Determinants of regional land-taking processes: findings from a case-study concerning Sardinia (Italy)

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Abstract

Land take is a process of significant relevance in the countries of European Union (EU). In 2011, the European Commission (EC) put in evidence that an important milestone for the EU should be to reach the goal of no net land take by 2050, and to take under strict control the impact on land-taking processes of the EU policies in the new Structural Funds programming period (2014-2020) (Communication of the EC to the European Parliament COM(2011) 571 of 20.9.2011).

In this paper we analyze the Sardinian land-taking process as related to factors which are identified as relevant variables in several studies concerning land take, such as area size, accessibility, proximity to regional and local cities and small settlements, natural risk, proximity to nature conservation areas.

1. Introduction

The EC indicates that land take in the EU amounted to more than 1,000 km^2 per year between 1990 and 2000, decreasing to about 920 km^2 between 2000 and 2006 (European Commission, 2011), and that, as a consequence, the objective of no net land take by 2050 would imply a decrease rate of about 800 km^2 per year.

Land take in Italy parallels the difficult general situation of the EU countries. Figures at the national level put in evidence that in 2009 a 7.3 percent of the Italian land had an artificial land cover (European Commission, EUROSTAT, 2012), with an average growth rate of about 6 percent between 1990 and 2000 and of about 3 percent between 2000 and 2006 (ISPRA, 2011, p. 479). The implementation of analyses of land-taking processes at the regional level is problematic since currently available geographic databases and information systems do not provide systemic information on the phenomenon (CRCS, 2012).

However, some Italian regional administrations, such as Lombardy and Sardinia, have set up regional information systems that address land-taking processes. The geographic information systems of these regions allow to relate land take with spatial, economic and planning-policy related variables, and to infer on correlations between such variables and the land-taking phenomenon.

We study the land-taking process through the land cover maps of Sardinia, made available in 2003 and 2008 by the Sardinian regional administration[3]. The results and inferences of our

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study could be easily generalized to other Italian and EU regions, under the necessary condition that geographic databases and maps were made available for these contexts as well.

This paper is organized as follows. In the third section we propose the definition of land take for the purpose of this paper. We feel that we have to clarify what we mean by land take, which is a rather controversial issue. In the following section, we discuss the set of variables that we use as covariates to frame the Sardinian land-taking process in the context of relevant studies concerning this topic. Explanatory and dependent variables are described and spatially represented in the fifth section, and correlations between covariates and the dependent (land take) variable discussed.

The sixth section presents the results of regression models which use the land take variable and covariates in order to analyze if, and to what extent, the land-taking process is related to the covariates altogether. In the concluding section, we discuss the influence of the factors/variables found relevant on land take that could be taken into account to define regional planning policies to limit or possibly prevent land take, and, by doing so, help implementing the EC recommendation on no net land take by 2050 into the EU regional policies.

2. What is land take?

As we put in evidence above, the EC considers to reach no net land take by 2050 as an important milestone for a roadmap to a resource-efficient Europe. One of the most dangerous consequences of land take is soil sealing, but other related phenomena are soil contamination and erosion, decrease of soil organic content and of agricultural production and productivity. In a recent study published by the Italian Institute of Urban and Regional Planning (CRCS, 2012), a systematic discussion on the impacts of land-taking processes is proposed; such impacts are grouped as follows:

- impacts on the carbon cycle: a decline of the power of the soil's organic content to fix carbon dioxide in the atmosphere and an increase in concentration of carbon dioxide generated by the mineralization of the carbon present in the excavated soil of new urban developments;
- impacts on the water cycle and microclimate: soil sealing implies: i. a significant decline of stored ground- and underground water; ii. an increased flood risk due to the rising quantity of rainfalls which run directly into rivers, augmenting their levels, turbulence, and sediments in the water; iii. impacts on urban microclimate, since the decrease of the soil evapotranspiration power may very possibly generate an increase of the atmospheric temperature;

[3] The 1:25,000 "Land Use Map of the Region of Sardinia – 2003 Edition" and "New Land Use Map of the Region of Sardinia - 2008 Edition" are actually two land cover maps that cover the whole island. Data were obtained mainly from photo-interpretation of aerial photographs, satellite images, and orthoimages, but other vector data sets (e.g., regional digital cartography) were also used, together with on-site surveys. The maps' minimum mapping unit (Longley et al., 2001, 151) equals 0.5 ha in urban areas and 0.75 ha in rural areas. Both maps can be freely downloaded from http://www.sardegnageoportale.it/index.php?xsl=1598&s=141401&v=2&c=8831&t=1 [accessed December 12, 2012].

