fruit trees	Uncultivated	Unproductive	Forest	Urban area	Other	Total 2010	
														ha	%
Rain-fed cereal	214.0	77.2	61.3	3.1	0.0	5.7	4.6	0.5	9.6	0.0	39.9	1.5	0.1	417.5	1.9
Irrigated cereal	308.7	696.2	90.2	3.9	0.0	2.4	5.2	12.6	16.1	0.0	74.4	2.5	2.1	1214.3	5.5
Vineyard	46.1	15.0	142.3	2.6	0.0	7.3	2.8	0.2	3.6	0.0	14.6	0.4	0.3	235.2	1.1
Horticulture	152.8	238.6	130.6	223.9	0.0	15.2	6.6	3.8	17.0	0.1	43.4	4.0	0.9	836.9	3.8
Green house	14.4	42.6	31.4	106.1	0.0	3.1	0.0	1.1	1.8	0.0	3.6	0.9	0.0	205.0	0.9
Carob trees	2.5	0.5	13.4	1.0	0.0	24.3	0.9	0.0	0.2	0.0	4.0	0.1	0.0	46.9	0.2
Dry fruit trees	17.7	10.0	18.1	3.5	0.0	1.3	13.6	2.6	3.2	0.0	5.9	0.4	0.0	76.3	0.3
Irrigated fruit trees	13.9	45.0	5.8	2.0	0.0	0.3	0.4	4.8	1.6	0.0	3.2	0.1	0.1	77.2	0.3
Uncultivated	143.0	116.8	171.0	19.9	0.0	10.3	13.4	2.3	39.8	0.0	116.7	6.0	2.3	641.5	2.9
Unproductive	79.1	68.6	66.5	54.5	0.0	13.1	4.8	3.7	35.9	0.3	96.2	15.3	10.0	448.0	2.0
Forest	717.9	326.4	903.2	18.3	0.0	94.2	163.6	16.1	165.6	0.0	9975.5	27.1	9.3	12,417.2	56.0
Urban area	675.5	481.7	721.9	655.8	0.0	168.0	31.0	19.5	96.2	4.4	1304.1	915.4	114.1	5187.6	23.4
Other	3.2	7.9	3.0	3.2	0.0	0.1	0.4	0.0	1.2	0.0	6.7	4.8	339.8	370.3	1.7
Total	2388	2126.5	2358.7	1097.8	0.0	345.3	247.3	67.2	391.8	4.8	11,688.2	978.5	479.0	22,173.9	100.0
1954															
%	10.8	9.6	10.6	5.0	0.0	1.6	1.1	0.3	1.8	0.0	52.7	4.4	2.2	100.0	

Source Parcerisas (2012)

Table 3 Crops and agro-forest value per hectare in El Maresme based on the 2005 data (values are expressed in 2013EUR/ha/year)

Land-use	Incomes	Total expenses	Benefit
Cereal—irrigated land	5881	1537	4344
Cereal—rain-fed land	1700	808	892
Wine	3061	2486	575
Horticulture	19,705	10,475	9230
Flowers	68,057	53,488	14,569
Irrigated fruit trees	7113	4623	2490
Olive trees	1352	890	462
Rain-fed fruit trees	3980	2984	996
Carob and chestnut trees	748	574	174
Forest	126	37	89
Meadows	784	525	259

Source Idescat; XCAC (2010a); Gencat (2014a, 2014b)

county. Cattle and agro-tourism values remained quite stable between 1850 and 1954, but have lost more than 20 % of their potential value since 1954, again mainly due to the loss of useful agrarian surface (UAS) due to urban sprawl.

We used 156 monetary estimates coming from 87 peer-reviewed studies to perform our analysis. Table 4 shows the value for the non-market ES resulting from the benefit transfer analysis. When comparing our results with those found in Brenner et al. (2010), we see that the only significant difference found is in the value of the pasture and is being explained by the consideration of an economic value for the service or biodiversity habitat. Although woodlands and pastures provide more ES, beach or dunes provide the highest land-use non-market value for ES, with 97,143 Euros per hectare per year. In fact, beach and dunes provide important services as for regulating disturbances, recreational purposes, urban green spaces, woodlands, croplands, pastures, and open freshwaters (Table 5). These results concur with the ES values assessed in other regions, such as in Mexico (Mendoza-González et al. 2012). Table 6 presents the cumulated market and non-market values for each land-use class.

