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Regional drivers of land take: a comparative analysis in two Italian regions

Abstract

Recent research has focused on quantitative measurement of land take at both the international and the national level, so much so that systematic information has been collected and made available at the EU level. However, not much literature has up to now explored the quantitative relationship between factors affecting land take and land-taking processes. Moreover, still little investigated is the relation between land-taking processes and territorial policies and plans.

By building upon previous studies on the identification of the main drivers of land take and on the analyses of the influence of such drivers on the phenomenon at the regional level, this paper aims at understanding whether the drivers act similarly in different contexts. Of particular interest here is the role played by planning-related factors, since, in a planning system in which many competences are devolved to regions, regional plans lay their own set of rules and regulations, which might (or might not) effectively counter land taking processes.

We choose to explore this issue by looking at two coastal Italian regions, as coastal areas' intrinsic territorial fragility and residential polarization might significantly amplify the magnitude of negative impacts associated with land take.

1. Introduction

Notwithstanding the growing interest in measuring its magnitude, and assessing its unwanted consequences, a rigorous and unambiguous definition of land take has not been provided yet. In itself, “land take” is a Euro-English expression which is usually and variously associated to urban and other artificial land developments and to the loss of agriculture, forest and other natural or semi-natural land. Among the various extant definitions, and following Zoppi and Lai (2014; 2015), we choose the operational definition provided by the European Environment Agency (EEA) (2013), which defines land take as the “Change of the amount of agriculture, forest and other semi-natural and natural land taken by urban and other artificial land development. It includes areas sealed by construction and urban infrastructure as well as urban green areas and sport and leisure facilities”.

The reason for this choice is that the selected definition allows for a quantitative assessment of the phenomenon over the years, provided that consistently produced measurements of artificial land are available within the chosen time frame.

The very lack of such consistently produced, hence comparable, measurements is the main reason that explains the conflicting assessments of worldwide magnitude of land take. Assessments of artificial land range from 0.18% of the world land area in the ‘90s (Hansen et al., 2000:1350) to 0.20% in 2000 (European Commission, Joint Research Centre, 2003), to 0.88% in 2010 (Chen et al., 2014), and it is indisputable that in such years a significant land take occurred globally. However, to compare such data in order to derive a quantitative assessment of land take would be wrong because of the irreconcilable differences in data production.

At the National (Italian) level, a recent report produced by the National Research Institute for the Protection of the Environment (ISPRA, 2015, pp. 10-11) shows that land take has increased steadily - albeit with a slight decrease in pace in the latest years - from 8,100 km^2 (equaling 2.7% of the national land mass) in the ‘50s to approximately 17,000 km^2 (5.7%) in the ‘90s, to 21,000 km^2 (7.0%) in 2014.

Within this context, we analyze and compare land-taking processes in two Italian NUTS2 regions, Liguria and Sardinia, by building upon two previous studies by Zoppi and Lai (2014; 2015) that estimate the magnitude of land take in Sardinia over two different timeframes (2003-2008 and 1960-2008 respectively), analyze Sardinian drivers of land take, and assess their quantitative impacts.

The aim of this paper is therefore to understand whether land take processes in Liguria and in Sardinia over two similar time periods were influenced by the same drivers or whether regional peculiarities must be taken into account to explain differences. The results of this comparison are of particular relevance in terms of policy making and evaluation, since this paper highlights that the main differences between the two case studies are related to different regional policies and planning measures in force in the two selected studies, while the significance and the impact of other drivers is quite similar in the two regions.

This paper is organized as follows. The second section provides the reader with a definition of land take, followed by a presentation of the case studies and by a preliminary identification of potential drivers of land take. In the third section, data on the magnitude and the trend of land take in the two regional selected case studies and chosen timeframes are presented; next, we provide the results of the econometric model correlating land take and its drivers, as well as regional inferences drawn upon the results. Finally, in the fourth and concluding section, we discuss relevant similarities and differences that should be taken into account to define customized regional planning policies that help limit land take.

2. Land-take and its drivers

2.1 Defining land take

To identify an agreed-upon measure of land take is difficult for a number of reasons, among which the most important is the definition of land take itself. Among the various available definitions, we choose to follow the one provided by the European Environment

Agency (2013), according to which land take is the “Change of the amount of agriculture, forest and other semi-natural and natural land taken by urban and other artificial land development. It includes areas sealed by construction and urban infrastructure as well as urban green areas and sport and leisure facilities”.

If we agree on the above definition, then land take occurs when a piece of land, classed as agricultural or forestry or natural land in a given year, in a subsequent year is “taken” by artificial land development. Artificial areas, in the definition of land take provided by the EEA, include, but are not limited to, sealed surfaces and urban areas. Small green areas surrounded by built-up areas, for instance, are included within artificial areas, as well as natural or seminatural areas in low-density outskirts (Comber, 2008, Serra et al. 2008, Ferreira, 2010, Sharma et al. 2012, Başnou et al. 2013).

From this standpoint, the Corine Land Cover (CLC) classification is quite handy to assess quantitatively land take for two reasons. First, it groups land cover types into five main classes at Level 1: (1) artificial areas, (2) agricultural areas, (3) forests and semi-natural areas, (4) wetlands, and (5) waterbodies; hence, land take as defined by the EEA can be measured as the size of areas that were classed as non-artificial classes (that is, belonging to classes 2, 3, 4, or 5 as above listed) in a given year and that are classed as artificial (that is, belonging to class 1) in a subsequent year. Second, available and comparable datasets based on this classification exist, which in principle makes it possible to obtain consistent measures across Europe and in different timeframes.

2.2 The two regional case studies

Two Italian coastal regions, Sardinia and Liguria (Figure 1), in which the relation inland-coastal area dramatically changed in the XX century, are here chosen as case studies because of two main reasons: first, the population shift from rural to the main (and coastal) urban areas; second, the significance of tourism-related land development. The two above factors jointly contribute to exacerbate the differences between inland and coastal areas in terms of population and income. A second common aspect is the fairly large number of municipalities in the two regions (377 in Sardinia, which spans over approximately 24,000 km^2 and has a population of about 1.64 million people in 2011, and 235 in Liguria, which has an area of around 5,400 km^2 and a population of about 1.57 million people in 2011), which in Italy are responsible for granting planning permits and for building and maintaining local infrastructure. Moreover, in both regions, strong planning rules have been recently implemented in order to control development and transformation of land in areas deemed as worth preserving for their landscape characteristics or natural assets.

FIGURE 1

2.3 Potential drivers of land take in the context of the two case studies

After Zoppi and Lai (2014; 2015)and in accordance with Lambin (2001) and Veldkamp and Lambin (2001), we hypothesize that land take is affected by physical aspects, by spatial planning-related factors, and by social determinants.

Among physical factors we include the average size of a municipality's non-artificial-land areas at the beginning of each time period that became "artificialized" (meaning that they can be classed as "artificial" in the CLC) by the end of that period, as well as their slope and their distance from the nearest town[1]; we also include accessibility (in terms of: endowment of roads[2], proximity to the regional administrative capital center, proximity to the closest province administrative center); finally, we also consider the distance from the shoreline.