- impacts on biodiversity: land-taking processes cause the soil's impoverishment and, as a consequence, the loss of huge quantities of microorganisms, which could mitigate soil contamination, filter percolation waters and make available nutrients for vegetation and pastures;
- impacts on agricultural production: potential agricultural crops are heavily and progressively hindered by land take and soil sealing.

However, if we read the relevant paragraph concerning land–taking processes of the EC communication quoted above (paragraph 4.6), it will be rather difficult to derive a rigorous definition of land take, which should be based on its unwanted impacts in order to effectively address and mitigate their consequences.

Let us consider, for example, the Land Use and Cover Areas frame Survey (LUCAS) of EUROSTAT (European Commission, EUROSTAT), and the COoRdination de l'INformation sur l'Environnement (CORINE) Land Cover vector map (CLC) of the European Environment Agency (EEA) of the EU (European Environment Agency). In LUCAS, "artificial land", that is land *taken* by land-taking processes, is classified into two main groups, that is "built-up" and "non built-up" areas, where the former are further classified according to the number of floors of their buildings, while a separated sub-group is represented by greenhouses (Technical reference, document C-3 - Land use and Land Cover: Nomenclature, pp. 14-16). In CLC, "artificial surfaces" are classified into four groups (CORINE Land cover - Part 2: Nomenclature, p. 1): i. urban fabric; ii. industrial, commercial and transport units; iii. mine, dump and construction sites; and, iv. artificial, non-agricultural vegetated areas. Even though both LUCAS and CLC address the issue of artificial land cover, propose definitions of artificial vs. non-artificial land cover, and identify artificial and non-artificial areas, it is quite clear that CLC and LUCAS greatly differ from each other.

The example above shows that it is quite difficult and controversial to frame and identify a precise measure of land take, which in some way can make it difficult to implement rigorous quantitative studies on this subject. From this perspective, there are at least two relevant general issues to be taken into account. First, it is rather controversial to state univocally that land take is always negative in terms of the negative impacts indicated above, since there are types of land take which do not generate those impacts. For example, soil sealing, one of the most dangerous impacts, is not a necessary consequence of land-taking processes, as indicated by the EC, which puts in evidence that soil sealing is limited to about a 50 percent of the land taken: "In the EU, more than 1,000 km² are subject to 'land take' every year for housing, industry, roads or recreational purposes. About half of this surface is actually 'sealed'." (EC COM(2011) 571, paragraph 4.6)

Second, there is the trade-off critique. This critique considers land take as a process caused by a strong pressure in favor of settlement development, which implies that the land taken will increase its market value once new land uses displace existing uses. So, why, in principle, existing uses should be preferred over the new ones? Moreover, is a prohibitionist, normative, approach the most efficient way to prevent the negative impacts of land-taking processes from taking place in the long run? Neo-liberist positions support this critique (see, for example: MacCallum, 2003; Moroni, 2007). From this point of view, heavy taxation on land rent could possibly be the most effective means to counter demand for land take, which is consistent with Henry George's proposal of eliminating land monopoly "by shifting all taxes from labor and the products of labor and concentrating them in one tax on the value of land." (George, 1971, p. viii)

In this paper we do not propose ethic narratives or value judgments on land take, but we analyze land-taking processes in order to detect which factors, and possibly to what extent, can be considered relevant to explain the phenomenon. We implement our analysis with reference to the Sardinian region, one of the two Italian islands which are governed by regional administrative bodies. Sardinian is located to the west of Central Italy, off the west coast just below the French island of Corsica. Sardinia has advanced land-cover maps based on the CLC classification, available for 2003 and 2008, that make it possible to analyze the dynamic of land cover through the comparison of land cover classes which are consistent with each other. So, we use the CLC-based maps of Sardinia to study land take processes, since the LUCAS data, available for 2008 only, would have not allowed us to study land take as a dynamic process.

In the CLC classification, non-artificial surfaces are classified into four classes (at Level 1): i. agricultural areas; ii. forests and semi-natural areas; iii. wetlands; and, iv. waterbodies. The land-taking process is identified in this study as the passage of areas from non artificial classes in 2003 to the artificial land-cover class in 2008. Sardinia has experienced an increase in artifical land from a 2.75 percent in 2003 (66,206 hectares) to a 3.22 percent in 2008 (77,516 hectares).

Table 1 shows the variables that describe non-artificial and artifical land cover and their descriptive statistics. The variables refer to spatial units identified with the 377 municipalities of Sardinia.