Historical variation of ecosystem services values

The results of this study show that, over the period studied, there was a loss of around 16 % of the annual non-market value of ES due to the loss of natural and semi-natural ecosystems (see Table 6). However, this loss occurred mainly since the 1960s. Despite the major changes occurring between 1850 and 1954, non-market values did not change very much. The large decrease in cropland area, no matter which kind of agriculture practiced, has been a key factor in this loss, costing about 12 million Euros per year

(Table 7). This loss has been partly compensated for by the value supplied through the reforested area. The almost 40 hectares of beach lost have also had tremendous negative consequences, evaluated at 3.2 million Euros per year. As urban spaces (built-up) are valued as zero, urban sprawl is clearly the main cause of decline in the value of non-market and market ES. Despite their high non-market value, the few urban green spaces are not enough to compensate the loss caused by urban sprawl.

Our analysis shows that non-market values of ES clearly exceed the market values of ES (Table 6). This fact shows the impacts of transforming natural areas into new urban infrastructures based only on short-term market benefits. This point is corroborated by comparing the evolution of mountain and coastal areas within the county. In coastal municipalities, where urban sprawl has been higher and where there have been major losses of natural areas, the loss of ES is much higher than in mountain municipalities.

Table 7 shows the variation of the non-market valuation of ES between 1954 and 2010. It indicates that the huge loss of non-market-valued ES (12.2 million 2013 Euros) is due to the conversion of former natural and cropland areas into urban uses (including here unproductive uses¹). Again, we see how the main losses have taken place in former cropland and beach areas, which suffered a net extension loss in favour of urban uses. The gains of non-market ES values from woodland areas, but at the expense mostly of cropland areas ES, have not been sufficient to compensate the overall loss.

Based on the evolution of the total value between 1954 and 2010 for the 12 municipalities studied—presented in Fig. 3a—only one municipality, Dosrius, shows a positive variation, while Mataró, a coastal municipality presents the most important decrease in total value. These results are presented in an ES valuation map (Fig. 3). The municipalities of Tordera, Vilassar de Mar, and Arenys de Mar also show important losses in total value. To avoid a scale bias related to the size of the municipalities, we show on Fig. 3b the evolution of the ES value per hectare per year. This figure clearly shows that the main negative ES value changes occurred in coastal municipalities. These municipalities all present more important losses in ES value per hectare than the mountain municipalities. The most important losses being observed in Premià de Mar, Vilassar de Mar, and Arenys de Mar.

¹ There was a large increase in unproductive areas between 1954 and 2010, a land-use type that was almost non-existent before this time. This land is largely abandoned, in the process of urbanization. For our calculations, we considered and valued it as urban.

Table 4 Detail of the non-market services valuation (values are expressed in 2013EUR/ha/year)

Ecosystem services	Crops	Woodlands	Pastures	Beach and dunes	Open freshwater	Urban green spaces
Climate regulation	–	127 (32)	53 (5)	–	–	775 (3)
Disturbance regulation	–	–	–	62,843 (2)	–	–
Water regulation	–	–	49 (1)	–	–	14 (1)
Water supply	–	317 (3)	–	–	505 (4)	–
Erosion control	59 (3)	114 (1)	33 (1)	36 (1)	–	–
Soil formation	–	13 (1)	14 (1)	–	–	–
Nutrient cycling	120 (1)	–	–	–	–	–
Waste treatment	–	–	76 (2)	–	–	–
Pollination	18 (2)	373 (1)	18 (2)	–	–	–
Biological control	–	30 (1)	37 (1)	–	–	–
Habitat/refugia	1913 (2)	1646 (20)	2012 (1)	–	–	–
Genetic resources	–	19 (1)	–	–	–	–
Aesthetics and recreation	48 (8)	673 (28)	116 (6)	34,208 (4)	618 (9)	3107 (7)
Cultural and spiritual	–	–	–	55 (1)	–	–
Total	2158	3312	2408	97,143	1123	3896
Values from Brenner et al. (2010)	1987	3517	213	96,715	1756	5676

In the parenthesis, the number given represents the number of monetary estimations used. Original Brenner et al. (2010) values are in 2004USD, which have been converted into 2013USD according to data from Bureau of Labour Statistics (www.bls.gov), and later converted into 2013EUR using the historic annual media conversion rate from 2013 according to European Central Bank (www.ecb.europa.eu)

Table 5 Market and non-market values for ecosystem services provided by the land-use cover classes of El Maresme County (values are expressed in 2013EUR/ha/year)