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[1] The centroid of a town's built-up area was used to calculate the distance.
[2] We only included those roads that the Italian Code concerning Road Regulation (Italian law enacted by Decree n. 1992/285) classifies as "Highways", "Main extra-urban roads" and "Secondary extra-urban roads"; this means

Among factors related to spatial planning we consider the presence and endowment of nature conservation areas (such as national parks, regional parks, nature reserves, Sites of Community Importance Special Protection Zones, Special Conservation Areas, Ramsar sites: see Pileri and Maggi (2011) for a comparative analysis in the Italian territory), and of natural and seminatural areas as defined in the planning instruments in force in the two regions (the Sardinian RLP in Sardinia and the Landscape Plan in Liguria, next LP). Next, because the regional planning tools in force in the two regions differ in defining areas that should be either more suitable for, or less prone to, urbanization, for each time period here considered for Sardinia we include the amount of area that was included in the so-called “coastal strip” as defined in the same RLP, or in which land transformation was not allowed under the previous landscape plans in force until 2006. For the Liguria region, strict building restrictions are in force in a 300-metre buffer zone along the shoreline, and “softer” restrictions in a 1,000-metre buffer zone along the shoreline, hence we consider these two variables. Moreover, we also include for each time period the amount of area that was artificialized and that was classed either as “conservation” or as “maintenance” areas in the Liguria LP in force since 1991. “Conservation” areas are defined in the LP as areas in which new development and infrastructure are forbidden so as to preserve current features and built volume, and to prevent the sealing of previously non-sealed surfaces, whereas in the so-called “maintenance” areas increase in built volume is allowed, provided that such increase does not entail transformation of rural settlements into urban ones. However, the implementation of the plan provisions was not straightforward, especially in the western part of the region, where new development entailed the rise of new “hybrid” (rural-urban) settlements.

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that basically only roads connecting towns and city centers were included in our analysis, leaving aside minor tracks and dirt roads. In the Sardinian case, the layout of such roads is provided within the so-called “Regional Multiprecision Spatial Dataset” (available from http://www.sardegnageoportale.it/index.php?xsl=1598&s=291551&v=2&c=8831&t=1); for the Liguria region within the so-called “Topographic Database” (available from http://www.cartografia.regione.liguria.it/apriFoglia.asp?itemID=30102&fogliaID=1237&label=Carta%20Tecnica%20Regionale%201:5000%20dal%202007%20-%20II%20Edizione%203D%20/%20DB%20Topografico).

Among social determinants we here consider residential density, which accounts for spatial polarization of urban settlements.

Finally, a series of Moran tests was performed in order to derive an autocorrelation-related spatially-lagged dependent variable (Anselin 1988; 2003), under the assumption that proximity to areas that have been artificialized also plays a role in affecting land take.

The full list of potential drivers is provided in Table 3, together with their definitions and motivation for their selection on the basis of the literature.

TABLE 3

3. A quantitative assessment of land-take at the regional scale: the case of Liguria and Sardinia

3.1 Land take in Liguria and Sardinia

In order to measure land take in the two regions selected as case studies, an appropriate selection of relevant spatial datasets was made, and various GIS-based analyses were performed.

Our spatial units coincide with the municipalities, while our selected time intervals are as follows: 1960-1990 and 1990-2008 for the Sardinian case study and 1960-1994 and 1994-2008 for the Liguria case study. The slight difference in the above timeframes is due to differences in land cover data availability for the two regions. For Sardinia, data were obtained from the Regional Landscape Plan (RLP, for the year 1960)[3], from the European

[3] The spatial dataset of the Sardinian RLP (produced in 2006, scale 1:10,000) is available at http://www.sardegnageoportale.it/index.php?xsl=1598&s=291552&v=2&c=8831&t=1 [accessed February 9, 2016]. We selected two vector layers, of which the first describe historic settlements, defined as artificial areas as of the end of the XIX century on the basis of the maps produced by the (then) Royal Geographic Italian Military

Environment Agency (Urban Morphologic Zones as of 1990)[4] and from the regional CLC map (for the year 2008)[5]; because of the differences in aim and resolution, the three datasets were preprocessed to avoid inconsistencies. For Liguria, data were obtained from the National Land-use Map published by the Italian Touring Club at the beginning of the ‘60s[6], and from a selection of appropriate layers of the Regional technical map edited by Regione Liguria in 1994[7] and 2007[8]. We believe that, since our aim is here to compare land take phenomena in two regions and in two different timeframes in order to understand whether drivers of land take act similarly, this choice of data sources was the best possible solution, because it allowed us to build comparable datasets for the two regions.

Tables 1 and 2 show the definitions of the variables and the descriptive statistics concerning non-artificial and artificial land cover for all of the 377 municipalities in Sardinia and the 235 municipalities in Liguria.

Institute, and the second urban development as of the end of the1950’s on the basis of the coeval maps produced by the Italian Military Geographic Institute.

[4] The 1990 Urban Morphologic Zones (scale 1:100,000) can be retrieved from http://www.eea.europa.eu/data-and-maps/data/urban-morphological-zones-1990-2 [accessed February 9, 2016]. The EEA defines these areas as “sets of urban areas laying less than 200 m apart” and identifies them on the basis of a selection of appropriate subclasses of the CLC class “artificial surfaces” that characterize the urban fabric and layout;

[5] The so-called “2008 Regional Land-Use Map of Sardinia” (produced in 2008 by refining the map produced in 2003, scale 1:25,000) is actually a land-cover map, where land covers are classed according to the Corine nomenclature, generally at the fourth level, in a limited number of subclasses at the fifth level; the dataset is available from http://www.sardegnageoportale.it/index.php?xsl=1598&s=291548&v=2&c=8831&t=1[accessed February 9, 2016] and from this dataset we selected only polygons belonging to the first-level class of the CLC, “artificial surfaces”.

[6] The map is distributed as scale 1:200,000, but the survey was actually carried out at 1:25,000 (Barbera et al., 2014). This map was digitized and compared with the coeval map of the Italian Military Geographic Institute so as to obtain a land cover map having the same detail as the CLC map, third level of nomenclature (see also Romano and Zullo, 2014b; Frondoni et al., 2011)

[7] Land cover data for the Liguria region are available off-the shelf as the so-called “Land use map scale 1:25,000, year 2000” (available at http://www.cartografia.regione.liguria.it/apriFoglia.asp?itemID=30209&fogliaID=39&label=Carta%20Uso%20del%20Suolo%20sc.%201:25000 [accessed February 9, 2016]), which was actually produced by building upon an aerophotogrammetric survey carried out between 1994 and 1997. From this map, artificial areas (as defined in the Corine class, first level = 1, that is, “artificial areas”) were selected.

[8] Similarly to the previous case, land cover data for Liguria are available as “Land use map scale 1:10,000, year 2009” (available at http://www.cartografia.regione.liguria.it/apriFoglia.asp?itemID=30209&fogliaID=1415&label=Uso%20del%20Suolo%20sc.%201:10000%20-%20ed.%202009 [accessed February 9, 2016]), which was actually generated by photointerpreting satellite imagery and assuming the 2007 Regional technical map as the base map.