Variable	Definition	Mean	St.dev.
ARTIF03	Artificial land cover in 2003 (ha) (source: Corine Land Cover Map of Sardinia – 2003 Edition, next "CLCMS03", level 1)	175.62	318.47
NARTIF03	Non-artificial land cover in 2003 (ha) (source: CLCMS03, level 1)	6,212.60	5,993.52
NARTIF08	Non-artificial land cover in 2008 (ha) (source: Corine Land Cover Map of Sardinia – 2008 Edition, next "CLCMS08", level 1)	6,181.76	5,956.36
PERLTAKE	2003-2008 percent change from non-artificial to artificial land cover (sources: CLCMS03, CLCMS08)	0.53	0.99
PVARLU1	2003-2008 percent change in artificial land cover (sources: CLCMS03, CLCMS08)	13.55	18.81
PVARLU2	2003-2008 percent change in non-artificial land cover, agricultural areas (sources: CLCMS03, CLCMS08)	2.39	12.57
PVARLU3	2003-2008 percent change in non-artificial land cover, forests and semi-natural areas (sources: CLCMS03, CLCMS08)	-4.65	24.32
PVARLU4	2003-2008 percent change in non-artificial land cover, wetlands (sources: CLCMS03, CLCMS08)	0.96	32.57
PVARLU5	2003-2008 percent change in non-artificial land cover, waterbodies (sources: CLCMS03, CLCMS08)	11.51	59.69

Table 1. Definition of land-cover variables and descriptive statistics.

3. Factors related to land take

Land take is related to location-related, socio-economic and planning code determinants (Sklenicka et al., 2013; Huang et al., 2006) and it is essentially a consequence of pressure for future land development (CRCS, 2012).

In terms of location-related and physical determinants, we consider the average size, slope and distance from the closest market place, that is the closest urban center, of a municipality's non-artificial-land areas in 2003 which became artificial in 2008, as these are frequently cited as important factors for land development (Sklenicka et al., 2013; Cheshire, 1995; Palmquist and Danielson, 1989). Accessibility is another characteristics related to the physical location of non-artificial land (Stewart and Libby, 1998), which we describe through: i. endowment of roads which connect regional town and city centers, which the Italian Code concerning Road Regulation (Italian law enacted by Decree no. 1992/285) classes as "Highways", "Main extra-urban roads" and "Secondary extra-urban roads;" ii. proximity to the regional administrative capital city, that is Cagliari, which is also the most important city center of the region; iii. proximity to the nearest province administrative center.

In the case of Sardinia, an island which coincides with an administrative region of Italy, the distance from the coast is of particular importance, since the so-called "coastal strip" (CS) is defined in article 19 of the Planning Implementation Code (PIC) of the Regional Landscape Plan of Sardinia (RLP, approved by the Regional Government of Sardinia in 2006[4]) as a "strategic resource, vital for the achievement of sustainable development in Sardinia, that requires integrated planning and management." Under article 20 of the PIC, as a general rule, new development of land and transformation of current land uses are not allowed in the CS; in particular, construction of new major roads, of new industrial or commercial developments, of new camping sites and of facilities associated with golf courses is forbidden within the CS. Some exceptions to the general rule are allowed, provided that municipalities and developers abide by regulations and procedures given by the PIC. Due to these particular restrictions in force in the CS, it was believed that the amount of municipal land area included in the CS could be a relevant impact factor on the ability of cities and towns to spend funds allocated for public services and infrastructure (Zoppi and Lai, 2013). So, a proximity-to-coast effect could be expected, since coastal land is demanded for future tourism development. If land-taking processes related to tourism development are forbidden, it seems very possible that land take will occur in the proximity of the CS. This argument is discussed by Dewi et al. (2013), who found that the establishment of protected areas in Asian and African tropical forestry regions determines an increased exploitation of the marginal lands just outside the protected areas.

Among planning-code-related determinants, we consider the endowment of protected areas, since these areas provide environmental amenities. Proximity to protected areas should increase the demand for new residential, commercial or recreational developments, which may possibly generate a change from agricultural to artificial land cover. The argument is even stronger than the Dewi's cited above, since, from this perspective, land take is also driven by the availability of environmental amenities.

Other planning-code factors are related to the class of an area according to the PIC of the RLP. The PIC establishes a rigid conservative regime with respect to areas classified as "landscape components with an environmental value, defined as natural and seminatural areas." It should be comparatively fairly more difficult that an area classified in this way changes its status from non-artificial to artificial land cover. The other class of landscape components with an environmental value is defined as "agricultural and forestry areas."

[4] Available at: http://www.sardegnaterritorio.it/paesaggio/pianopaesaggistico.html [accessed December 12, 2012], which includes the PIC of the RLP, its cartography and its cartographical zoning classes.

