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LAND COVER CHANGES IN THE NW SPANISH COASTAL ZONE: DRIVERS AND IMPACT ON ECOSYSTEM SERVICES

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Abstract: The increase in the amount of agricultural, forest and other seminatural and natural land taken by urban and other artificial land development is of worldwide concern. Land take is generally more intense in littoral zones, which in turn are especially vulnerable. In this study, the artificialization patterns of the Galician coast (NW Spain) were assessed using the high-resolution land cover map SIOSE. Land take between 2005 and 2014 was monitored, changes in land cover patterns were analysed and their impact on ecosystem services was assessed. The artificialization rate in the coastal municipalities in that period was 1.07 ha day^{-1}, being particularly intense in the first four years, with a value of 2.05 ha day^{-1}. Land take mainly occurred at the expense of forest and seminatural classes. Consequently, potential services provided by ecosystems were affected; particularly provisioning services which decreased at a 0.35% annual rate.

The relationship between artificialization rates and demographic and economic variables were also analysed, resulting in a different significant correlation between population, new buildings and domestic gross disposable income among the studied zones.

Keywords: land take, SIOSE, socioeconomic indicators, artificialization rates, littoralization, land take patterns, ecosystem services

CAMBIOS EN LAS COBERTURAS DEL SUELO EN LA COSTA NW DE ESPAÑA: FUERZAS TRACTORAS E IMPACTO EN LOS SERVICIOS ECOSISTÉMICOS

Resumen: El aumento de la ocupación de zonas agrícolas, forestales y otras zonas seminaturales por asentamientos urbanos u otras superficies artificiales es motivo de preocupación mundial. La ocupación del suelo es generalmente más intensa en zonas litorales, las cuales a su vez son especialmente vulnerables. En este estudio se evaluaron los patrones de artificialización de la costa gallega (noroeste de España) utilizando el mapa de cobertura de suelo de alta resolución SIOSE. Se monitoreó la ocupación del suelo entre 2005 y 2014, se analizaron los cambios en los patrones de ocupación del suelo y se evaluaron sus impactos en los servicios ecosistémicos. La tasa de artificialización en los municipios costeros en ese periodo fue de 1,07 ha día^{-1}, siendo particularmente intensa en los cuatro primeros años con un valor de 2,05 ha día^{-1}. La ocupación del suelo se produjo principalmente en zonas forestales y seminaturales. En consecuencia, la potencialidad de los servicios ecosistémicos se vio afectada, en particular aquellos de aprovisionamiento que disminuyeron con una tasa anual del 0,35%.

También se analizó la relación entre las tasas de artificialización y va riables demográficas y económicas, lo que resultó en correlaciones significativas diferentes entre la población, las nuevas edificaciones y la renta bruta disponible entre las zonas estudiadas.

Palabras clave: ocupación del suelo, SIOSE, indicadores socioeconómicos, tasas de artificialización, artificialización del litoral, patrones de ocupación del suelo, servicios ecosistémicos

1. INTRODUCTION

Land take refers to the transformation of natural and/or agrarian areas to artificial surfaces destined to diverse uses such as residential, industrial, commercial, equipment, transport infrastructures, etc. (European Environment Agency, 2017; Olazabal and Bellet, 2018). It is a direct indicator of urbanization processes (European Environment Agency, 2017; Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente, 2017) that allows analysing the land cover spatio-temporal dynamics that could result from the socioeconomic and environmental pressures operating in a given territory. Due to its irreversibility, these changes are a potential threat to sustainability and have direct implications on the supply of ecosystem services (Prieto and Ruiz, 2013). Land take is a process of relevance in all UE countries and one of the major environmental challenges Europe is facing (European Commission, 2011; Wang, Liu & Peng, 2012). "No net land take by 2050" has been fixed as a goal in the UE due to its consequences such as losses in biodiversity, habitat fragmentation, soil sealing, urban sprawl, economic impacts derived from the loss of agricultural land, or impacts on the carbon and water cycles (Decoville and Schneider, 2015).

The increase of artificial surfaces has been recorded in Europe through the Corine Land Cover (CLC) project since 1987. The European Environment Agency (EEA) publishes periodically the results of the indicator "urban land take" which measures the increase of artificial surfaces occurring at the expense of agricultural, forestry or seminatural covers since year 2000. This indicator shows that artificialization rates in Spain have always been above the European average, although the temporal trends are not totally coincident. Thus, for instance, the annual average value of the "urban land take" indicator in Europe for the periods 2000-2006 and 2006-2012 was 0.5% and 0.4% respectively, while in Spain they were 2.8% (the third in Europe) and 1.5% (the first in Europe) in the same periods. In fact, 23.5% of the European urbanization took place in Spain in the period 2000-2006, in contrast with 12.2% in France and 9.5% in Germany (Couch, 2016). These high rates were mainly associated with building activity connected with the dispersed urban model and the large investment in infrastructures (Observatorio de la Sostenibilidad, 2006). As a consequence, the area covered by urban land classes increased in Spain by 25.4% in the 1990-2000 period, while the population rose up by only 5% (Greenpeace, 2010).

This urbanization process was not homogeneous throughout the territory but is generally more intense in the littoral zone (Observatorio de la Sostenibilidad, 2006), a phenomenon known as "littoralization" which consists in the concentration of the population, infrastructures, economic activities and settlements in the coastal areas (Barragán Muñoz, 1994). A result of this pattern is that approximately 40% of the European population lives in the first 50 kilometers from the coastline and almost 40% of the European gross domestic product is generated in those maritime regions (European Environment Agency, 2013). The increase in artificial areas in the European 10 km coastal zones was, on average, 12% between 1990 and 2000. This value was even higher in Portugal (34%), Ireland (27%) or the whole Spanish territory (18%) (Jiménez Herrero, Guaita García, López Hernández & Delgado Jiménez, 2009), where the increase of artificial areas in the 10 km coastal zone between 1990 and 2006 represented about 1/3 of the total area built in the previous centuries. Simultaneously, the population living in Spanish coastal municipalities (which represent 8% of the territory) rose from 24% of the total population in 1960 to 44% in 2010 (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2014). The *Observatorio de la Sostenibilidad* (OSE) studied the urbanization process in the Spanish coastal area from 1987 to 2011 showing rates of 2.2 hectares per day in the first 500 meters from the coastline, with some areas showing a complete urbanization of the available space (Observatorio de la Sostenibilidad, 2016a). According to the Bank of Spain, the number of new houses built in Spain per 10000 inhabitants during the period 2004-2007 was 9.1, which contrasts with the value of 5.7 reported for Europe. Only in 2007, Spanish coastal municipalities approved the construction of nearly three million new dwellings (Greenpeace, 2010).

The Galician coast was also affected by the substantial expansion of urbanization, with varying intensity depending on the area, but tending towards scattered settlements (Xunta de Galicia, 2011). Several areas of the Galician region were subjected to an intense artificialization process in the period 1997-2007, with relatively large urban expansions, whereas in other areas this process was moderate. The physiography of the Galician coast presents significant differences between northern and western areas, being, in general, much more exposed and steep in the north and much sheltered in the west. The major singularities of the Galician coast are the rias, ancient valleys occupied by the sea with average depths in the mouth of about 50-60 meters. They are highly productive zones that concentrate a large part of the Galician population, where different uses coexist, therefore supporting a significant human pressure (Fernández, Álvarez-Salgado, Beiras, Ovejero & Méndez, 2016). The rugged coastal morphology of the rias occupies 34.5% of the Spanish peninsular coastline.