TABLE 1

TABLE 2

Our analyses show that the relevance of land take processes is quite different in the two regions, and also that such processes show different time patterns. During the first period (1960-1990 or 1960-1994) artificial land in Sardinia increased from 0.54% (13,090 ha) to 1.59% (38,182 ha) and in Liguria from 1.99% (10,813 ha) to 6.24% (33,837.84 ha), therefore in both regions artificial land approximately tripled. With reference to the second time interval (1990-2008 or 1994-2008), artificial land in Sardinia rose from 1.59% (38,182 ha) to 3.25% in 2008 (78,379 ha), while in Liguria it increased from 6.24% (33,837.84 ha) to 7.81% (42,438 ha). Therefore, the accrual was much more prominent in Sardinia (where artificial land nearly doubled) while in Liguria in relative terms a slowdown in the pace of the land-taking process can be observed.

3.2 Drivers of land take in Liguria and Sardinia

The values that each variable listed as potential driver of land take in Table 3 takes in the two regions and in the two time intervals are shown in Table 4, together with their descriptive statistics (mean and standard deviation); as with land take, GIS-based analyses were performed in order to calculate such values.

TABLE 4

The linear correlations between the dependent variables (PLT_A and PLT_B for the two time periods), accounting for the magnitude of land take in the two time periods and their respective sets of factors, can be measured through the Pearson correlation coefficient ρ. The values that ρ takes are provided in Table 5, which puts in evidence not only various significant correlations, but also similarities and differences between the two case studies.

TABLE 5

In the first time interval (1960-1990 in Sardinia and 1960-1994 in Liguria) PLT_A is strongly correlated in both cases to DENS1961 (ρ=0.7185 in Sardinia and ρ=0.6225 in Liguria), meaning that that the larger the population in 1960, the larger the size of land take.

Next come PSIZ_A and COASTRIP in both cases, but with a slightly different level of importance: PSIZ_A comes second in Sardinia and third in Liguria (ρ=0.5259 and ρ=0.3923 respectively), while COASTRIP comes third in Sardinia and COAST300/COAST1K second in Liguria (ρ=0.4328 in Sardinia, and ρ=0.4874 or ρ=0.5738 in Liguria depending on whether the 300-metre or the 1000-metre buffer zone is considered). This indicates a positive correspondence between the magnitude of land take and the size of parcels which became artificial (more important in Sardinia than in Liguria), and also a positive correlation between the magnitude of land take and the amount of municipal land in which land transformation is somehow restricted (in different ways in the two regions) due to planning policies currently in force.

In the same time period, negative values of ρ can be observed in both regions with reference to the variables DISTCAPC, DISTNEAC, DISC_A, which indicates that in both regions (albeit with different levels of importance) land take more frequently occurs close to regional and province administrative centers and closer to the coastline.

During the second period (1990-2008 in Sardinia and 1994-2008 in Liguria) significant differences emerge: in Sardinia, PLT_B is strongly correlated to PSIZ_B and to DENS1990

($\rho=0.6068$ and $\rho=0.4951$ respectively), meaning that in Sardinia also in the second time period land take is significantly correlated to residential density and to the size of the parcel that is "taken". On the other hand, in Liguria the most important positive correlations are those with OLPL_B and SLOP_B ($\rho=0.5221$ and $\rho=0.4468$ respectively), meaning that in this second period land take is associated with inclusion of the parcel in an area designated by the 1991 Landscape plan as "maintenance area" and with high levels of slope. Since Liguria is very hilly, this does not simply indicate that the flattest areas had already been taken in the previous urbanization stage and that only hilly (and steep) areas were left for new urbanization. Rather, and counter-intuitively, it indicates that (due to the region's peculiar morphology) steeper areas were favored over other hilly areas because of the scenic view over the seaside that one can enjoy only from such areas.

As far as negative correlations are concerned, the highest correlation in both cases is that between PLT_B and DISC_B ($\rho=-0.3408$ in Sardinia and $\rho=-0.4554$ in Liguria), which means that in the two regions land take occurred preferably closer to the coastline, which confirms the coastal characterization of land take processes already highlighted in previous studies concerning urbanization in the Mediterranean area (e.g. Bajocco et al. 2012, Romano and Zullo 2014a, Salvati et al. 2014, Maraccini at al., 2015).

Figures 2 and 3 show the spatial distribution of the land-take related variables (PLT_A and PLT_B) and of their main drivers in the two regions.

FIGURE 2

FIGURE 3

Afterwards, a simple OLS model that uses the actual values of the explanatory variables was used was implemented for each region separately in the two time periods (1960-1990 and 1990-2008 for Sardinia; 1960-1994 and 1994-2008 for Liguria) so as to identify the most significant and relevant correlations between land take and its drivers.

With reference to the goodness of fit, the values of adjusted Rs-squared for the first time period (1960-1990 or 1960-1994) are about 80% in Sardinia and about 70% in Liguria, while for the second time period (1990-2008 or 1994-2008) they are about 63% in Sardinia and about 66% in Liguria.

TABLE 6

In Sardinia, the estimates related to the 1960-1994 period, reported in Table 6, show significant correlations (p-values lower than 0.1%) for:

a) the size of parcels that changed their status from non-artificial to artificial in the period 1960-1990 (PSIZ_A, positive);

b) the size of a municipality’s environmentally valuable landscape components (NAT_A, positive);

c) the percentage of a municipality’s area included in the coastal strip (COASTRIP, positive);

d) the municipality’s area classed in the planning code in force before 2006 as areas where land transformations and new developments were almost totally forbidden that became artificial between 1960 and 1990 (OLPL_A, positive);

e) the residential density in 1961 (DENS1961, positive);

f) the spatially-lagged dependent variable (AUTC_A, positive).

In the 1960-1990 period, less significant estimates are reported for: the distance of a municipality from the regional capital city (DISTCAPC, negative, p-value: 6%); the distance of a municipality from the closest province administrative center (DISTNEAC, positive, p-value: 7%).

The estimates related to the 1990-2008 period are consistent with the 1960-1990 estimates for the variables PSIZ_B, ACCESS, CONSAREA, COASTRIP, DENS1990 and AUTC_B. On the other hand, the variables DISTCAPC, DISNEAC, DISC_B, NAT_B, and OLPL_B do not seem to impact on land take between 1990 and 2008. Slope (variables SLOP_A and SLOP_B) does not seem to influence land take in both time periods.

As far as Liguria is concerned, the estimates related to the 1960-1994 period, also reported in Table 6, show significant correlations (p-values lower than 0.2%) for:

a) the size of parcels that changed their status from non-artificial to artificial in the period 1960-1994 (PSIZ_A, positive);

b) the distance from the regional capital city (Genoa) (DISTCAPC, negative);

c) the presence of protected natural areas, also including some parks created before 1945 (CONSAREA, negative);

d) the percentage of a municipality's area included in a 300-m buffer along the coastline (COAST300, negative);

e) the percentage of a municipality's area included in a 1,000-m buffer along the coastline (COAST1K, positive);

f) the area classed in the planning code as areas where land transformations and new developments were almost totally forbidden, that changes from non-artificial to artificial between 1960 and 1994 (OLPL_A, positive);

g) the residential density in 1961 (DENS1961, positive);

h) the spatially-lagged dependent variable (AUTC_A, positive).