Since the conservative regime is less rigid for these areas, areas located there could be more likely to become non-artificial than the former. As we put in evidence above, the CS is a class for which the PIC of the RLP establishes a very restrictive and conservative regime, so areas located in the CS should be particularly unlikely to change their non-artificial land cover. Finally, a planning-code-related variable is represented by the areas for which the planning code in force before the PIC, that is before 2006, forbade almost completely any land transformations and new developments.

Variable	Definition	Mean	St.dev.
PARCSIZE	Municipality's average size of areas classified as non-artificial in 2003 and artificial in 2008 (ha) (sources: CLCMS03, CLCMS08)	0.33	0.29
SLOPE	Municipality's average slope of areas classified as non-artificial in 2003 and artificial in 2008 (percent) (sources: CLCMS03, CLCMS08, Digital Terrain Model of Sardinia, cell size 90 m)	8.97	6.60
PROXSETL	Municipality's weighted average distance from areas classified as non-artificial in 2003 and artificial in 2008 CLC to the closest urban center (km); weight = area size (sources: CLCMS03, CLCMS08, Spatial Dataset of the Regional Geographic Information System of Sardinia, next SDRGISS[5])	2.62	1.64
ACCESS	Endowment of roads connecting regional town and city centers per unit of municipal land area (km/km^2) (source: SDRGISS)	0.95	0.47
DISTCAPC	Distance of a municipality from the regional capital city, Cagliari (km) (source: Google Maps)	126.45	71.17
DISTNEAC	Distance of a municipality from the closest province administrative center (km) (source: Google Maps)	30.98	16.67
DISCOAST	Municipality's weighted average distance of areas classified as non-artificial in 2003 and artificial in 2008 from the shoreline (km); weight = area size (sources: CLCMS03, CLCMS08, SDRGISS)	21.02	13.99
CONSAREA	Municipality's total protected area in 2008: parks, reserves, etc. (ha) (sources: CLCMS03, CLCMS08, SDRGISS)	1,342.74	2,632.62
NATAR	Municipality's landscape components with an environmental value, defined as natural and seminatural areas that change from non-artificial to artificial land cover in 2003-2008 (ha) (sources: CLCMS03, CLCMS08, RLP spatial dataset)	11.67	26.05
AGRFORAR	Municipality's landscape components with an environmental value, defined as agricultural and forestry areas that change from non-artificial to artificial land cover in 2003-2008 (ha) (sources: CLCMS03, CLCMS08, SDRGISS, RLP spatial dataset)	25,70	50.83
COASTRIP	Percentage of a municipality's area included in the CS (sources: SDRGISS, RLP spatial dataset)	11.18	24.96
OLDPLAN	Municipality's area classed under the planning code in force before 2006 as area where land transformations and new developments are almost totally forbidden that changes from non-artificial to artificial land cover in 2003-2008 (ha) (sources: CLCMS03, CLCMS08, SDRGISS)	14.85	43.06
DENSITY	Municipality's population density in 2008 (residents per square kilometer) (source: web site Sardegna Statistiche: http://www.sardegnastatistiche.it [accessed December 12, 2012])	77.42	209.25
INC2008	Municipality's real per-capita income in 2008 (euros; 2008 consumer price index = 1) (source: web sites Sardegna Statistiche and Comuni-Italiani.it: http://www.sardegnastatistiche.it and http://www.comuni-italiani.it [accessed December 12, 2012])	9,212.95	1,391.61

Table 2. Definition of land-cover covariates and descriptive statistics.

[5] Available from the Regional Geoportal, at: http://www.sardegnageoportale.it/index.html [accessed December 12, 2012].

Moreover, we consider two socio-economic factors as possible determinants. First, population density, whose correlation with land cover change, which puts in evidence a positive agglomeration effect, is underlined by several studies (Sklenicka, 2013; Guiling et al., 2009; Forster, 2006). Second, we use change in per-capita income from 2003 to 2008 to control for a possible income effect. It is quite likely a significant factor, although we do not have a definite expectation as to the sign of the coefficient, since, for example, increasing per-capita income could make a municipality more willing to invest in agriculture or could displace agriculture if the available investment from increased income is diverted elsewhere (Lai and Zoppi, 2012).

Table 2 shows the variables which describe factors related to land-taking processes and their descriptive statistics.

4. Land take and its covariates: spatial representation and correlations

Except for DISTCAPC and DISTNEAC, none of the land-cover variables and covariates listed in Table 1 and Table 2 were available "off the shelf"; therefore, some kind of analysis was required and performed on data (both geographic and non- geographic) collated from different sources. In most cases, GIS-based analyses consisting in combinations of basic geoprocessing operations were performed; in some cases (e.g. to estimate the values of SLOPE, PROXSETL, DISTCOAST), however, more advanced analyses were performed using algorithms built in two open source software programs.[6] This made it possible to develop a geographic dataset, to calculate the value of each land-cover variable and covariate for each of the 377 Sardinian municipalities, and to analyze their spatial distributions.