Land-use cover	Non-market value	Market value	Total value
Rain-fed cereal crops	2158	892	3050
Irrigated cereal	2158	4344	6502
Orchards	2158	9230	11,388
Flower cropping	2158	14,569	16,727
Vineyards	2158	575	2733
Irrigated fruit trees	2158	2490	4648
Olive tress	2158	462	2620
Rain-fed trees	2158	996	3154
Carob and chestnut	2158	174	2332
Woodlands	3312	89	3401
Pastures	2408	259	2667
Beach or dune	97,143	0	97,143
Open freshwater	1123	0	1123
Urban green space	3896	0	3896
Urban build-up	0	0	0
Unproductive	0	0	0

Source Tables 4 and 5

Discussion

Our results show how land-use changes that have taken place in El Maresme County during the last 60 years have profoundly affected the ES of the area and their non-market and market values. Concretely, the overall net loss has been

estimated at 23.6 million 2013 Euros per year. This loss can be attributed to urban sprawl, which has transformed former natural areas such as croplands, woodlands, pastures, beach and coastal zones, and waterways into urban land-uses. This change also caused a decrease in the ecological connectivity by increasing landscape fragmentation,

Table 6 Total value of ecosystem services in 12 municipalities of El Maresme, 1850–2010 (values are expressed in million 2013EUR)

	1850			1954			2010			Δ TV 1850–1954	Δ TV 1954–2010
	NMV	MV	TV	NMV	MV	TV	NMV	MV	TV		
Alella	2.1	0.7	2.8	2.2	1.3	3.5	1.6	0.5	2.1	0.7	–1.4
Dosrius	11.6	1.4	13.0	12.2	1.2	13.4	10.8	1.0	11.8	0.4	–1.6
Palafolls	4.2	0.9	5.1	4.2	2.0	6.2	3.2	2.5	5.7	1.1	–0.5
Sant Iscle de V.	4.8	0.7	5.5	5.0	0.8	5.8	5.1	0.8	5.9	0.3	0.1
Teià	1.5	0.7	2.2	1.6	1.5	3.1	1.2	0.7	1.9	0.9	–1.2
Tordera	23.1	3.5	26.6	24.5	6.7	31.2	22.7	6.1	28.8	4.6	–2.4
Mountain municipalities	47.3	7.9	55.2	49.7	13.5	63.2	44.6	11.6	56.2	8.0	–7.0
Arenys de Mar	3.4	0.5	3.9	3.6	1.3	4.9	0.7	0.6	1.3	1.0	–3.6
Masnou, el	1.8	0.3	2.1	1.7	1.2	2.9	1.3	0.1	1.4	0.8	–1.5
Mataró	7.1	2.0	9.1	6.2	6.9	13.1	4.4	2.8	7.2	4.0	–5.9
Premià de Mar	1.1	0.1	1.2	1.0	1.5	2.5	0.8	0.1	0.9	1.3	–1.6
Sant Pol de Mar	3.2	0.4	3.6	3.1	1.1	4.2	1.9	1.1	3.0	0.6	–1.2
Vilassar de Mar	2.1	0.3	2.4	2.0	4.3	6.3	1.6	1.9	3.5	3.9	–2.8
Coastal municipalities	18.7	3.6	22.3	17.6	16.3	33.9	10.7	6.6	17.3	11.6	–16.6
Total	66.0	11.5	77.5	67.3	29.8	97.1	55.3	18.2	73.5	19.6	–23.6

Source Parcerisas (2012). Urban green spaces extension for 1954 and 1850 is a supposition from the same % in the urban area in 2010
 NMV non-market value, MV market value, TV total value

Table 7 Matrix of non-market ES values variation between 1954 and 2010 (in thousand 2013EUR)

	Cropland	Woodlands	Pastures	Beach or dune	Open freshwater	Urban area	Unproductive	Var. 1954–2010
Cropland	0.0	–218.1	–13.3	0.0	1.1	21.4	0.2	–11,888.4
Woodlands	2584.6	0.0	149.7	0.0	14.2	89.8	0.0	2418.4
Pastures	119.2	–105.5	0.0	0.0	0.0	14.4	0.0	598.6
Beach or dune	0.0	0.0	0.0	0.0	0.0	58.3	0.0	–3215.4
Open water	–2.2	–5.9	0.0	0.0	0.0	3.3	0.0	–85.9
Urban area	–5941.8	–4319.2	–231.6	–2661.7	–84.2	0.0	0.0	0.0
Unproductive	–626.5	–318.6	–86.4	–612.0	–1.8	0.0	0.0	0.0
Total 1954	18,593.1	38,698.1	940.6	8626.3	409.3	0.0	0.0	–12,172.7