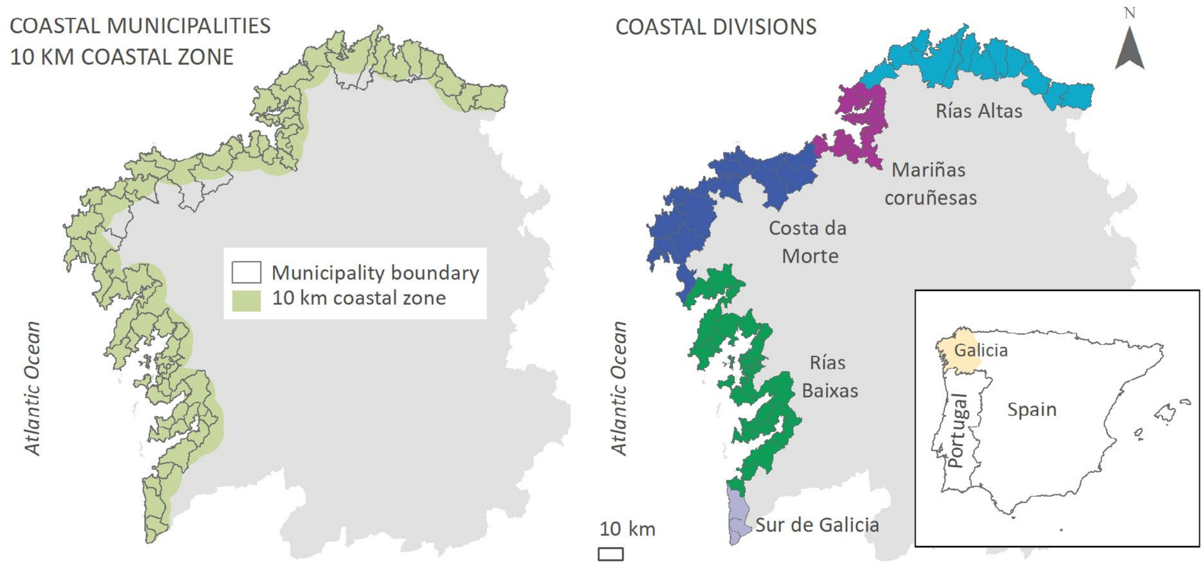
Data on artificial cover for Spain generally derives from the Corine Land Cover project, which is known to have several methodological limitations (Ovejero-Campos, Fernández, Ramos, Bento & Méndez-Martínez, 2019), such as those related to the resolution due to the minimal cartographic unit (Batista e Silva, Lavalle & Koomen, 2013), the possible underestimation of the artificial coverages (Bach *et al*., 2006), or the existence of unlikely changes in the assigned land cover (Bach *et al*., 2006; Barreira González, González, Cascón & Sendra, 2012; Catalá Mateo, Bosque Sendra & Plata Rocha, 2008; Martínez-Fernández, Ruiz-Benito & Zavala, 2015; Martínez-Fernández, Ruiz-Benito, Bonet & Gómez, 2019; Pontius and Lippitt, 2006). In this connection, Decoville and Schneider (2015) monitored land take rates at a very accurate scale, and demonstrated that although the results from CLC seem acceptable at the country level, they lack precision when analysing smaller territories. Consequently, in this study we used data derived from the SIOSE project (reference scale 1:25000), as it represents a substantial improvement in the description and assignation of land cover.

Land cover and land use changes are closely related to the provision of ecosystem services (Burkhard, Kroll, Müller & Windhorst, 2009). The analysis and mapping of ecosystem services is presently recognised as a key element of sustainable management, thus drawing the attention of policymakers (Bastian, Haase & Grunewald, 2012; Burkhard *et al*., 2009; Kandziora, Burkhard & Müller, 2013) in this paper we suggest returning to the landscape potential concept developed by landscape ecologists in the 1970s. Emerging from both concepts is the hereinafter discussed EPPS framework – ecosystem (or landscape as they allow estimating the impact of human activity (Hasan, Shi & Zhu, 2020; Li and Zhou, 2016; Mendoza-González, Martínez, Lithgow, Pérez-Maqueo & Simonin, 2012; Riitters, Wickham, Vogelmann & Jones, 2000).

Besides the intrinsic interest of the spatial and temporal analysis of land cover and its effect on the ecosystem services, it is of particular relevance assessing the socioeconomic drivers behind those patterns. This research topic has been addressed in the literature using different approaches based on population (Carr, 2004; Kamwi, Chirwa, Manda, Graz & Kätsch, 2015; Orenstein and Hamburg, 2010), births, deaths and migration patterns (Clement and York, 2017) and household formation (Barbieri, Bilsborrow & Pan, 2005).

The objectives of our research are: (1) to quantify the artificialization rate of the Galician coast in the last decade, (2) to map and estimate changes in ecosystem services resulting from the artificialization process and (3) to relate magnitudes and patterns of

FIGURE 1
MAP OF THE COASTAL AREAS STUDIED IN THIS INVESTIGATION AND THEIR LOCATION



Map of the coastal areas studied in this investigation. (A) Superposition of the two coastal zones considered in this study: in green, the 10 km coastal zone (535054 ha), and in grey, the coastal zone delimited by the Galician coastal municipalities (451401 ha). (B) Coastal divisions adopted in this study by grouping coastal municipalities according to their physiographic similarities.

coastal artificialization to socioeconomic indicators *a priori* associated with the artificialization process itself, such as the construction of new dwellings or the generation of wealth (expansion of leisure activities, tourism, creation of industries…).

2. METHODS

We estimated the artificial cover in the Galician coast (located in the NW of Spain) following two approaches. Firstly we analysed the 10 km coastal zone, which allows us to compare the results with those published by the OSE and the EEA. Secondly, we carried out the same procedure but in this case, considering the coastal zone as the area delimited by the coastal municipalities, as they are the territorial units of relevance for socioeconomic data (Instituto Galego de Estatística - IGE) (Fig. 1). Besides, municipalities are the minimum administrative unit with competence in spatial planning in the region.

The SIOSE project analyses land cover and land use. This work focuses on land cover, ie. physical and biological cover of the earth's surface, including artificial surfaces, agricultural areas, forests, natural and seminatural areas, wetlands and water bodies. The concept of land use characterises the territory according to its functional dimension or its socioeconomic dedication, for example, residential, industrial, commercial, agricultural, forestry, recreational (Instituto Geográfico Nacional, 2015; Valcárcel and Castaño, 2012).

The SIOSE project does not follow a traditional thematic classification model, but assigns to each polygon one or several land cover classes (simple and composed), using occupation percentages and attributes. Simple classes present homogeneity in 100% of the surface and exceed the minimum surface requirement; they include crops, pastures, forests, scrubs, open spaces with little or no vegetation, wetlands, water bodies, and artificial surfaces. Composed classes are described from several land cover classes, which in turn can be simple or composed and, depending on the combination, are called "Association" (no-fixed distribution) or "Mosaic" (geometric distribution). Composed classes could be predefined or not predefined. Among the predefined ones, widely distributed by the study area, the class "Residential agricultural settlement", includes fractions of herbaceous and/or woody crops, buildings, and may also contain forests, pastures, scrubs or any artificial classes (for example roads, parking lots or bare pedestrian zones) (Equipo Técnico Nacional SIOSE, 2015).

We used available SIOSE databases corresponding to 2005, 2009, 2011 and 2014, covering a 9 years period when the artificialization dynamics were explosive due to the "real estate boom" which occurred in Spain by that time. Vectorial format municipal boundaries supplied by the *Instituto Geográfico Nacional* (IGN) were included in the geodatabase. Alphanumeric data related to human pressures, population, and new buildings were obtained from the *Instituto Gallego de Estadística* (IGE) and related to the municipal geographic data.

The wide availability of artificial covers provided by the SIOSE database, justifies its use in this work. Nevertheless, this database also presents some limitations (Valcárcel and Castaño, 2012). The exploitation of SIOSE data is laborious and has limitations when representing mixed land covers, frequently present on the Galician coast. Scattered settlements, widespread throughout the Northwest Iberian Peninsula, causes confusion in the SIOSE classification between the discontinuous urban fabric and non-urban classes, reflecting a continuous transfer between both land covers, which may cause slightly altered results (Olazabal and Bellet, 2017). Another limitation, common to this type of data, is the supposed "naturalisation" that occurs in some polygons, consisting of unlikely changes from artificial surfaces to agricultural or forest areas. The presence of a high contribution of disseminated settlements makes difficult the identification of classes such as "Residential agricultural settlement", as it depends on the time of the year when the photograph is taken. On some occasions, polygons bordering road networks are classified as broad-leaved forest or scrubs as a consequence of the appearance of green masses (Olazabal and Bellet, 2017).

This paper sets a hierarchical nomenclature derived from SIOSE, and similar to Corine Land Cover (CLC), which includes five land cover classes: artificial surfaces, agricultural areas, forests or seminatural areas, wetlands and water bodies. A reclassification of the SIOSE codes was performed to maintain the polygons and assign each one to a single class. Firstly, a direct

TABLE 1
RECLASSIFIED LAND COVER CLASSES AND THEIR CODES

SIOSE land cover classes	Reclassified land cover classes
Artificial surfaces	Artificial surfaces (1)
Crops	Agricultural areas (2)
Pastures	Forest and seminatural areas (3)
Forests	
Scrubs	
Open spaces with little or no vegetation	
Wetlands	Wetlands (4)
Water bodies	Water bodies (5)

reclassification to simple-classes polygons (Table 1) was performed, and secondly, codes of the polygons classified as "associations" or "mosaics" were split into simple classes and then reclassified attending to the dominant land cover class (Table 2).