The spatial distribution of three of the land-cover variables is shown in Fig. 1: in the first map (PVARLU1), darker polygons correspond to municipalities with the highest values of the ratio of amount of land taken between 2003 and 2008 to amount of land that was already classed as artificial in 2003. In the second map (PVARLU2), paler polygons highlight those municipalities which lost the highest share of their agricultural areas between 2003 and 2008 (positive values of PVARLU2 indicate that between 2003 and 2008 agricultural areas increased); similarly, in the third map, paler polygons higlight those municipalities which lost the highest share of their forests and semi-natural areas between 2003 and 2008 (positive values of PVARLU2 indicate that between 2003 and 2008 forests and semi-natural areas increased). Such maps only put in evidence changes in land cover between 2003 and 2008, without necessarily implying that land take actually occurred; for instance, where PVARLU2 is negative and PVARLU3 is positive, part of the decrease in agricultural land might be due to forestation or to abandonment of agricultural uses, rather than to urbanization.

The values of the correlation coefficients (ρ) measuring the linear dependence between the variable PERLTAKE (accounting for land take at the municipal level) and its covariates are shown in Table 3, where a high and positive correlation between PERLTAKE and PARCSIZE is put in evidence (ρ=0.68). This means that, in general, the higher the value of land take, the larger the size of parcels whose land cover changed from non-artificial to artificial between 2003 and 2008. Lower, and yet relevant (between 0.40 and 0.30), are the positive correlation coefficients between PERLTAKE on the one hand and DENSITY, NATAR, AGRFORAR and INC2008 on the other hand. This means that, usually, higher

[6] "Quantum GIS", available at http://hub.qgis.org/projects/quantum-gis/wiki/Download, and "gvSIG", available at http://www.gvsig.org [accessed December 12, 2012].

values of land take occur in municipalities where the residential density is higher, where areas artificialized between 2003 and 2008 that were classed by the RLP either as natural and seminatural areas or as agricultural and forestry areas are larger, and having a higher per-capita income.

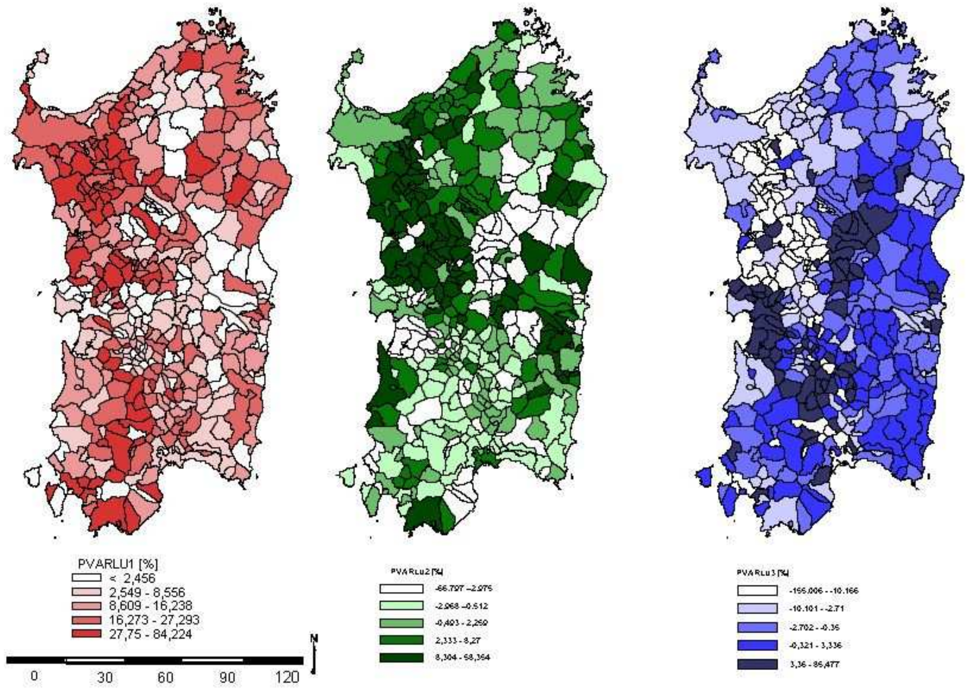

Fig. 1: Spatial representation of the land-cover variables PVARLU1, PVARLU2 and PVARLU3 at the municipal level (20th, 40th, 60th, and 80th percentiles).