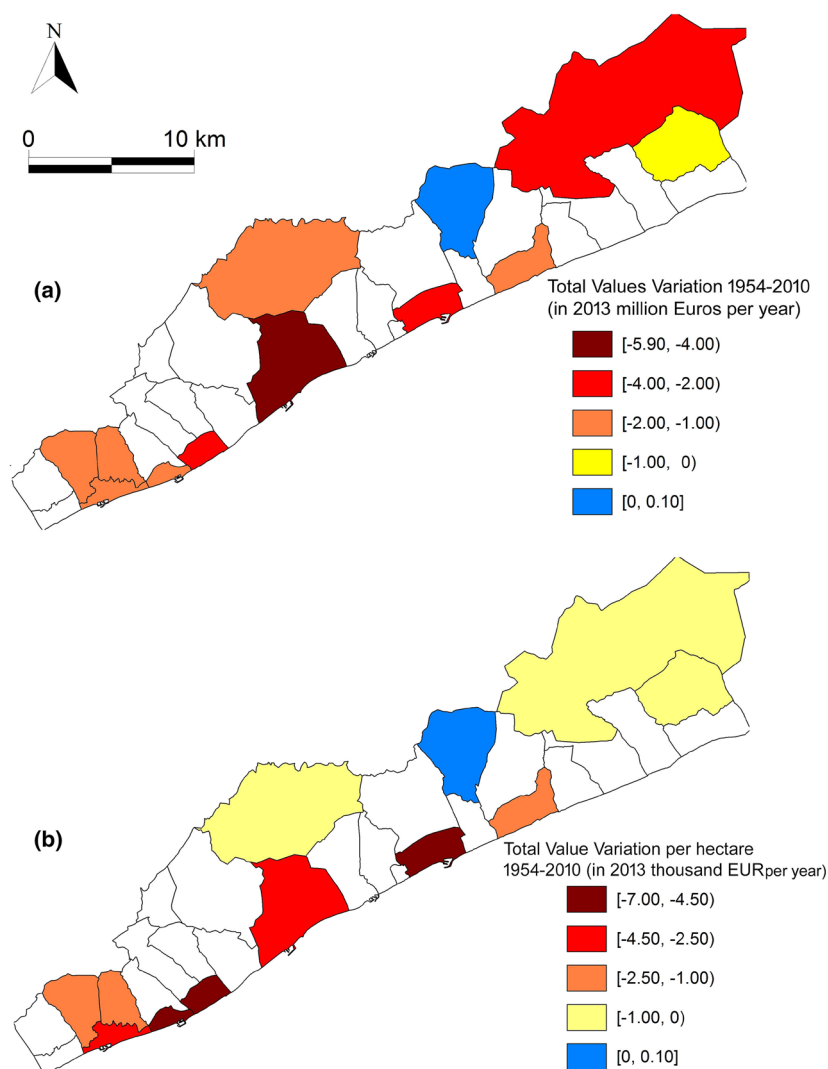
The row “Total 1954” indicates the total non-market value in 1954. The rest of the cells indicate the variation between 1954 and 2010
 Source Tables 3 and 5

acting as a barrier among the different natural mosaics (Parcerisas et al. 2012). This uncontrolled urban sprawl has caused the loss of important ecosystem benefits provided by nature, such as disturbance regulation, water supply, climate regulation, erosion control, pollination, habitat for species, along with aesthetics and recreation.

Urban sprawl has been especially significant in coastal areas, where it has been particularly aggressive since the arrival of Franco’s dictatorship, forming a continuous line all along the coast. Several facts can explain this process. First, increasing population pressure in the metropolitan region of Barcelona and the conversion of the county into

an important tourist destination had major impacts. Second, and more importantly, the failure from Spanish authorities over the long term to support land preservation actions has favoured a real-estate boom to supply demands for accommodation and leisure. This situation has undermined the historical power of local farmers and diminished their capacity to compete with urban developers. Local and national institutions may have looked favourably upon this process, believing it provided huge economic benefits to the local region and thus furthering its development. However, doing this at the expense of the free ES provided by nature has led to enormous costs not being evaluated by

Fig. 3 Total economic value and value per hectare variation of the ecosystems of the municipalities of El Maresme County between 1954 and 2010



the market and may involve larger economic and environmental costs in the future, which may in turn affect the same economic activities, such as tourism.