In the 1960-1994 period, in Liguria less significant estimates are reported for: the municipality's landscape components with environmental value, defined in the Liguria LP as conservation and maintenance areas, that change from non-artificial to artificial between 1960 and 1994 (NAT_A, negative, p-value: 5%); the municipality's weighted average distance from the closest urban center to areas classed as non-artificial in 1960 and artificial in 1994 (PRS_A, negative, p-value: 8%).

The 1994-2008 estimates are consistent with the 1960-1994 estimates for the variables CONSAREA, COAST1K, OLPL_B and AUTC_B, while in this second period DISCAPC and COAST300 are far less significant and PRS_B and DENS1990 are not significant at all.

Moreover, in this second period the municipality's weighted average slope of areas classed as non-artificial in 1994 and artificial in 2008 is very significant (SLOP_B, positive, p-value: 0.1%) while it was not significant in the first time period, and the municipality's landscape components with environmental value, defined in the Liguria LP as conservation and maintenance areas, that change from non-artificial to artificial between 1994 and 2008 (NAT_B, negative, p-value: 4%) remain somewhat significant. Hence, some clear differences between the two periods under consideration emerge in Liguria. However, the endowment of roads connecting regional town and city centers per unit of municipal land area (ACCESS), the distance of a municipality from the closest province administrative center (DISTNEAC) and the weighted average distance from the shoreline to areas that became artificial in the time interval under consideration (DISC_A and DISC_B) do not seem to affect land take in Liguria in both time periods.

4. Discussion and conclusion

Building on Zoppi and Lai (2014; 2015), we have here analyzed land take in two Italian regions (Liguria and Sardinia) through OLS regression models in two time periods, 1960-

1990 (or 1960-1994) and 1990-2008 (or 1994-2008) in order to identify, for each region and for each time period, the most significant drivers of land take on the basis of the outcome of the mainstream literature. In this section we draw a comparison between the two regional case study, so as to identify similarity and differences that can help policy makers and planners tailor policies, plans and programs to regional contexts. A full summary of the comparison is reported in Table 7.

TABLE 7

As far as the similarities are concerned, in both regions the impact of the variable PRS_A and PRS_B is consistently negative in both periods and for both regions; this means that, not surprisingly, land take occurs more likely close to urban areas, although it must be noted that this impact is somewhat significant only in the case of PRS_A, that is, in the first time period.

In both regions the impact of the variables PSIZ_A and PSIZ_B is positive and nearly always very significant, except for the period 1994-2008 in Liguria. This means that, the amount of land that is “taken” is greater in those municipalities in which the size of the parcels that become artificial is greater, hence, everything else being equal, in order to counter land take policies that favor the development of small plots, rather than large ones, should be implemented. Moreover, if we look at the variables accounting for residential density (DENS1961 and DENS1990), the influence is always positive and mostly very significant, again except for the period 1994-2008 in Liguria, which suggests that land take is greater where population density is greater (again, everything else being equal). Hence, policies aiming at tackling land take should favor low residential densities and small plots, rather than high-density, large plots concentrated in only some municipalities.

The variable DISTCAPC is significant and negative in both regions in the first time period, and in Liguria in the second time period, in which is positive but non-significant in Sardinia. This means, fairly intuitively, that the regional capital cities in general act as drivers of land-taking processes because they attract not just housing but also infrastructure and the tertiary sector. Part of the explanation for its being non-significant in Sardinia in the second time period is to be found in the saturation process that has taken place around the capital city (Cagliari) where there is very little room for new development, notwithstanding the high amount of non-built areas, as such areas are wetlands, parks and Natura 2000 sites.

The impact of the variable CONSAREA is always negative, but much more significant in Liguria than in Sardinia, hence conservation areas (parks, nature reserves, Natura 2000 sites) play a key role in contrasting land take processes. For this reason, regional policy makers should be advised to fully integrate nature protection within spatial plans and policies and possibly expand their regional ecological networks. To the opposite, positive effects on land take are associated with two other planning-related variables: one accounts for the amount of area where landscape plans set conservative rules on development (OLPL_A and OLPL_B, mostly very significant except for Sardinia in the period 1990-2008), and the other accounts for planning restrictions in force close to the coastline (COASTRIP in Sardinia and COAST1K in Liguria, always very significant). Following Zoppi and Lai (2015), it can be argued that restrictive rules in some areas may, paradoxically, spur land take in the surrounding areas. In a way, this is similar to Dewi et al.'s (2013) finding concerning deforestation and protected areas, as they found out that areas immediately close to the boundaries of protected areas experience the highest rate of land-use change. However, it must be also noted that COAST300, which accounts for the amount of area in a 300-metre buffer zone along the coastline, in which any development is severely restricted in Liguria, has a negative effect and is significant in both time periods. Therefore, and contrary to the previous case, stricter planning rules can sometimes help counter land take. In this specific Liguria case, this happens because the 300-m buffer in which development is completely forbidden is enclosed in the 1,000-m buffer in which restrictions are in place. Hence, the "border effect" earlier described cannot take place, since, contrary to Dewi et al.'s (2013) case, the outer area close to the 300-m boundary is still regulated, although less strictly than the inner one.

As for the differences, the most notable one concerns the variable ACCESS, which brings about a positive impact in both cases, that is, endowment of roads determines land take; hence, to reduce land take, transport plans should pay close attention to balancing accessibility opportunities across municipalities. However, it can be noted that this variable is significant only in the case of Sardinia and not in the case of Liguria, possibly due to the fact that in the latter case the layout of the road network is more influenced by the morphology than by the spatial pattern of settlements.

Another important difference between the two case studies concerns a planning variable (NAT_A and NAT_B) accounting for the amount of land where special rules are set by landscape plans currently in force in the two regions. This variable is significant for both regions in the first time period (negative in Liguria and positive in Sardinia), and significant only in Liguria (where it is consistently negative) in the second time interval. We feel we have to say that to draw a comparison is quite difficult in this specific case, because the two regional plans define such areas differently and moreover set different rules.

To sum up, by looking at two regional case studies, this paper has put in evidence that many drivers of land take previously identified in other studies act similarly in different regional contexts. The influence of demographic factors on land-take is documented in Sklenicka et al.'s (2013) and in Forster's (2006) studies concerning conversion of agricultural land into residential and commercial use, as well as in several studies concerning drivers of land-use changes in developing countries (among many, Ebanyat et al. 2010, Girma and Hassan, 2014). Furthermore, the importance of distance to urban areas, be they market towns (e.g. Verburg et al., 2004a) or capital cities (e.g. Serneels and Lambin, 2001), in affecting land use choices and land use change is included in a number of studies following Bockstael (1996). Drivers of land take related to spatial planning and policies are less studied, and yet of great importance (Verburg et al., 2004b; Abrantes et al., 2016); the border effect that we here identified with reference to areas in which land take occurred possible because of their close to areas subject to building restrictions might be somehow assimilated to the "displacement of the environmental impact [which counteracts] the intended effects of the initial policy" which is labeled as "leakage" in Meyfroidt et al. (2013).