	ρ		ρ		ρ
PARCSIZE	0.68	*DISTNEAC*	-0.21	*COASTRIP*	0.19
SLOPE	-0.22	*DISTCOAST*	-0.20	*OLDPLAN*	0.21
PROXSETL	0.06	*CONSAREA*	-0.06	*DENSITY*	0.40
ACCESS	0.12	*NATAR*	0.36	*INC2008*	0.32
DISTCAPC	-0.08	*AGRFORAR*	0.33		

Table 3. Pearson product-moment correlation coefficients between PERLTAKE and all of the land-cover covariates in Table 2.

The highest negative values of the correlation coefficient are those between PERLTAKE on the one hand and the variables SLOPE, DISTNEAC and DISTCOAST on the other hand, although the linear correlation is not very relevant (ρ takes values between -0.20 and -0.22).

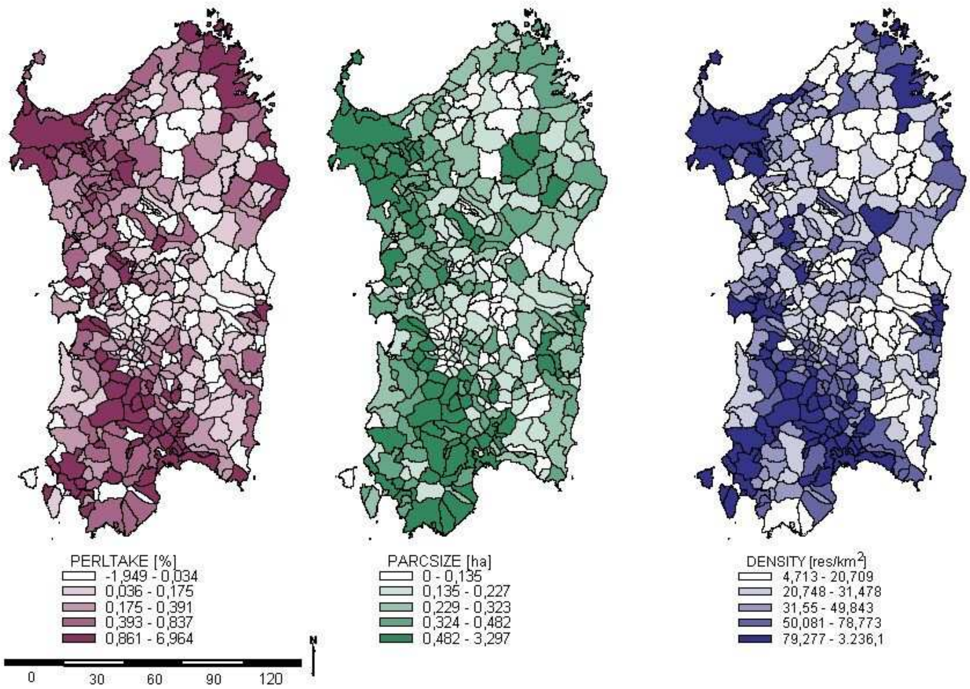

Fig. 2: Spatial representation of the variables PERTAKE, PARCSIZE and DENSITY at the municipal level (20th, 40th, 60th, and 80th percentiles).

Maps in Fig. 2, where polygons represent Sardinian municipalities, depict the spatial distribution of the variable PERTAKE and of its two covariates having the highest positive values of the correlation coefficient, that is, PARCSIZE and DENSITY. They unveil similarities in the geographic distribution of the variables with reference to both high and low level of the variables: large dark clusters of polygons are clearly identifiable in the south-western, north-western and north-eastern parts of the island in all of the maps. To the contrary, small clusters of polygons having paler colors emerge in some inner parts of the island and close to the Gulf of Orosei (middle-eastern coast).

5. Results

In the first place, we use a simple ordinary-least-squares (OLS) model to analyze if and to what extent each factor which the literature quoted in the fourth section identifies as possibly related to land-take processes. Table 4 shows significant correlations, at 10 percent level of statistical significance, for the average size of areas classified as non-artificial in 2003 and artificial in 2008 (PARCSIZE), endowment of roads connecting a municipality to the main regional urban centers (ACCESS), which is a measure of a municipality's accessibility, distance from Cagliari (DISTCAPC), the regional capital city, which is another accessibility indicator, extent of protected areas (CONSAREA), extent of areas where transformations were prevented by the planning code in force before year 2006 (OLDPLAN), and population density.