Once the information was generated, total areas were calculated for each land cover class and geoprocessing was performed, integrating land cover information, socioeconomic data, and digital aerial orthophotos derived from the "Plan Nacional de Ortofotografía Aérea" (PNOA).

TABLE 2
EXAMPLES OF RECLASSIFIED SIOSE POLYGONS

SIOSE code	Percentages of land cover class	New code
A(60FDPpl_40MTR)	100% (3)	3
A(50SDN_35MTR_10PST_05FDP)	100% (3)	3
I(60CNF_15FDP_10MTR_05PRDsc_05MTRct_05SDNfc)	95% (3), 5% (2)	3
I(80ZEV_15MTRct_05A(90MTR_10FDP))	80% (1), 20% (3)	1
I(80VAP_10EDFnv_10OCT)	100% (1)	1
R(35CHLsc_20EDFva_15PRDsc_10VAP_10LFNsc_05OCT_05MTRpc)	60% (2), 35% (1), 5% (3)	2
R(35EDFva_20PRDsc_15FDC_10VAP_10CHLsc_10CNF)	45% (1), 30% (2), 25% (3)	1

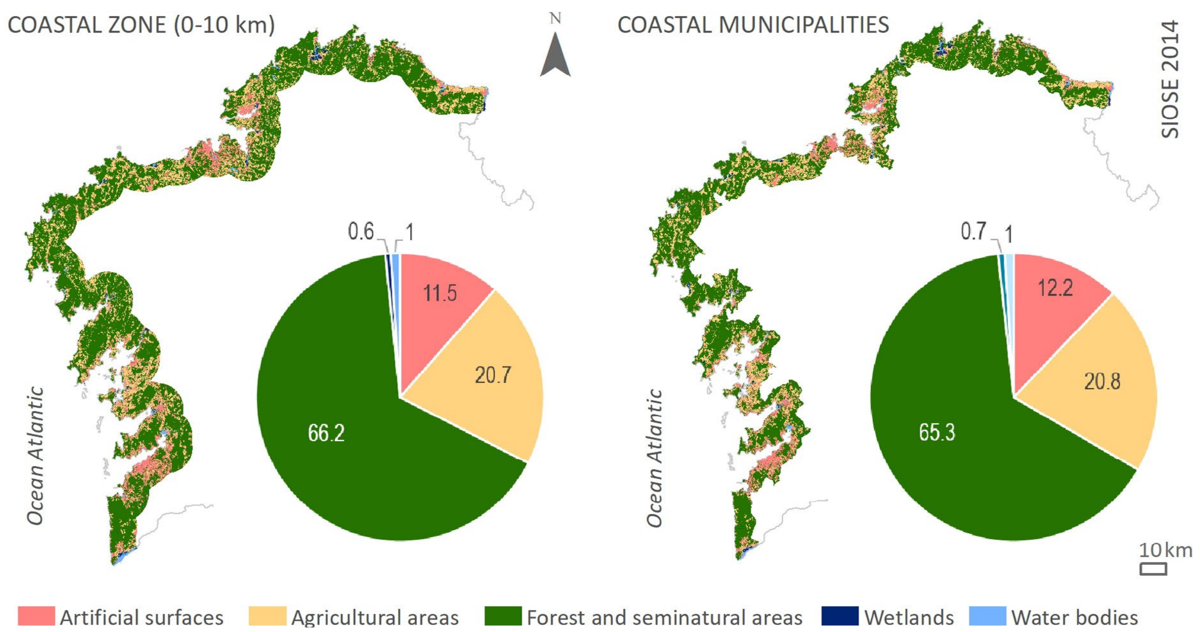
In this study, we estimated the potential of the coastal zone to deliver ecosystem services from the ecosystem service potential matrix described in (Burkhard, Kandziora, Hou & Müller, 2014). As that matrix derived from CLC classes, it was adapted to the land cover classes defined in our study which derived from the SIOSE 3-level classes. The ecosystem service classification used was based on 11 regulation services, 10 provisioning services and 6 cultural services (see supplementary material). The potential of each land cover class to produce the selected ecosystem services was assessed on a scale from 0 (no relevant potential) to 5 (very high relevant potential). Regulation, provisioning and cultural ecosystem services were mapped using the mean value of their components. The evolution of each ecosystem service from 2005 to 2014 was assessed taking into account the area occupied by each land cover class and then estimating annual changing rates.

3. RESULTS AND DISCUSSION

3.1. Artificial land cover changes and fluxes in the Galician coast

The land cover distribution observed in the Galician coast in 2014 (last year available) is shown in Figure 2. 65% of the coastal area was dedicated to forest and

FIGURE 2
RECLASSIFIED LAND COVER CLASSES DERIVED FROM SIOSE 2014 IN THE 10 KM COASTAL ZONE VERSUS THE AREA DELIMITED BY THE COASTAL MUNICIPALITIES

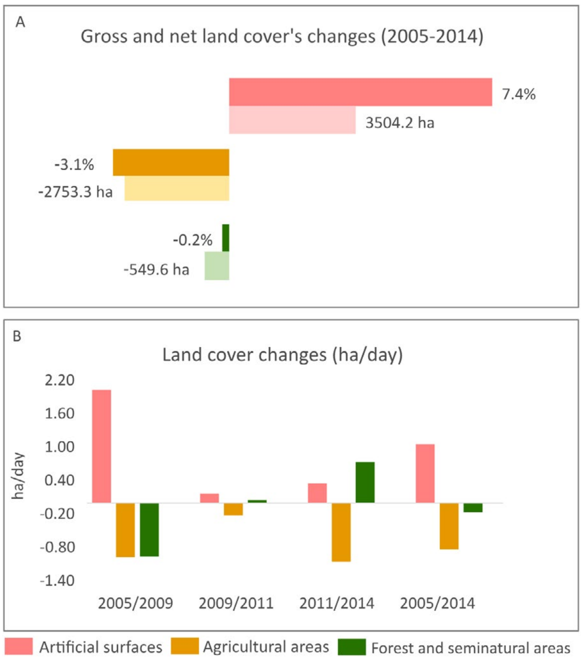


Reclassified land cover classes derived from SIOSE 2014 in the 10 km coastal zone versus the area delimited by the coastal municipalities. Pie charts represent the relative contribution of the land classes to the total area (% of the total surface).

seminatural areas, occupying a total of 273534 hectares when the coastal municipalities were considered. Agricultural areas accounted for 21% of the coastal area whereas artificial surfaces, located mainly around the coastal cities, represented 12%. Wetlands and water bodies were much less represented. These results were very similar when the 10 km coastal zone or the municipalities' coastal strip was considered, suggesting that both methodological approaches could be used indistinctly.

Figure 3A shows absolute and relative changes in land cover in the area delimited by the Galician coastal municipalities in the period 2005-2014. The largest relative change occurred in the artificial surfaces, which increased by ca. 7.4% in the study period. Agricultural areas decreased by 3% and the other land classes varied less than 1%. However, the most considerable absolute losses were found in the agricultural areas, showing a decrease of 2753 hectares, albeit only represented 3% in relative terms.

FIGURE 3
A: GROSS AND NET LAND COVER'S CHANGE. B: LAND COVER CHANGES



A: Absolute and relative change in land cover classes in the coastal municipalities between 2005 and 2014. Relative change is expressed as the % with respect to the total area of the same land cover class in the year 2005 (dark bars) and absolute change is expressed in hectares (soft bars). Changes in wetlands and water bodies are not represented because of their small magnitude. B: Daily land cover changes in the municipalities' coastal zone in the 2005-2009, 2009-2011, 2011-2014 and 2005-2014 periods.

As expected, the same pattern was observed when the 10 km coastal zone was used, although differences were found in the absolute number of hectares, as the total extent of both areas differed (Fig. 1). Figure 3B shows daily rates of land cover changes in the municipalities of the coastal strip. In general, artificial areas increased and agricultural areas decreased. However, forest and seminatural areas decreased from 2005 to 2009, but increased in the 2009-2014 period. Artificial land cover rose from 47361 ha in 2005 to 50350 ha in 2009, which yields a daily growth rate of ca. 2 ha day^{-1} (i.e. /day) in that period, while in the 2009-2011 and 2011-2014 periods these rates were 0.2 and 0.4 ha day^{-1}. The estimated rate for the 10 km coastal zone from 2005 to 2009 was 2.5 ha day^{-1} due to the large size of some coastal municipalities, which penetrate into the continent where exposition to anthropogenic pressures is less intense.