We have also highlighted that some regional peculiarities do exist and these have to do with transport infrastructure networks and with planning restrictions set up in regional landscape plans. Hence we can conclude that not all of the policies aimed at addressing land take can be developed similarly in different regional contexts, and that a more comprehensive comparative study involving, for instance, a larger number of regions could help understanding whether the main drivers here identified as common to Liguria and Sardinia act as the main drivers, and in a similar way, also in other NUTS 2 regions. This would be especially helpful to better explore the role that planning-related variables, which are very much context dependent, might play in tackling land take. For instance, in our case studies variables accounting for planning restrictions in force close to the coastline are important, but in inland areas such variables might not make much sense, and other variables relating to conservative policies should be considered instead.

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FIGURES

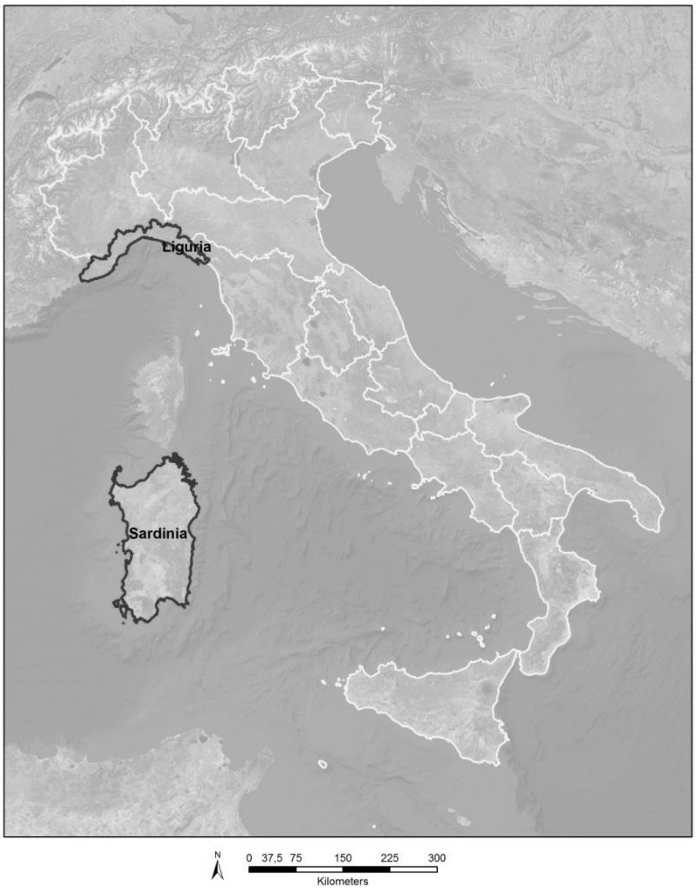

Figure 1. Selected case studies (Liguria and Sardinia) and the other eighteen NUTS 2 Italian regions.

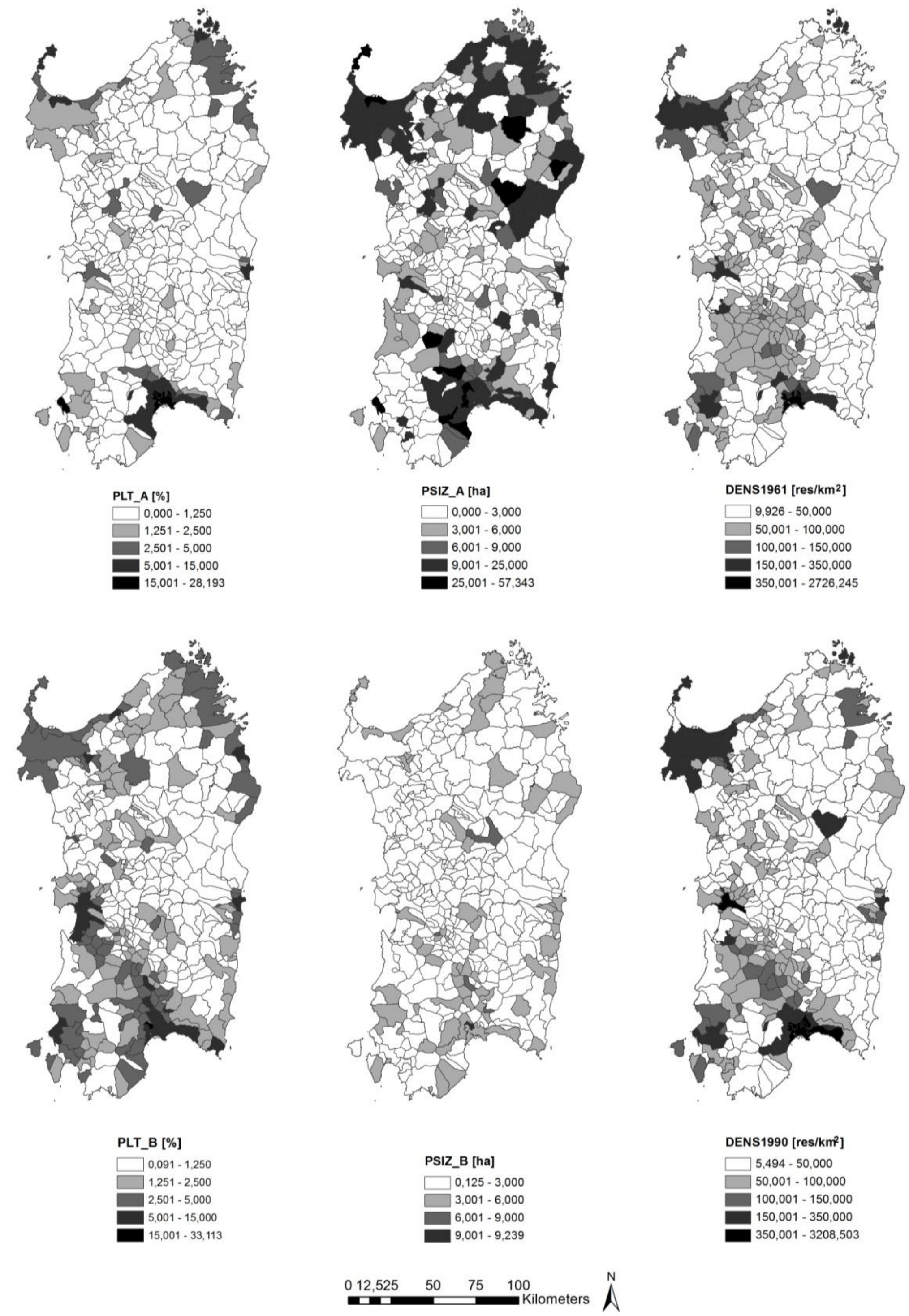

Figure 2. Spatial distribution of the variables PLT_A, PSIZ_A and DENS1961 (top) and PLT_B, PSIZ_B and DENS1990 (bottom) in Sardinia. Polygons represent municipalities.