The distance of a municipality from the closest province administrative center (DISTNEAC), the average income level of a municipality (INC2008) and the size of a municipality's environmentally-valuable landscape components (NATAR), are less-significantly correlated to land take (25-30 percent), while no significant influence on land-take processes is put in evidence by the other covariates. In particular, there is no significant correlation between land take and proximity to the coast or to the closest urban center, nor is there with reference to the land taken's status of agricultural and forestry landscape component or inclusion in the CS.

Moreover, we estimate an OLS-regression model which includes the covariates whose coefficients are significant at 30 percent. The model's results are reported in Table 5. The model with a reduced set of explanatory variables substantially confirms the estimates of the model whose results are shown in Table 4. The values of the adjusted R-squared's are almost the same as well, so we are quite confident that the excluded variables would not have contributed to the goodness of fit of the estimated OLS model, while uncertainty remains on the influence of DISTNEAC, NATAR and INC2008.

Variable	**Coefficient$_i$**	**Stand.error**	**t-statistic**	**Hypothesis test: coefficient=0**
Constant	-1.1696	0.3047	-3.839	-0.0001
PARCSIZE	2.3516	0.1443	16.300	0.0000
SLOPE	0.0018	0.0056	0.327	0.7436
PROXSETL	-0.0111	0.0261	-0.427	0.6696
ACCESS	0.2378	0.0833	2.855	0.0046
DISTCAPC	0.0013	0.0005	2.437	0.0153
DISTNEAC	0.0025	0.0023	1.107	0.2690
DISTCOAST	0.0015	0.0031	0.476	0.6347
CONSAREA	-2E-05	1E-05	-1.754	0.0803
NATAR	-0.0026	0.0021	-1.214	0.2256
AGRFORAR	0.0003	0.0009	0.347	0.7291
COASTRIP	-9E-05	0.0018	-0.048	0.9617
OLDPLAN	0.0021	0.0011	1.878	0.0612
DENSITY	0.0016	0.0002	8.889	0.0000
INC2008	4E-05	3E-05	1.202	0.2301
Adjusted R-squared= 0.5918				

Table 4. OLS results, dependent variable PERLTAKE: the regression model includes all the covariates of Table 2.

Since 301 out of 377 (about 80 percent) values of 2003-2008 percent change from non-artificial to artificial land cover (the dependent variable PERLTAKE) are included in the interval (0,1), we also estimate a censored-regression model, considering only the values of PERLTAKE of the interval (0,1), in order to check the robustness of the OLS estimates, under the work hypothesis that the values outside the interval were outliars.[7] The model's estimates, shown in Table 6, confirm the results of the OLS model, with the exception of the variable NATAR, which is less signicant than in the case of the OLS model.

[7] The censored-regression model is estimated following the methodology proposed by Lai and Zoppi, 2012. Censored-regression models are also known as *Tobit* models. Censored-regression models allow to estimate the covariates' marginal effects on the dependent variable. We omit the model specification, which is discussed by Lai and Zoppi (2012).

Variable	$Coefficient_i$	Stand.error	t-statistic	Hypothesis test: coefficient=0
Constant	-1.1068	0.2664	-4.1540	0.0000
PARCSIZE	2.3407	0.1379	16.9780	0.0000
ACCESS	0.2400	0.0759	3.1630	0.0017
DISTCAPC	0.0012	0.0005	2.3550	0.0191
DISTNEAC	0.0028	0.0021	1.3380	0.1817
CONSAREA	-3E-05	1E-05	-1.9350	0.0537
NATAR	-0.0023	0.0019	-1.1830	0.2378
OLDPLAN	0.0020	0.0010	1.8990	0.0583
DENSITY	0.0016	0.0002	9.0300	0.0000
INC2008	3E-05	3E-05	1.1450	0.2528
Adjusted R-squared= 0.5964				

Table 5. OLS results, dependent variable PERLTAKE: the regression model includes the covariates whose coefficient estimates are significant at 30 percent with reference to the OLS-model of Table 4.

6. Discussion and conclusion

This paper analyzes the Sardinian land-taking process as related to factors which are identified as relevant variables in several studies concerning land take in several studies of the mainstream literature, through censored and OLS regression models. We tentatively consider a set of variables which includes location-related and physical determinants, planning code rules, and socio-economic factors.

We find that there is a double agglomeration effect, since land-taking processes are positively and significantly related to high population density and high concentration of land which changes its status from non-artificial to artificial. This indicates that saving non-artifical land, or limiting land take, could be effectively supported by low-density settlements and extensive and light land-taking processes, since the concentration of land take in a limited number of municipalities would imply a larger extent of land which becomes artificial, being non-artificial in the first place.