The lack of sand and sediment in the El Maresme beaches is a good example of a recent problem threatening functional coastal systems, which derives from the failure to value ES. The current deration of beach ecosystems has a negative impact on the ecological stability of the coastal environment and on the ES provided by beaches and tourism. This is due to two factors, worsened by typical annual storms in the fall. First, the reduction in the beach area due to seaport construction diminishes the capacity of beaches to regulate disturbances and to protect coastal urban infrastructure and communities. Second, the urban invasion of natural waterways and construction of barriers all along the coastline eliminates the connectivity between sea and mountain and prevents the beaches from receiving the sediments and materials to maintain and regenerate beach sand seasonally. The temporary and costly solution

that local governments are taking to solve this situation is to import sand every spring and renourish tourist beaches. This clearly unsustainable and expensive solution would have been unnecessary if proper land-use planning had been implemented in the past, and shows the necessity to integrate and take into account the non-market-valued ES when designing land planning and development policies.

Limits of spatial and economic analyses

The spatial and economic methodologies employed in this study have proven to be useful and successful for the valuation of market and non-market ES and in helping to better plan land-use decision-making. However, we must remain aware of the limits of this approach.

One disadvantage of this coarse estimate of the value of ES is its vagueness, especially because the spatial, biophysical, and socio-economic heterogeneity are not taken into account (Troy and Wilson 2006; Plummer 2009;

Eigenbrod et al. 2010; Maes et al. 2012; Schägner et al. 2013; Alam et al. 2016). Among others, there is yet insufficient knowledge about how the ES and values vary in space and what their spatial determinants are (Bockstael 1996; Plummer 2009; Mitchell et al. 2013).

With respect to the spatial analysis, the benefit transfer analysis assumes a meta-evaluation that implies that there are enough values in the transfer database (i.e. empirical valuation studies for each pair of ES value and ecosystem) to cover every ES and land-use cover. It also ensures that the variance in the economic evaluation of ES can be explained by biophysical and socio-economic characteristics that are homogenous in time and space. These generalization errors limit the interpretation of results. Indeed, several primary factors were not taken into account here, such as the methodologies of the various studies used (e.g. contingent valuation, transport cost, replacement cost methods) and the type and degree of marginal change in economic evaluations of the studied ES.

This high degree of variability in the source is important in explaining the variance in the ES values. If other methods of benefit transfer, including meta-analysis, reduce these sources of errors (Rosenberger and Loomis 2001; Navrud and Ready 2007; Johnston and Rosenberger 2010), the fact remains that generalization errors arising from the wide variety of periods, geographical areas, and analytical methods used are inherent to the benefit transfer approach. These errors are related to both spatial analysis and economic evaluation of ES (Naidoo et al. 2009; Eigenbrod et al. 2010; Schägner et al. 2013). Measurement errors inherent to primary studies also constitute a source of bias.

By using economic coefficients for ES valuation analysis, our study, as well as the study of Brenner et al. (2010) in this part of the Catalan coast and several other studies elsewhere (e.g. Liu et al. 2010; Mendoza-González et al. 2012; Dupras et al. 2015), shows the lack of value for ES in several different types of ecosystems (i.e. gap analysis). A more complete analytical coverage of empirical ES value studies would provide a more realistic estimate and, following the trend found in this study, perhaps increase the total value of ecosystems. In this sense, the development of other primary studies on a variety of ES, ecosystems, and regions could overcome this limitation.

Finally, we should put into perspective the historical analysis performed. Value systems of societies change and evolve over time. Thus, it is not realistic to believe that the social, cultural, and economic values of ES are homogeneous in time, especially over the long period that we cover in this study. The results and conclusions should only be interpreted from a contemporary perspective. Consequently, we must highlight that in our review and critics of planning policies, it is anachronistic to say that the ES non-market values were not taken into account. It is in the

future planning and management of the area that the concept of non-market ES must be integrated.

Conclusion

Urban sprawl is a social issue that concerns many stakeholders of land-use planning and management. In coastal areas, the development of areas on the outskirts of cities for residential, industrial, commercial, infrastructural, and tourism purposes is characterized by a low density of built structures and a loss of ecosystem functionality. The consequences are especially important because these losses are sometimes irreversible. In this study, we showed that certain land-use changes may be defended attending only to economic profits produced in the markets. However, the loss of non-market ES can cause higher economic losses in the long term. Coastal ecosystems produce highly economically valuable services that are associated with beaches, such as disturbance regulation, aesthetics, and recreational activities. The economic losses attributable to losses in ES in coastal municipalities between 1954 and 2010 are more than two times higher than those observed for municipalities located inland (16.6 vs. 7.0 million 2013 Euros per year). With this in mind, spatial planning policies should consider and incorporate both the concept of ES and non-market values to reflect the actual contribution of natural and semi-natural quality of life of human communities, particularly for coastal ecosystems.

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