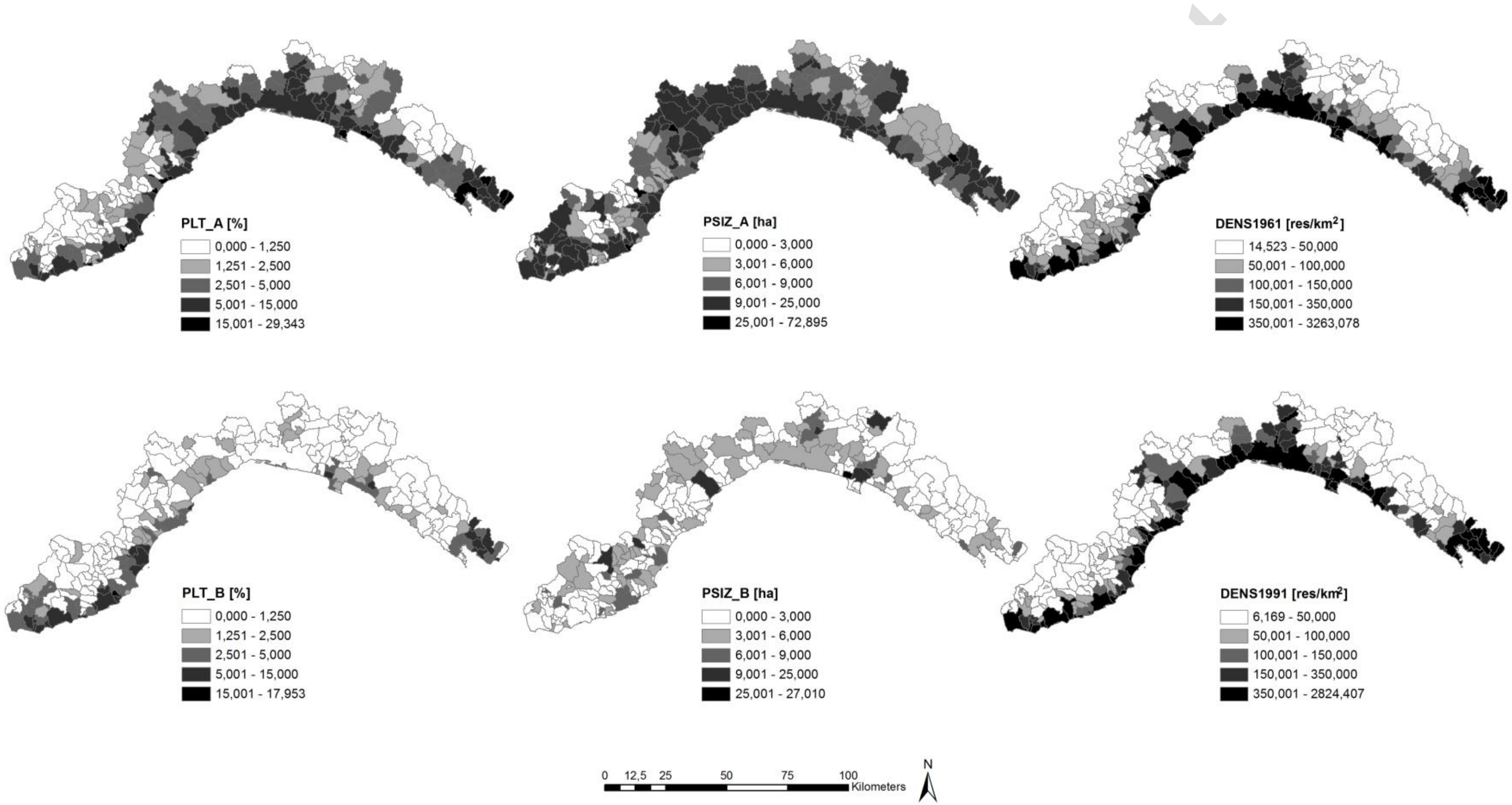

Figure 3. Spatial distribution of the variables PLT_A, PSIZ_A and DENS1961 (top) and PLT_B, PSIZ_B and DENS1991 (bottom) in Liguria. Polygons represent municipalities.

TABLES

Variable	Definition	Unit	Source(s)	Mean	St.dev.
AREA	Municipality's land areas		SDRGISS	6388.23	6180.41
NURB1960	Municipality's non-artificial areas in 1960	ha	RLP, SDRGISS	6353.51	6157.73
NURB1990	Municipality's non-artificial areas in 1990	ha	CLC1990, SDRGISS	6286.95	6081.00
NURB2008	Municipality's non-artificial areas in 2008	ha	CLCMS08, SDRGISS	6180.33	5963.59
PLT_A	Percentage of municipal area whose land cover changed from non-artificial to artificial between 1960 and 1990	%		1.05	2.58
PLT_B	Percentage of municipal area whose land cover changed from non-artificial to artificial between 1990 and 2008	%		1.89	2.35

CLC1990: European Corine Land Cover Map, 1990 release, Urban Morphological Zones
CLCMS08: Corine Land Cover Map of Sardinia, 2008 release, Level 1
RLP: Sardinian Regional Landscape Plan
SDRGISS: Spatial Dataset of the Regional Geographic Information System of Sardinia

563 *Table 1. Definition of land-cover variables and descriptive statistics. Case study 1: Sardinia.*

Variable	Definition	Unit	Source(s)	Mean	St.dev.
AREA	Municipality’s land areas		SDRGISL	2307.14	2383.51
NURB1960	Municipality’s non-artificial areas in 1960	ha	LGRTCI60	2261.12	2277.85
NURB1994	Municipality’s non-artificial areas in 1990	ha	LGRCTR94	2163.14	2138.76
NURB2008	Municipality’s non-artificial areas in 2008	ha	LGRCTR07	2126.93	2123.01
PLT_A	Percentage of municipal area whose land cover changed from non-artificial to artificial between 1960 and 1994	%		4.88	5.44
PLT_B	Percentage of municipal area whose land cover changed from non-artificial to artificial between 1994 and 2008	%		2.11	2.64

LGRTCI60: National Land-use Map published by CNR & the Italian Touring Club
LGRCTR94: Regional technical map (1994 edition)
LGRCTR07: Regional technical map (2007 edition)
SDRGISL: Spatial Dataset of the Regional Geographic Information System of Liguria

Table 2. Definition of land-cover variables and descriptive statistics. Case study 2: Liguria.