Secondly, the more a municipality is accessible, the more it is suitable to land-taking processes, which indicates that balancing the accessibility opportunities would be a strategic regional policy in order to limit the concentration of land take and, ultimately, to mitigate the agglomeration effect which characterizes land take. This goal could be reached by increasing the endowment of public roads connecting regional town and city centers to small municipalities, giving particular care to road connections to the regional capital and province cities.

Thirdly, we find that the presence and size of protected areas is negatively and significantly connected to land take, as expected. So, conservation of natural resources, habitats and environment could be strategically important in order to deal with land-taking processes, and to influence their territorial layout. This is also confirmed by the estimates related to the covariate OLDPLAN, which is positively correlated to the change of land from non-artificial to artificial. This indicates that the more conservative planning rules are weakened, the more land-taking processes occur, which is what happened (in year 2003) in the areas where the old regional landscape plans were not in force any more. A similar phenomenon is put in evidence by the covariate NATAR, which is positively, even though not significantly, correlated to PERLTAKE, which suggests, as before, that the more conservative planning rules are weakened, the more land-taking processes occur: in the case of NATAR it is evident that the conservation character of the RLP PIC was weak if non-artificial areas defined as landscape components with an environmental value were allowed to change their status from non-artificial to artificial land between 2003 and 2008.

Variable	**Coefficient$_i$**	**Stand.error**	**t-statistic**	**Hypothesis test: coefficient=0**
Constant	-0.5120	0.1330	-3.849	0.0001
PARCSIZE	1.4791	0.0940	15.736	0.0000
ACCESS	0.1309	0.0372	3.521	0.0004
DISTCAPC	0.0004	0.0003	1.395	0.1630
DISTNEAC	0.0014	0.0010	1.364	0.1726
CONSAREA	-2E-05	6E-06	-3.405	0.0007
NATAR	0.0029	0.0012	2.347	0.0189
OLDPLAN	0.0004	0.0006	0.653	0.5138
DENSITY	0.0008	0.0002	3.352	0.0008
INC2008	2E-05	1E-05	1.208	0.2269
Decomposition-based fit measure=0.5266				

Table 6. Marginal effects of covariates estimated on a censored-regression model based on Lai and Zoppi (2012), dependent variable PERLTAKE is censored between 0 and 1.

The fact that protection of nature, environment and natural resources matters is also put in evidence by the absence of correlation between land-taking processes and the variables COASTRIP and DISCOAST, which indicates that land take was not a coastal phenomenon in the period 2003-2008. Since in the eighties and in the nineties the Sardinian regional land-taking processes were almost exclusively concentrated in coastalmunicipalities, the non-coastal characterization of land take between 2003 and 2008 could only be related to the conservative planning rules that the regional landscape plans in force before 2006 and the RLP, from year 2006 on, have implemented.

Moreover, there is a slight, statistically-significant at 25 percent only, positive income effect, which indicates that a more balanced income distribution could help limit territorial concentration of land-taking processes. This slight income effect is consistent with the previous findings concerning the effectiveness of the 2000-2006 Sardinian Regional Operational Programme funded by the European Agricultural Guidance and Guarantee Fund (EAGGF) in maintaining and possibly increasing agricultural land use (Lai and Zoppi, 2012), that is, the higher the average household income of a municipality, the more agricultural (non-artificial) land is maintained and possibly increased.

In this paper, we tentatively consider a set of variables which includes location-related and physical determinants, planning code rules, and socio-economic factors. As we stated in the third section, we do not assume ethic narratives or value judgments on land take. Nevertheless, the findings imply a set of policy statements which can be taken into account in order to influence land-taking processes. Agglomeration effect both in terms of land which becomes artificial being non artificial in the first place, and of residential concentration increases the intensiy of land take. As a consequence, extensive urbanization and planning codes which prevent the artificialization of vast contiguous areas should be effective in saving-up non-artificial land. A balanced accessibility of regional cities and towns and a comprehensive regional policy concerning protection of nature, natural resources, environment and endangered species and habitats should be important as well. Moreover, supporting a more balanced distribution of the regional household income and restrictive planning rules concerning new development in the CS are policies which help to counter and limit land take.

This paper analyzes the Sardinian land-taking process as related to factors which are identified as relevant variables concerning land take in several studies of the mainstream literature, through censored and OLS regression models. The methodology can be easily replicated and exported with reference to other Italian and European contexts and results could be straighfowardly comparable. Policy implications of the findings could be a point of reference for future Italian and European land-use and planning policies which entail a careful consideration of the negative impacts of artificialization of land, as the Communication of the EC to the European Parliament COM(2011) 571 of 20.9.2011 puts in evidence. Future research should also relate to the construction of a spatial data infrastructure to monitor and control land-taking processes, with a view to the objective of no net land take by 2050.

7. References

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