When the results obtained in this study (using SIOSE), are compared with the data published by the Observatorio de la Sostenibilidad (2016b), derived from CLC, substantial differences were found in both the artificial area and the annual land cover change rate. According to CLC, 36054 hectares were classified as artificial surfaces in the 10 km coastal zone in 2011, which represents 6.8% of the total coastal area, whereas the results obtained in this study show that 11.4% of the 10 km coastal zone was covered by artificial surfaces (60963 ha) in the same year. Previous studies have warned about the underestimation of the artificial area along the Spanish coast due to the scale of CLC data, an error enhanced in areas with a dispersed settlement, for example, the Galician coast (Observatorio de la Sostenibilidad, 2016b). In addition, the CLC project discards linear data such as roads and rail networks as artificial surfaces, thus reinforcing this underestimation (Olazabal and Bellet, 2018). These authors also reported the potential effect of the minimum percentage (5%) considered by each SIOSE polygon when digitising large polygons representing disseminated urban settlements, which may result in abnormally high values of urban surfaces. The above-mentioned differences are also reflected in the between-periods variability of annual artificialization rates (Table 3) .

The artificialization of the 10 km coastal zone in Spain between 1987 and 2011 showed a rate of 15.4 ha day^{-1} according to CLC, increasing the artificial surface by 2.3% per year (Observatorio de la Sostenibilidad, 2016b). Specifically, artificial surfaces in Spain increased by 1.48% per year in the period 2006-2012, the highest rate in the EU, where the average rate was 0.41% year^{-1} (i.e. /year) (Dirección General de Medio Ambiente de la Comisión Europea, 2017). The annual growth rate of artificial surface in the Galician coastal zone (10 km)

TABLE 3
ANNUAL ARTIFICIALIZATION RATES

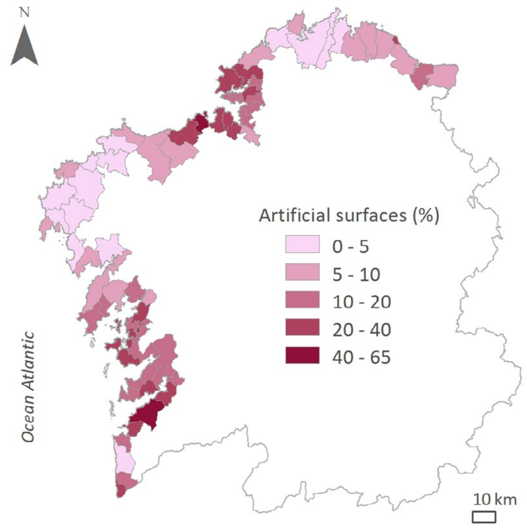
Area	Period	Artificialization rate (ha/day)	Annual change (%/year)	Data
Spain 10 km coastal zone	1987-2011	15.4	2.3	CLC
Galicia 10 km coastal zone	1987-2011	1.1	1.52	CLC
Spain 10 km coastal zone	2006-2012	20.6	1.48	CLC
Galicia 10 km coastal zone	2006-2012	0.64	0.67	CLC
Galicia 10 km coastal zone	2005-2011	1.7	1.1	SIOSE

Annual artificialization rates in Spain and Galicia (10 km coastal zone, 1987-2012).

according to CLC between 1987 and 2011, was 1.52%, which meant 1.1 ha day^{-1} (Observatorio de la Sostenibilidad, 2016b). However, the increase in artificial hectares in the Galician coastal zone (10 km) in the period 2006-2012 was 0.64 ha day^{-1}, representing an increase of 0.67% per year. When these data are compared with those obtained in this work using SIOSE, and choosing the closest available interval, 2005-2011, the artificial surface increased by 1.1% per year, with an annual rate of 1.7 ha day^{-1}. This is consistent with the underestimation of CLC and the overestimation of SIOSE in terms of artificial surfaces previously reported in the literature (Diaz-Pacheco and Gutiérrez, 2014; Observatorio de la Sostenibilidad, 2016b, 2017; Olazabal and Bellet, 2017, 2018; Ovejero-Campos *et al*., 2019).

The relative contribution of the artificial land cover in the Galician coast in 2014 is represented in Figure 4, and shows the presence of areas intensely artificialized mainly linked to the main coastal cities. The municipalities with the highest percentage of artificialization were A Coruña (64%) and Vigo (51%).

FIGURE 4
RELATIVE CONTRIBUTION OF ARTIFICIAL LAND COVER IN EACH COASTAL MUNICIPALITY

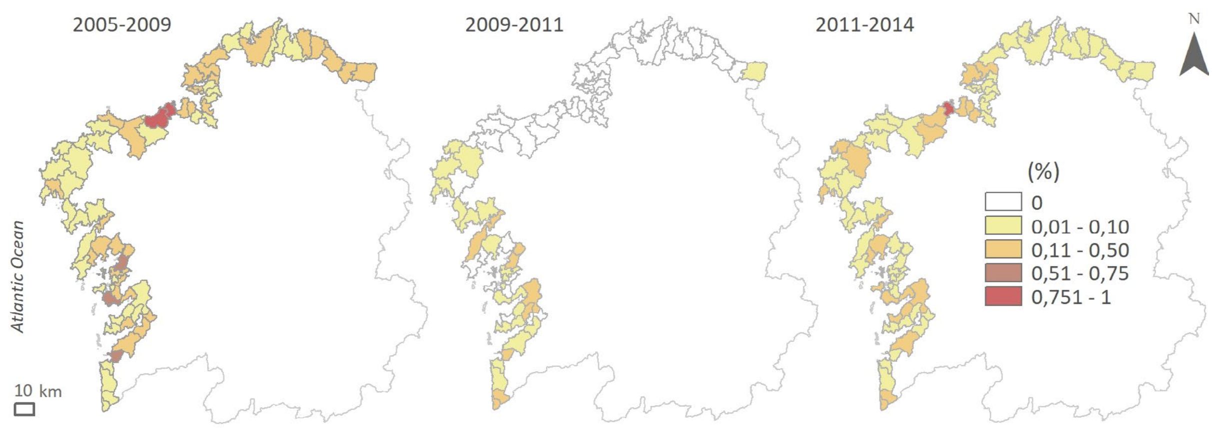


Relative contribution (%) of artificial land cover in each coastal municipality in 2014.

The distribution of this variable (Fig. 4) agrees with the location of the urban aggregates defined in the regional littoral planning (Plan de Ordenación do Litoral de Galicia) which corresponds to areas of concentration of urban growth where favorable topographic conditions facilitate the development of multiple economic activities (Xunta de Galicia, 2011). It also matches with the metropolitan areas of Vigo-Pontevedra and A Coruña-Ferrol.

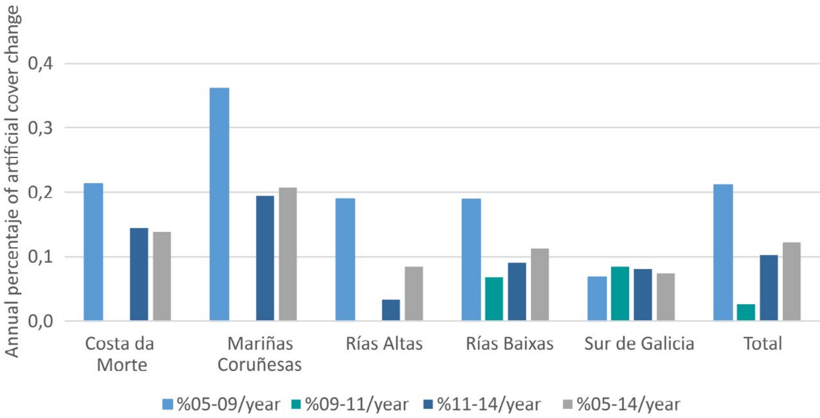
Figure 5 shows the annual artificialization rate (%) of the Galician coastal municipalities calculated with

FIGURE 5
ANNUAL ARTIFICIALIZATION RATES OF THE GALICIAN COASTAL MUNICIPALITIES



Annual artificialization rates of the Galician coastal municipalities (according to SIOSE), with respect to the total municipal area.

FIGURE 6
EVOLUTION OF ARTIFICIALIZATION RATES IN THE COASTAL DIVISIONS



Evolution of land artificialization rates in the groups of coastal municipalities identified in the Galician coast. Annual artificialization rate was calculated with respect to the total area of each group.