Type [(*)]	Variable	Definition	Motivation
PH	*PSIZ*	Municipality's average size of areas classed as non-artificial at the beginning of an interval and artificial at the end	Sklenicka et al., 2013
PH	*SLOP*	Municipality's weighted average slope of areas classed as non-artificial at the beginning of an interval and artificial at the end; weight = area size	Sklenicka et al., 2013; Cheshire and Sheppard, 1995; Stewart and Libby, 1998
PH	*PRS*	Municipality's weighted average distance from the closest urban center to areas classed as non-artificial at the beginning of an interval and artificial at the end; weight = area size	
PH	*ACCESS*	Endowment of roads connecting regional town and city centers per unit of municipal land area	
PH	*DISTCAPC*	Distance of a municipality from the regional capital city	Sklenicka et al., 2013
PH	*DISTNEAC*	Distance of a municipality from the closest province administrative center	Sklenicka et al., 2013
PH	*DISC*	Municipality's weighted average distance from the shoreline to areas classed as non-artificial at the beginning of an interval and artificial at the end; weight = area size	Dewi et al., 2013; Zoppi and Lai, 2014
PL	*CONSAREA*	Municipality's total protected area: National and Regional parks, nature reserves, Sites of Community Importance Special Protection Zones, Special Conservation Areas, Ramsar sites etc	Cheshire and Sheppard, 1995; Palmquist and Danielson, 1989; Zoppi and Lai, 2014
PL	*NAT*	Municipality's landscape components with environmental value, as defined in the regional planning tool in force, that change from non-artificial to artificial in the selected time interval	Planning tools that sets conservative rules for these areas are expected to preserve non-artificial land covers.
PL	*COASTRIP*	Percentage of a municipality's area included in the Coastal strip as defined in the Regional Landscape Plan	Dewi et al., 2013; Zoppi and Lai, 2014
PL	*COAST300*	Percentage of a municipality's area included in a 300-m buffer zone along the shoreline	
PL	*COAST1K*	Percentage of a municipality's area included in a 1,000-m buffer zone along the shoreline	
PL	*OLPL*	Municipality's area classed in the old planning tools as areas where land transformations and new developments were almost totally forbidden, that changes from non-artificial to artificial in the selected time interval	Dewi et al., 2013
SOC	*DENS*	Municipality's population density at the beginning of a given time interval	Sklenicka, 2013; Guiling et al., 2009; Forster, 2006; Huang et al., 2006
	AUTC	Municipality's spatially lagged dependent variable in a given time interval	Tobler, 1970

(*) Type of the variable: PH: physical; PL: planning-related; SOC: socio-economic

565 *Table 3. Potential drivers of land take: definitions and motivation for their selection.*

Variable	Definition	u.m.	Time period (**)	Sardinia		Liguria	
				mean	st. dev.	mean	st. dev.
PSIZ_A	Municipality's average size of areas classed as non-artificial in 1960 and artificial in 1990 (Sardinia) or 1994 (Liguria)	ha	A	4.60	7.18	8.60	6.86
PSIZ_B	Municipality's average size of areas classed as non-artificial in 1990 (Sardinia) or 1994 (Liguria)and artificial in 2008	ha	B	2.07	1.25	3.23	2.93
SLOP_A	Municipality's weighted average slope of areas classed as non-artificial in 1960 and artificial in 1990 (Sardinia) or 1994 (Liguria); weight = area size	%	A	6.99	7.08	49.33	26.77
SLOP_B	Municipality's weighted average slope of areas classed as non-artificial in 1990 (Sardinia) or 1994 (Liguria) and artificial in 2008; weight = area size	%	B	9.56	6.19	14.45	13.18
PRS_A	Municipality's weighted average distance from the closest urban center to areas classed as non-artificial in 1960 and artificial in 1990 (Sardinia) or 1994 (Liguria); weight = area size	km	A	0.96	1.54	0.99	0.74
PRS_B	Municipality's weighted average distance from the closest urban center to areas classed as non-artificial in 1990 (Sardinia) or 1994 (Liguria) and artificial in 2008; weight = area size	km	B	2.43	1.51	1.49	1.44
ACCESS	Endowment of roads connecting regional town and city centers per unit of municipal land area	km/km^2	A&B	0.96	0.47	3.48	7.20
DISTCAPC	Distance of a municipality from the regional capital city, Cagliari (for Sardinia) or Genoa (for Liguria)	km	A&B	126.46	71.27	87.05	43.46
DISTNEAC	Distance of a municipality from the closest province administrative center	km	A&B	30.99	16.70	34.67	16.69
DISC_A	Municipality's weighted average distance from the shoreline to areas classed as non-artificial in 1960 and artificial in 1990 (Sardinia) or 1994 (Liguria); weight = area size	km	A	17.23	14.98	8.97	7.49
DISC_B	Municipality's weighted average distance from the shoreline to areas classed as non-artificial in 1990 (Sardinia) or 1994 (Liguria) and artificial in 2008; weight = area size	km	B	21.05	13.91	9.10	7.35
CONSAREA	Municipality's total protected area: National and Regional parks, nature reserves, Sites of Community Importance Special Protection Zones, Special Conservation Areas, Ramsar sites etc,	ha	A&B	1342.74	2636.12	25.62	24.70
NAT_A	Municipality's landscape components with environmental value, defined in the Sardinian RLP as natural and seminatural areas and in the Liguria LP as conservation and maintenance areas, that change from non-artificial to artificial between 1960 and 1990 (Sardinia) or 1994 (Liguria)	ha	A	2.73	13.45	9.62	16.78
NAT_B	Municipality's landscape components with environmental value, defined in the Sardinian RLP as natural and seminatural areas and in the Liguria LP as conservation and maintenance areas, that change from non-artificial to artificial between 1990 (Sardinia) or 1994 (Liguria) and 2008	ha	B	10.79	22.16	3.58	5.63
COASTRIP	Percentage of a municipality's area included in the Coastal strip as defined in the Regional Landscape Plan (Sardinia)		A&B	1.22	2.41	---	---
COAST300	Percentage of a municipality's area included in a 300-m buffer zone along the shoreline	ha	A&B	---	---	3.58	8.48
COAST1K	Percentage of a municipality's area included in a 1,000-m buffer zone along the shoreline	ha	A&B	---	---	10.32	21.51
OLPL_A	Municipality's area classed in the planning code in force before 2006 in Sardinia and before 1991 in Liguria as areas where land transformations and new developments were almost totally forbidden, that changes from non-artificial to artificial between 1960 and 1990 (in Sardinia) or between 1960 and 1994 (in Liguria)	ha	A	20.35	87.46	23.65	35.40
OLPL_B	Municipality's area classed in the planning code in force before 2006 in Sardinia and before 1991 in Liguria as areas where land transformations and new developments were almost totally forbidden, that changes from non-artificial to artificial between 1990 and 2008 (in Sardinia) or between 1994 and 2008 (in Liguria)	ha	B	36.04	90.98	21.73	37.45
DENS1961	Municipality's population density in 1961	$people/km^2$	A	70.02	170.80	222.81	371.17

Variable	Definition	u.m.	Time period (**)	Sardinia		Liguria	
				mean	st. dev.	mean	st. dev.
DENS1990	Municipality’s population density in 1990	people/ km^2	B	74.73	213.84	255.84	406.22
AUTC_A	Municipality’s spatially lagged dependent variable 1960-1990 (Sardinia) or 1960-1994 (Liguria)	%	A	0.99	1.56	4.82	3.66
AUTC_B	Municipality’s spatially lagged dependent variable 1990-2008 (Sardinia) or 1994-2008(Liguria)	%	B	1.82	1.27	2.11	1.84

(**) Time period: A = 1960-1990 in Sardinia and 1960-1994 in Liguria; B = 1990-2008 in Sardinia and 1994-2008 in Liguria.

Table 4. Potential drivers of land take for the two selected regions: definitions, units of measurement, time periods and descriptive statistics for the two selected regions.