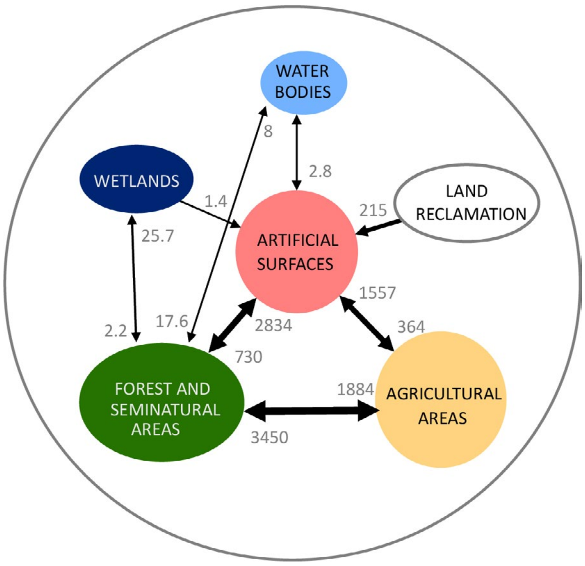
respect to the municipal area, which represents the amount of natural surfaces (forest and seminatural areas, agricultural zones and land reclamation) has been "denatured".

The highest artificialization rates with respect to the total area of the municipalities were found in the 2005-2009 period, in those areas contiguous to the larger coastal cities (Fig. 5). In the following period (2009-2011), clear differences were found between southern municipalities, showing relatively low land artificialization rates, and northern municipalities where this artificialization was practically non-existent. In the most recent period (2011-2014), a south to north artificialization gradient was observed, albeit rates were lower than in the first period (2005-2009).

To further investigate the patterns of land artificialization in this region, the Galician coast was divided into zones according to the different degrees of artificialization, derived from their physiographic characteristics, geographical location, climate, orientation, demographic burden, or even the economic and social characteristics. As a result, five groups of coastal municipalities were defined: Costa da Morte, Mariñas Coruñesas, Rías Altas, Rías Baixas and Sur de Galicia (Fig. 1). The maximum annual artificialization rates were generally observed in the period 2005-2009, albeit large differences among coastal groups were observed, with Mariñas Coruñesas almost doubling the artificialization rates of the Rías Baixas, Rías Altas and Costa da Morte, and the Sur de Galicia area showing an artificialization rate 5-fold lower than Mariñas Coruñesas. A similar pattern was observed in the 2011-2014 period. During the 2009-2011 period, land artificialization was only detected in the southern groups (Fig. 6).

Figure 7 shows fluxes between land cover classes in the municipalities' coastal strip (2005-2014) resulting from the corresponding cross-matrix, as proposed by Pontius, Shusas & McEachern (2004) and Martínez-Fernández *et al*. (2015). The total area transformed into the artificial class in this period was 4610 ha. Almost 3000 of them were previously classified as forest or seminatural areas, and around

FIGURE 7
LAND COVER FLUXES IN THE MUNICIPALITIES' COASTAL STRIP



Land cover fluxes in the municipalities' coastal strip between 2005 and 2014. Units: hectares. Data less than 0.01% are not included.

1600 hectares as agricultural areas. 215 hectares of total land uptake by artificial surfaces correspond with land reclamation.

Therefore, 61.4% of the new artificial areas derive from forests or seminatural areas, 33.8% from agricultural areas, 4.7% from areas reclaimed from the sea and 0.1% from wetlands and water bodies.

We further explored fluxes involving land artificialization to analyse and characterise their dynamics, aiming at a better understanding of the processes involved in the generation of artificial land (Table 4). It is worth mentioning that artificialization fluxes in the coastal municipalities strip and in the 10 km coastal zone coincide.

TABLE 4
LAND COVER ANNUAL CHANGE RATES WITH RESPECT TO THE TOTAL AREA OF EACH LAND COVER CLASS IN THE INITIAL YEAR OF EACH PERIOD AND WITH RESPECT TO THE AREA OF EACH CLASS

	Land cover annual change with respect to the total area			
	05-09	09-11	11-14	05-14
Agricultural zones to artificial surfaces	0.073	0.008	0.028	0.042
Forest or seminatural areas to artificial surfaces	0.132	0.016	0.071	0.076
Land reclamation	0.009	0.002	0.005	0.006

	Land cover annual change with respect to the area of each class			
	05-09	09-11	11-14	05-14
Agricultural zones to artificial surfaces	0.338	0.039	0.133	0.193
Forest or seminatural areas to artificial surfaces	0.199	0.025	0.107	0.115
Land reclamation	-	-	-	-

Land cover annual change rates (%) with respect to the total area of each land cover class in the initial year of each period, and with respect to the area of each class; agricultural zones changing to artificial surfaces; forests or seminatural areas changing to artificial surfaces, and land reclamation (classified as artificial surfaces). Municipalities' coastal strip. (Periods: 2005-2009; 2009-2011; 2011-2014; 2005-2014).

The largest changes were concentrated again in the period 2005-2009, being the forest and seminatural classes those presenting the more intense annual changes. During that period, 0.13% of the municipalities' coastal strip became artificialized at the expense of forests or seminatural areas. The most noticeable change from agricultural areas to artificial surfaces occurred in the same period (0.07% of the total area of the strip per year). When land cover annual changes (%) with respect to the total area of each class were considered, the agricultural class presented the higher rates in all the periods. A total of 1211 agricultural hectares were artificialized between 2005 and 2009, representing a rate 17-fold higher than in the 2009-2011 period and more than 3-fold higher than in the last one (2011-2014). In the forestry class, 2180 hectares classified as forest or seminatural areas in 2005 were transformed into artificial surfaces until 2009, 16-fold higher than in the period 2005-2009 and 2.5 higher than in the last period.

The high demand for human settlements and the development of economic activities in the coastal zone triggers a high rate of land consumption. In this study, we found the largest changes in the artificial class, which increased by more than 7% in the studied period, at the expenses of forest and seminatural areas. In most cases, the spatial pattern of this artificialization process was associated with disorganised growth detached from traditional urban settlements, resulting in a diffuse transformation of the Galician coast leading to significant territorial and landscape fragmentation. This fragmentation directly affects ecological connectivity, thereby amplifying several environmental problems such as soil sealing, deforestation, water, soil or air pollution, as well as biodiversity losses (Celliers and Ntombela, 2016; Pasquali and Marucci, 2021).

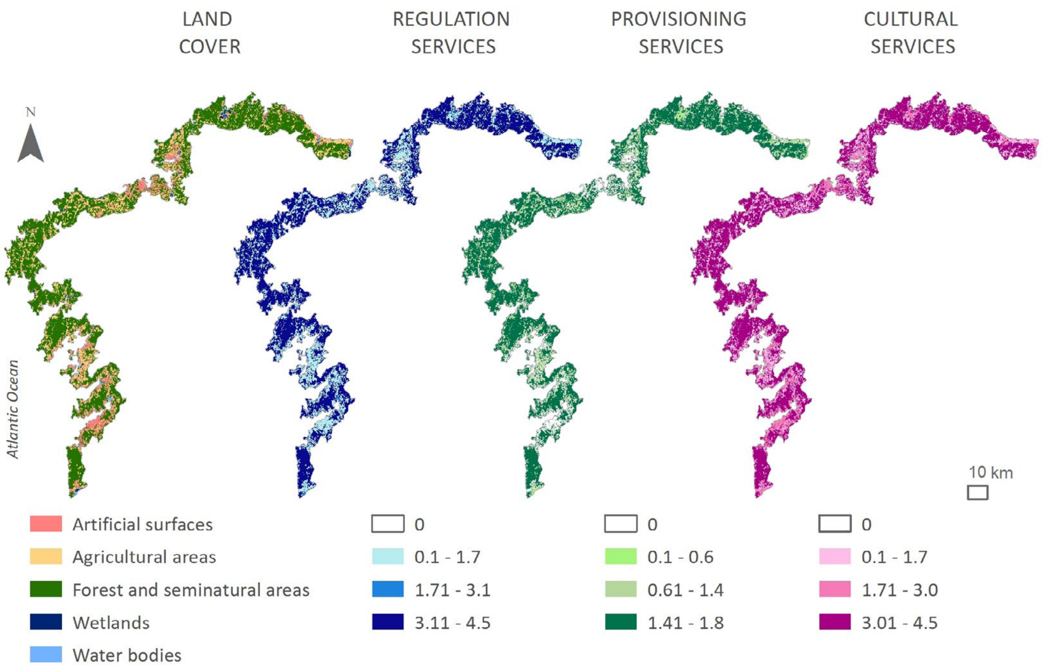
3.2. Impact of artificialization on ecosystem services

Figure 8 shows the spatial distribution of land cover and the potential to provide ecosystem services (ES) of the three main categories (regulation, provisioning and cultural).

The lower potential to provide ecosystem services is generally associated with the anthropogenic land cover types (except some cultural ecosystem services), while agricultural and forest or seminatural areas show high potential in the regulation and provisioning ecosystem services. The two divisions characterised by the highest artificialized areas present the lowest values of ES (Mariñas Coruñesas and Rías Baixas).