Dependent variable: PLT_A			Dependent variable: PLT_B		
	Sardinia	**Liguria**		**Sardinia**	**Liguria**
	ρ	**ρ**		**ρ**	**ρ**
PSIZ_A	0.5259	0.3923	*PSIZ_B*	0.6068	0.0686
SLOP_A	-0.1316	0.0275	*SLOP_B*	-0.3039	0.4468
PRS_A	0.2664	-0.0944	*PRS_B*	0.0884	-0.1464
ACCESS	0.1442	0.1649	*ACCESS*	0.2869	0.1337
DISTCAPC	-0.1464	-0.2297	*DISTCAPC*	-0.1901	0.2532
DISTNEAC	-0.2438	-0.3559	*DISTNEAC*	-0.3402	-0.1891
DISC_A	-0.1827	-0.485	*DISC_B*	-0.3408	-0.4554
CONSAREA	0.0405	-0.2121	*CONSAREA*	-0.0704	-0.1943
NAT_A	0.3361	0.1094	*NAT_B*	0.1846	0.1494
COASTRIP	0.4328	---	*COASTRIP*	0.3823	---
COAST300	---	0.4874	*COAST300*	---	0.2623
COAST1K	---	0.5738	*COAST1K*	---	0.3207
OLPL_A	0.2904	0.3311	*OLPL_B*	0.1972	0.5221
DENS1961	0.7185	0.6225	*DENS1990*	0.4951	0.3704

Table 5. Pearson product-moment correlation coefficients between the two dependent variables (PLT_A and PLT_B) and all of their covariates in the two case studies.

Variable	coef$_i$	st. error	t-stat	hyp. test: coef=0	coef$_i$	st. error	t-stat.	hyp. test: coef=0
	Sardinia: 1960-1990 period				**Liguria: 1960-1994 period**			
Constant	-0.9315	0.2730	-3.413	0.0007	0.7326	1.1671	0.6280	0.5309
PSIZ_A	0.1122	0.0106	10.627	0.0000	0.1768	0.0309	5.7280	0.0000
SLOP_A	0.0018	0.0101	0.174	0.8621	0.0013	0.008	0.1600	0.8732
PRS_A	-0.0740	0.0495	-1.494	0.1361	-0.5381	0.3013	-1.7860	0.0755
ACCESS	0.2315	0.1431	1.618	0.1065	0.0197	0.0276	0.7120	0.4771
DISTCAPC	-0.0018	0.0009	-1.944	0.0527	-0.0118	0.0053	-2.2340	0.0265
DISTNEAC	0.0073	0.0039	1.867	0.0627	0.0078	0.0137	0.5730	0.5673
DISC_A	0.0066	0.0051	1.299	0.1947	0.0538	0.0366	1.4700	0.1431
CONSAREA	-4.1E-05	2.5E-05	-1.624	0.1053	-0.0373	0.0085	-4.3950	0.0000
NAT_A	0.0337	0.0063	5.359	0.0000	-0.0382	0.0194	0.0000	0.0496
COASTRIP	0.1483	0.0330	4.499	0.0000	---	---	---	---
COAST300	---	---	---	---	-0.4663	0.0951	-4.9030	0.0000
COAST1K	---	---	---	---	0.2667	0.0401	6.6560	0.0000
OLPL_A	0.0037	0.0008	4.397	0.0000	0.0275	0.0103	0.0000	0.0080
DENS1961	0.0075	0.0004	17.616	0.0000	0.0029	0.0008	3.4880	0.0006
AUTC_A	0.4777	0.0547	8.727	0.0000	0.466	0.0742	6.2770	0.0000
	Adjusted R-squared = 0.8024				*Adjusted R-squared = 0.7034*			
	Sardinia: 1990-2008 period				**Liguria: 1994-2008 period**			
Constant	-17.298	0.4922	-3.514	0.0005	0.1049	0.4344	0.2410	0.8095
PSIZ_B	0.8553	0.0679	12.588	0.0000	0.0172	0.0350	0.4930	0.6222
SLOP_B	-0.0150	0.0139	-1.073	0.2839	0.0647	0.0096	6.7640	0.0000
PRS_B	-0.0232	0.0691	-0.336	0.7372	-0.0046	0.0752	-0.0610	0.9510
ACCESS	0.7924	0.1869	4.239	0.0000	0.0008	0.0144	0.0580	0.9541
DISTCAPC	0.0011	0.0012	0.890	0.3741	-0.0047	0.0029	-1.6100	0.1088
DISTNEAC	0.0050	0.0054	0.917	0.3596	-0.0086	0.0071	-1.2170	0.2251
DISC_B	-0.0023	0.0076	-0.302	0.7626	0.0139	0.0194	0.7180	0.4738
CONSAREA	-7.0E-05	3.2E-05	-2.189	0.0293	-0.0132	0.0045	-2.9220	0.0038
NAT_B	-0.0024	0.0053	-0.450	0.6532	-0.0466	0.0226	-2.0650	0.0401
COASTRIP	0.1201	0.0443	2.712	0.0070	---	---	---	---
COAST300	---	---	---	---	-0.0696	0.0494	-1.4070	0.1607
COAST1K	---	---	---	---	0.0496	0.0211	2.3500	0.0197
OLPL_B	0.0006	0.0013	0.447	0.6553	0.0243	0.0036	6.6890	0.0000
DENS1990	0.0026	0.0004	6.261	0.0000	0.0002	0.0004	0.5480	0.5840
AUTC_B	0.4222	0.0941	4.489	0.0000	0.5926	0.0847	7.0000	0.0000
	Adjusted R-squared = 0.6289				*Adjusted R-squared = 0.6603*			

Table 6. OLS results, dependent variables PLT_A and PLT_B: the regression models include the covariates of Table 4.

Variable	significance Sardinia	significance Liguria	Sign
	Comparison Sardinia-Liguria first time period (dependent variable: PLT_A)		
PSIZ_A	***	***	Both +
SLOP_A	-	-	Both +
PRS_A	*	*	Both -
ACCESS	*	-	Both +
DISTCAPC	**	**	Both -
DISTNEAC	**	-	Both +
DISC_A	*	*	Both +
CONSAREA	*	***	Both -
NAT_A	***	**	Opposite
COASTRIP	***		Opposite (but complex)
COAST300		***	
COAST1K		***	
OLPL_A	***	***	Both +
DENS1961	***	***	Both +
AUTC_A	***	***	Both +
	Comparison Sardinia-Liguria second time period (dependent variable: PLT_B)		
PSIZ_B	***	-	Both +
SLOP_B	-	***	Both +
PRS_B	-	-	Both -
ACCESS	***	-	Both +
DISTCAPC	-	**	Opposite
DISTNEAC	-	-	Opposite
DISC_B	-	-	Opposite
CONSAREA	**	***	Both -
NAT_B	-	**	Both -
COASTRIP	***		Opposite (but complex)
COAST300		**	
COAST1K		***	
OLPL_B	-	***	Both +
DENS1990	***	-	Both +
AUTC_B	***	***	Both +

*Significance levels: *** (p-value ≤0.01%); **(p-value <0.5%); * (p-value <20 %); - (p-value≥20%)*

Table 7. Comparison between the OLS results (fully listed in Table 6) concerning the two selected regions (Sardinia and Liguria); the covariates are listed and explained in Table 3 and the values they take in Sardinia and Liguria are provided in Table 4.