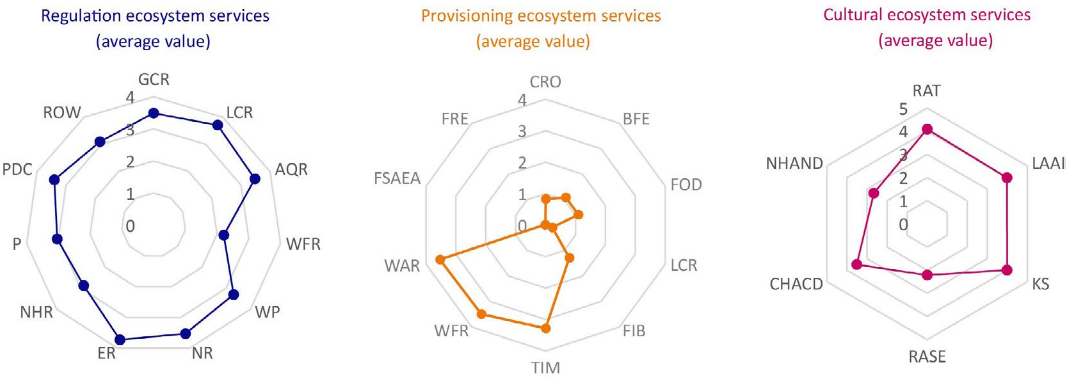
Local Climate Regulation and Erosion Regulation showed the highest values within the regulation services whereas Wild Foods and Resources and Wood Fuel scored high in provisioning services. Recreation and Tourism, Landscape aesthetics and Inspiration and Knowledge Systems were the most important cultural services. Regulation and provisioning services were largely associated with forest and seminatural areas (the predominant land cover class in the study area, 65%). On the contrary, all the land cover classes contributed to cultural services.

FIGURE 8
SPATIAL DISTRIBUTION OF LAND COVER CLASSES AND ECOSYSTEM SERVICES' POTENTIAL IN THE COASTAL MUNICIPALITIES



Spatial distribution of land cover classes and regulating, provisioning and cultural ecosystem services' potential (scale from 0 = no potential to 5 = very high relevant potential) in the coastal municipalities in 2014.

FIGURE 9
AVERAGE VALUES OF THE DIFFERENT ECOSYSTEM SERVICES IN THE STUDY AREA



Average values of the different ecosystem services in the study area in 2014. Global climate regulation: GCR; Local climate regulation: LCR; Air quality regulation: AQR; Water flow regulation: WFR; Water purification: WP; Nutrient regulation: NR; Erosion regulation: ER; Natural hazard regulation: NHR; Pollination: P; Pest and disease control: PDC; Regulation of waste: ROW; Crops: CRO; Biomass for energy: BFE; Fodder: FOD, Livestock (domestic): LCR; Fibre: FIB; Timber: TIM; Wood Fuel: WFR; Fish, seafood & edible algae and aquaculture: FSAEA; Wild foods & resources: WAR; Freshwater: FRE; Recreation & tourism: RAT; Landscape aesthetics & inspiration: LAAI; Knowledge systems: KS; Religious & spiritual experience: RASE; Cultural heritage & cultural diversity: CHACD; Natural heritage & natural diversity: NHAND.

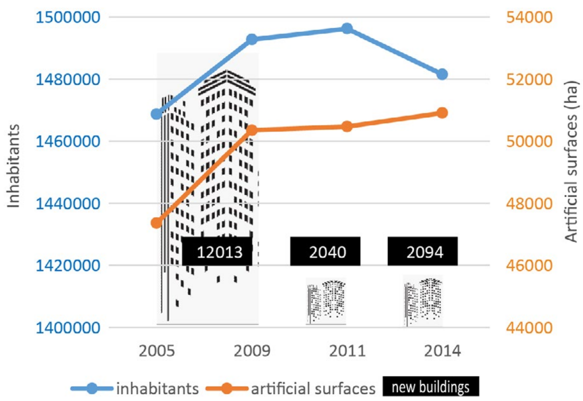
The potential to deliver ecosystem services showed a temporal declining trend in the study period, showing annual decreasing rates of -0.13% (provisioning services), -0.05% (regulation services) and -0.003% (cultural services). The highest annual loss rates corresponded with two provisioning services, crops (-0.35%) and livestock (-0.32%), and it is related to the decreased by 3% of the agricultural areas.

Ecosystem services have been presented as a useful tool to assess de parallel evolution between natural and human processes (Burkhard *et al*., 2009; Hasan *et al*., 2020). This study revealed that land cover changes produced in the study area had a direct effect on ecosystem services, as previously detected by other authors (Burkhard, Kroll, Nedkov & Müller, 2012; Hasan *et al*., 2020; Kandziora *et al*., 2013; Yirsaw, Wu, Temesgen & Bekele, 2016). Therefore, it would be desirable to integrate the ecosystem services approach into land use planning as it demonstrated to be a useful tool for environmental sustainable management or (Baral, Keenan, Fox, Stork & Kasel, 2013; Bastian *et al*., 2012; Burkhard *et al*., 2014; Müller and Burkhard, 2007; Vihervaara, Kumpula, Tanskanen & Burkhard, 2010).

3.3. Relationship between artificialization rates and demographic and economic variables

In Figure 10, the temporal evolution of the population, artificial area and number of new buildings in the coastal municipalities of the Galician coast is shown.

FIGURE 10
EVOLUTION OF THE NUMBER OF INHABITANTS, HECTARES CLASSIFIED AS ARTIFICIAL SURFACES AND NUMBER OF NEW BUILDINGS



Evolution of the number of inhabitants, the hectares classified as artificial surfaces in the coastal municipalities, and the number of new buildings (2005-2009; 2009-2011; 2011-2014). ("Building: permanent construction, fixed on the ground, separate and independent, conceived to be used for residential purposes and/or for the development of an activity").

The three variables show a sharp increase from 2005 to 2009, when the registration of new buildings was 6-fold higher than in the rest of the periods studied. Population increased until 2011, then decreased in the last period, although the number of new buildings was similar and, consequently, the artificialized area still increased with respect to the previous period. The number of hectares classified as artificial surfaces per capita raised continuously from 322 m^2 of artificial surface per inhabitant in 2005 to 343 m^2 in 2014.

Galicia showed a negative demographic growth (-0.06% $year^{-1}$) in the period 2005-2014. However, in the coastal municipalities, the temporal evolution of this variable was positive (+0.10% $year^{-1}$). Spanish population growth in the period 1991-2011 was positive (1.02% $year^{-1}$) and slightly lower (0.87% $year^{-1}$) when the 10 km coastal zone was considered (Observatorio de la Sostenibilidad, 2016b).

The domestic gross disposable income was also used in this analysis as it measures the income of the residents of a given territory used for consumption and savings operations. This indicator, therefore, may reflect if the artificialization process carried out in the territory directly reverts to the families' economy or, on the contrary, it does not represent an improvement in economic terms for the local populations.

A correlation analysis was performed among the different variables, including artificialization (artificialized hectares excluding those dedicated to transport networks or industrial development, which represent 55% of the total artificialized area between 2005 and 2014), the variation in the number of inhabitants, the number of new buildings and the changes in the domestic gross disposable income (by municipality in the period 2005-2014). Two municipalities were excluded from the analysis: Ferrol and Arteixo due to their demographic and economic singularities (supplementary material).

A bivariate Pearson correlation was calculated to assess the relationship between the selected variables in the coastal zone and in each of the geographical di-

TABLE 5
A: PEARSON CORRELATION MATRIX. VARIABLES: ARTIFICIALIZATION, NEW BUILDINGS, CHANGES IN NUMBER OF INHABITANTS, CHANGES IN DOMESTIC GROSS DISPOSABLE INCOME ALONG THE COASTAL MUNICIPALITIES' ZONE. B: CORRELATIONS IN THE COASTAL DIVISIONS

A	Artificialization	New buildings	Population	Domestic gross income
Artificialization	1	0.611**	0.460**	0.540**
New buildings		1	0.706**	0.641**
Population			1	0.519**
Domestic gross income				1

B	N	Artificialization-New buildings	Artificialization-Population	Artificialization-Domestic gross income
Costa da Morte	14	0.817**	0.587*	0.726**
Mariñas Coruñesas	13	0.592*	0.603*	0.782**
Rías Altas	13	0.083	0.052	0.310
Rías Baixas	29	0.782**	0.432*	0.435*

A: Pearson correlation matrix. Variables: artificialization, new buildings, changes in the number of inhabitants, changes in the domestic gross disposable income along the coastal municipalities' zone (except Ferrol and Arteixo). B: Correlations in the coastal divisions (Sur de Galicia is ruled out because of the low number of municipalities to perform a statistical analysis).
** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

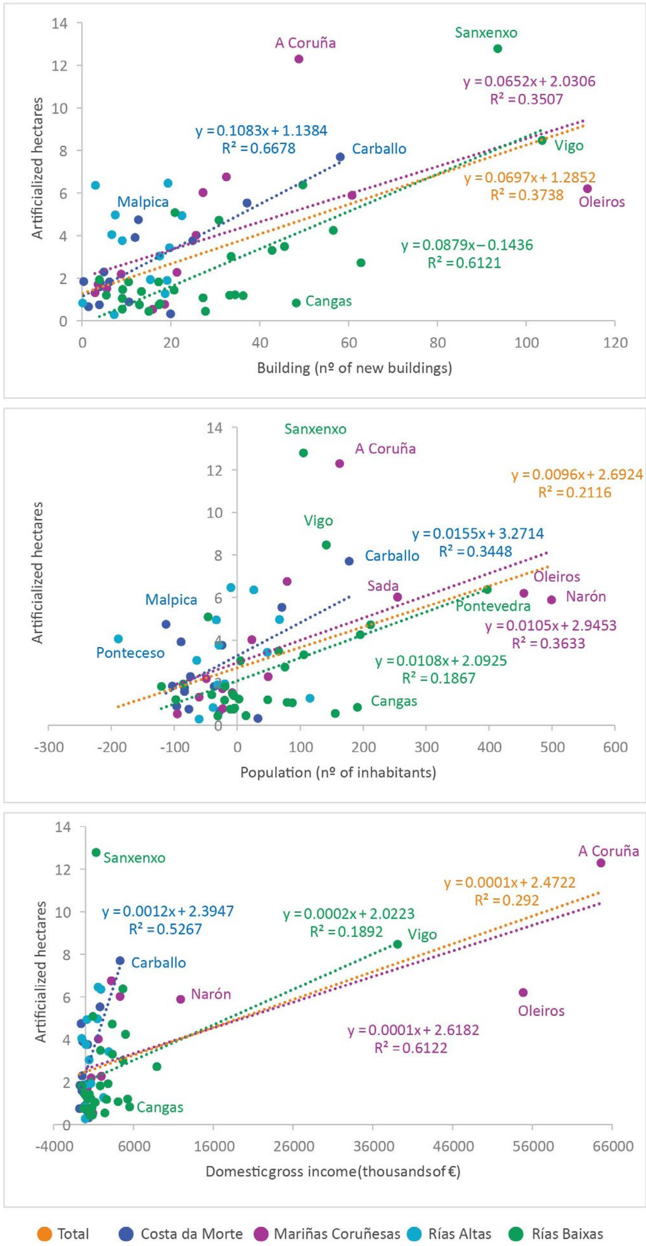
visions. The four variables are significantly correlated when all the coastal municipalities were considered (Table 5). The significant correlation between population and land cover/land use changes found in this study is consistent with the results reported in previous investigations focused on the drivers of land use and land cover (Clement and York, 2017; Kamwi *et al*., 2015; Oreinstein and Hamburg, 2010).

Neither of the tested variables showed statistically significant correlations in the Rías Altas division. This area is characterised by the absence of large urban centers concentrating the population and economic activity and, consequently, transforming the environment. Despite this division showed the second highest averaged rates of artificialization (3.33 ha $year^{-1}$), it is not related to parallel population increases (70% of the municipalities in this division show a demographic decrease between 2005 and 2014), nor to domestic gross income variability. Several processes could account for the observed pattern, such as second home developments, which accounted for a large fraction of the total artificialization process in some municipalities or the dispersed occupation of the territory, mainly with single-family buildings, surrounded by small yards, whose designation in the SIOSE classification represents an overestimation of artificial land cover (Olazabal and Bellet, 2017).

Almost half of the artificialization of the Galician coast (41.5%) occurring from 2005 to 2014, derived from non-artificial land covers corresponding to the categories: "Residential agricultural settlement" (areas with mainly residential use, characterised by a dispersed settlement of buildings, accompanied by arable and/or woody crops), or "Discontinuous urban fabric", ie. areas occupied by buildings mainly for housing associated with vegetated areas and bare surfaces, including urban areas that may be consolidated or in the process of consolidation. In both cases they do not represent crowded areas of buildings, so it is unlikely that the number of buildings could account for the whole of the artificialized area. The existence of these scattered settlements is the reason why many polygons appeared as transformations from non-artificial land cover to discontinuous urban fabric land covers, thereby yielding inconsistent results.

The slopes of the linear regressions between changes in population or new buildings and artificialization rates did not significantly differ depending on the zone (ANCOVA p = 0.852 and p = 0.467, respectively). By contrast, significant differences were found in the slope of the regression lines derived from the relationship between artificialization rates and domestic gross income in the different divisions, although the p-value resulting from the correlation between artificialization and domestic gross income (0.08) is close to the reference value (0.05), it does not seem correct to rule out the existence of significant differences (Amrhein, Greenland & McShane, 2019) since, as shown in Figure 11, the re-

FIGURE 11
LINEAR REGRESSIONS BETWEEN ARTIFICIALIZED AREAS, NUMBER OF NEW BUILDINGS, POPULATION AND DOMESTIC GROSS INCOME IN THE COASTAL DIVISIONS



Linear regressions between artificialized areas, number of new buildings, population and domestic gross income in the coastal divisions. (Only regression lines with significant correlation are represented). Period: 2005-2014.

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gression line corresponding to Costa da Morte shows a different pattern from the other divisions.

On average, 700 m^2 became artificialized per each new building and 96 m^2 of the territory were transformed into artificial per each new inhabitant when the 2005-2014 period was considered. These values can be compared with the data provided by the European Environment Agency, although this comparison should be made with caution since they referred to the whole country and are divided into two periods (2000-2006 and 2006-2012). According to EEA, 115 m^2 was artificialized in Spain per each new inhabitant in the first period and 29 m^2 new inhabitant^{-1} in the second one, while the values for France were 149 and 126 m^2 new inhabitant^{-1} and 438 and 426 m^2 new inhabitant^{-1} in the case of Portugal. It is worth noting that despite the higher number of artificialized hectares per new inhabitant estimated for Spain or France, the subtle demographic growth of Portugal in this period causes the higher amount of surface assigned to each new inhabitant.

Sanxenxo, located in the Rías Baixas division, was the municipality with the highest artificialization rates (12.79 ha), and the city of Vigo showed the largest number of new buildings built, with 104 new buildings year^{-1}. Unlike the other divisions, in which population decreased, more than 50% of the municipalities belonging to the Rías Baixas division increased their population (2005-2014). The highest averaged domestic gross income and population are concentrated in the Mariñas Coruñesas division, although this division did not show the highest average number of new buildings per year. This observation can be explained by the patterns found in urban areas of A Coruña and Ferrol, characterised by an increase in population and domestic gross income. These municipalities form a supramunicipal area, with one of the most important industrial conglomerates in Spain, where energy, construction, shipyards, clothing and metallurgy industries are concentrated. Both divisions (Rías Baixas and Mariñas Coruñesas) present very similar patterns, as shown in Figure 11, and as evidenced by the correlation analyses discussed above.

The relationships between artificialization and domestic gross income present different patterns in the divisions considered in this study. As noted earlier, Mariñas Coruñesas and Rías Baixas present similar results, with 1-2 m^2 of territory required to increase the domestic gross disposable income by one unit (thousand of €). On the contrary, the division Costa da Morte, characterised by decreasing population and domestic gross income values, required 12 m^2 to achieve the same goal. Two municipalities under the influence of the urban area of A Coruña, A Laracha and Carballo, stand out with respect to the others, concentrating the largest increases both in inhabitants and domestic gross income and presenting artificialization rates 2 to 3-fold higher than the average of the division, respectively. In the case of this division, the slopes of the regression lines between artificialization and population or income were positive. Most of the municipalities of this division showed increases in artificialization and new buildings that are not associated with parallel increases in population or income. This division contains 5 of the 6 most extensive municipalities of the Galician coastal zone, with a high percentage of non-coastal territory and with a markedly disseminated settlement, ie. the dominant land cover class is the "discontinuous urban fabric", which as mentioned above, may involve an overestimation of the artificial surface resulting from the SIOSE classification. It should also be noted that, unlike the other two divisions, Costa da Morte has not any urban aggregate with the potential for development and growth, thus constraining population growth and economic development of this area.

The results obtained in this study show that land take occurring in the Galician coastal zone, mainly at the expense of forest and seminatural territories, affected the potential services provided by ecosystems but was not generally related to demographic or domestic economic drivers.

4. CONCLUSIONS

Land use change (especially urbanization) directly affect the food provisioning and regulation services, being an anthropogenic driver which modulates ecosystem functioning and structure. The artificialization process led to the reduction of ecosystem services related to local and global climate regulation. Processes derived from land use changes, such as the increase of impervious surfaces or the artificialization of riverbanks give rise to a lower response capacity of the territory, resulting in territories less resilient to climate change. Riparian ecosystems contribute to ecological adaptation to climate change, particularly facing the observed and expected increases in extreme meterological events, in the magnitude and seasonality of precipitation and run-off, and in atmospheric and water temperature. The increase in impervious surfaces prevents infiltration and increases surface run-off, making the territory vulnerable to extreme meteorological events. In addition, the increase in artificial surfaces also has a direct effect on the territory's ability to mitigate climate change, altering its function of carbon sink. When replacing forests with artificial surfaces, fewer areas contribute to carbon dioxide uptake, so the amount of CO_2 in the atmosphere increases.

In this context, the location of a substantial part of urban spaces in the coastline exposes them to the impact of extreme coastal events and sea level rise while, at the same time, lead to a loss of environmental quality and value of coastal ecosystems.

The significant loss of forests and seminatural areas observed in our study was related to a loss of regulation services and a decrease in the provision of ecosystem services. Soil sealing irreversibly affects highly productive agricultural areas since it causes loss of productive capacity and, ultimately the decline of the primary sector, traditionally very important in the Galician economy. The progressive contraction of agricultural, livestock and forestry activities is parallel to the decrease in the absolute and relative importance of the population employed in the sector. In the 2009-2014 period, the population employed in the "Agriculture, livestock, hunting and forestry" represented 6.2% in mid-2009 and decreased to 4.9% in 2014 (IGE-INE, Economically Active Population Survey, data consulted 03-22-2022).

The results obtained in this study indicated that despite the decrease in population of the Galician coastal zone in the last period of this study, the number of artificialized hectares and the construction of new buildings increased.

The observed changes in the land cover patterns in Galicia, and their effect on ecosystem services and impact on the regional economy, warn of the need to reverse this trend of land occupation. This reversing process should be based on solid territorial planning that integrates the dimensions of urban and rural development, considering energy, housing, infrastructures, economic development and human well-being. In this regard, two relevant planning instruments were established in Galicia in 2011, aiming at the sustainable development of the territory: the "Directrices de Ordenación del Territorio" and the "Plan de Ordenación Litoral". Although both territorial planning instruments were already operative during the second period analysed in this study, the results of our investigation suggest that they have not been capable of reversing the artificialization trend of the Galician territory. The regional scale of these planning instruments and the diversity of processes and conditions taking place in the littoral strip, makes difficult establishing and implementing territorial indicators leading to the limitation of coastal artificialization. However, the definition of land consumption or land artificialization ratios at the municipal planning scale, or even at more detailed scales, can help promoting compactness and rational use of the territory. In this sense, the definition of one or several strips from the coastline, where anthropization, or some of its components, such as urbanization, could not exceed predetermined values, such as the municipal average, might be an action leading to a more rational territorial management of the coastal areas.

Our results suggest that modification of the existing planning instruments fostering a sustainable articulation of the territory and improving resilience is needed. The assessment of changes in the ecosystem services provided by the territory introduces a new relevant element to be considered in the evaluation of its use-value and highlights the role of the territory at the service of human well-being.

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SUPPLEMENTARY MATERIAL

I. Land cover accounts for the 10 km coastal zone. Units: hectares and percentage

Land cover class	2005	%	2009	%	2011	%	2014	%
Artificial surfaces	57236.55	10.70	60798.86	11.36	60962.80	11.39	61493.95	11.49
Agriculture areas	114150.83	21.34	112376.24	21.01	112210.41	20.97	110565.14	20.66
Forest and seminatural areas	354670.69	66.31	353038.98	65.99	353041.87	65.99	354190.09	66.20
Wetlands	3258.59	0.61	3261.53	0.61	3267.97	0.61	3281.30	0.61
Water bodies	5515.54	1.03	5512.10	1.03	5513.17	1.03	5525.69	1.03

II. Land cover accounts in the municipalities' coastal zone. Units: hectares and percentage

Land cover class	2005	%	2009	%	2011	%	2014	%
Artificial surfaces	47360.93	11.32	50350.24	12.03	50473.89	12.06	50865.13	12.15
Agriculture areas	89617.45	21.42	88188.86	21.07	88025.96	21.03	86864.14	20.75
Forest and seminatural areas	274083.74	65.51	272678.80	65.15	272719.05	65.16	273534.09	65.34
Wetlands	3048.35	0.73	3051.43	0.73	3057.87	0.73	3071.20	0.73
Water bodies	4266.32	1.02	4262.96	1.02	4264.03	1.02	4266.18	1.02

III. Population in 2005, 2009, 2011 and 2014 (SIOSE's dates) and number of new buildings in the periods in between (2005-2009, 2009-2011, 2011-2014) in the Galician coastal divisions

	Population 2005	Population 2009	Population 2011	Population 2014	New buildings 2005-2009	New buildings 2009-2011	New buildings 2011-2014
Costa da Morte	135592	136010	136307	133400	1498	274	288
Mariñas Coruñesas	456344	463551	464328	460928	2910	481	465
Rías Altas	87973	88846	88022	85720	1240	111	138
Rías Baixas	769402	784138	787339	781676	5923	1117	1129
Sur de Galicia	19430	20222	20276	19811	442	57	74
Total	1468741	1492767	1496272	1481535	12013	2040	2094

IV. Matrix for the assessment of the different land cover class and its capacity to provide ecosystem services (adapted from Burkhard's matrix)

	Regulating services	Global climate regulation	Local climate regulation	Air quality regulation	Water flow regulation	Water purification	Nutrient regulation	Erosion regulation	Natural hazard regulation	Pollination	Pest and disease control	Regulation of waste
Artificial surfaces		0	0	0	0	0	0	2	0	0	1	0
Agricultural areas		1	2	1	1	0	1	1	1	2	3	2
Forest and seminatural areas		5	5	5	3	5	5	5	4	4	4	4
Wetlands		1	1	0	2	1	3	1	4	1	2	2
Water bodies		1	1	0	3	3	3	0	3	0	3	5

	Provisioning services	Crops	Biomass for energy	Fodder	Livestock (domestic)	Fibre	Timber	Wood Fuel	Fish, seafood & edible algae and aquaculture	Wild foods & resources	Freshwater
Artificial surfaces		0	0	0	0	0	0	0	0	0	0
Agricultural areas		4	2	2	1	3	0	1	0	1	0
Forest and seminatural areas		0	1	1	0	1	5	5	0	5	0
Wetlands		0	0	3	2	0	0	0	0	1	0
Water bodies		0	2	0	0	0	0	0	4	4	2

	Cultural services	Recreation & tourism	Landscape aesthetics & inspiration	Knowledge systems	Religious & spiritual experience	Cultural heritage & cultural diversity	Natural heritage & natural diversity
Artificial surfaces		3	2	2	2	2	0
Agricultural areas		2	2	2	0	3	0
Forest and seminatural areas		5	5	5	3	4	4
Wetlands		2	2	3	0	2	2
Water bodies		3	4	4	1	2	3

0=no relevant potential; 1=low relevant potential; 2=relevant potential; 3=medium relevant potential; 4=high relevant potential; 5=very high relevant potential.

V. Municipalities excluded from the regression analysis

The municipality of Ferrol, presents a population decrease of 751 inhabitants year^{-1} and an increase in the artificialization rate of 13.92 ha year^{-1} between 2005 and 2014. It is an industrial municipality, which depends almost exclusively on the naval sector, therefore with a low productive flexibility. The lack of employment has caused a continuous and steeped demographic decrease, which is accompanied by population aging. In the case of Arteixo, three main events clearly distorted land use and demographic patterns in this municipality. Firstly the outer port of A Coruña (one of the largest in Spain) was built in that period, implying a high artificialization rate of 61 ha year^{-1}. Secondly, there is a disproportionate increase in population (509 inhabitants year^{-1}) and thirdly, a high increase in the domestic gross income was also observed (13000 thousand euros year^{-1}). Among the causes, it is worth highlighting the industrial complex of Sabón (which houses a relatively large number of companies with a high number of employees), its proximity to A Coruña (that makes Arteixo an alternative as a residence) and, finally, the presence of a powerful business group, Inditex (which positions it as one of the Galician municipalities with the highest per capita income).