🏆 *reviewed paper*

Factors Affecting Land-Taking Processes in Italy at the Regional Scale: Empirical Findings from Sardinia

Sabrina Lai, Corrado Zoppi

(Doctor Sabrina Lai, Department of Civil and Environmental Engineering and Architecture, University of Cagliari, Via Marengo, 2 - 09123 Cagliari, Italy, sabrinalai@unica.it)
(Doctor Corrado Zoppi, Department of Civil and Environmental Engineering and Architecture, University of Cagliari, Via Marengo, 2 - 09123 Cagliari, Italy, zoppi@unica.it)

1 ABSTRACT[1]

Land take is a process of significant relevance in the countries of European Union (EU), defined as the "Change of the amount of agriculture, forest and other semi-natural and natural land taken by urban and other artificial land development" (European Environment Agency, 2013a).

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 a previous paper, we analyzed the land-taking process in the period 2003-2008 through the land cover maps of Sardinia, made available in 2003 and 2008 by the Sardinian regional administration (Zoppi and Lai, 2014), as related to factors which are identified as relevant variables in several studies concerning land take, such as area size, accessibility, proximity to main cities and small settlements, to the coastline, or to nature conservation areas.

In this paper we study the Sardinian land-taking process in two time periods, 1960-1990 and 1990-2008. We assess if, and to what extent, these factors reveal similar, or different, effects in the two periods, and try to identify consistencies concerning the determinants of land take.

2 INTRODUCTION

We define 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" (European Environment Agency, 2013a). Findings and discussion proposed in this paper build upon the results of a previous paper (Zoppi and Lai, 2014), whose main points is worth summarizing here to make it clear to the reader how we address the issue of land take and what perspective we assume in order to assess the influence of physical, socio-economic and planning code factors on land-taking processes.

Land take amounted to more than 1,000 km2 per year between 1990 and 2000, and to about 920 km2 between 2000 and 2006 (European Commission, 2011), which means that the objective of no net land take by 2050 (Communication of the EC to the European Parliament COM(2011) 571 of 20.9.2011) would imply a decrease rate of about 800 km2 per year.

Italian figures concerning land take show 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).

To provide a comprehensive, agreed-upon definition of land take is rather difficult. Let us consider, for example, the Land Use and Cover Areas frame Survey (LUCAS) of EUROSTAT (European Commission, EUROSTAT, 2010), 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, 2013b). In LUCAS, "artificial land", that is land taken by land-taking processes, is classed into two main groups, that is "built-up" and "non built-up" areas, where the former are further classed 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 classed 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

[1] This essay comes from the joint research work of the authors. Sections 1, 2 and 6 have been jointly written by the authors. Corrado Zoppi has taken care of sections 3 and 5. Sabrina Lai has taken care of section 4 and has revised the whole essay and checked its comprehensive consistency.

ISBN: 978-3-9503110-8-2 (CD-ROM); ISBN: 978-3-9503110-9-9 (Print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C. BEYER

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, they greatly differ from each other.

Here, consistently with our previous paper (Zoppi and Lai, 2014), we do not propose a judgment on the rightness or wrongness of land take; rather, we analyze land-taking processes in order to detect what 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 major islands of Italy. We study the determinants of the dynamics of Sardinian land-taking processes in two time periods, 1960-1990 and 1990-2008, and assess these processes in terms of variables influencing land take, in order to evaluate if, and to what extent, these factors reveal similar, or different, effects in the two periods, and try to identify consistencies concerning the determinants of land take.

As of today, no detailed maps are available to describe, measure and compare land take over a large period of time in Italy. The European Environment Agency (EEA) does produce and make available land-cover maps but only from 1990 onwards[2]; moreover, the resolution of the map is not fully appropriate at the regional scale. Therefore, because we aimed at studying the process at the regional scale and by looking at a much larger space of time, we chose to study land take by integrating various sources as follows:

(1) two vector layers belonging to the dataset of the Regional Landscape Plan of Sardinia (RLP) (produced in 2006 and available from the regional geoportal[3]) that respectively describe historic settlements, defined as urbanized areas as of the end of the XIX century on the basis of the maps produced by the (then) Royal Geographic Italian Military Institute, and urban developments as of the end of the 1950's, which in Sardinia were usually built adjacent to the historic settlements, preserving their comparatively high density and compactedness together with the characteristics of older urban tissues and of the architectural features of the built environment;

(2) a vector layer produced by the EEA and describing Urban Morphologic Zones (UMZ) as of 1990[4]; these are defined by the EEA as "sets of urban areas laying less than 200m apart" and are identified on the basis of a selection of appropriate subclasses of the CLC class "artificial surfaces" contributing to the urban tissue and function;

(3) the 2008 Corine Land Cover Map produced by the Regional administration of Sardinia and available from the regional geoportal[5]; this is a vector dataset from which we selected only polygons belonging to the first-level CLC class "artificial surfaces".

The three above datasets differ in aim and resolution and for this reason they were preprocessed to avoid inconsistencies. As Figure 1 shows, such inconsistencies were corrected by means of basic geoprocessing operations.

Hence, we use the Sardinian CLC-based land-cover maps for 2008, the EEA's UMZ for 1990, and the above mentioned layers of the RLP to detect artificial land cover and land take in 1960.

In the CLC classification, non-artificial surfaces are classed 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, either in 1960, for the period 1960-1990, or in 1990, for the period 1990-2008, to the artificial land-cover class, either in 1990, for the period 1960-1990, or in 2008, for the period 1990-2008. Our analysis shows that Sardinia has experienced an increase in artificial land from 0.54 percent in 1960 (13,090 hectares) to 1.59 percent in 1990 (38,182 hectares), to 3.25 percent in 2008 (78,379 hectares).[6]

[2] Corine Land Cover 1990, 2000 and 2006 raster maps available at http://www.eea.europa.eu/data-and-maps/data/ (covering respectively 25, 39 and 37 countries); data for Italy are provided in all of the datasets [accessed February 24, 2015]

[3] http://www.sardegnageoportale.it/index.php?xsl=1598&s=135976&v=2&c=8831&t=1 [accessed February 24, 2015].

[4] http://www.eea.europa.eu/data-and-maps/data/urban-morphological-zones-1990-2 [accessed February 24, 2015].

[5] http://www.sardegnageoportale.it/index.php?xsl=1598&s=141401&v=2&c=8831&t=1 [accessed February 24, 2015].

[6] These findings are quite consistent with data on land take provided by ISPRA, the National Agency for Environmental Protection and available at http://www.isprambiente.gov.it/files/comunicati-stampa/2014/Tabelle_consumo_di_suolo.pdf [accessed February 24, 2015].

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

This paper is organized as follows. In the third section we discuss the set of variables that we use as covariates to frame land-taking processes in Sardinia. Explanatory and dependent variables are described and spatially represented in the fourth section, and correlations between covariates and the dependent (land take) variable discussed.

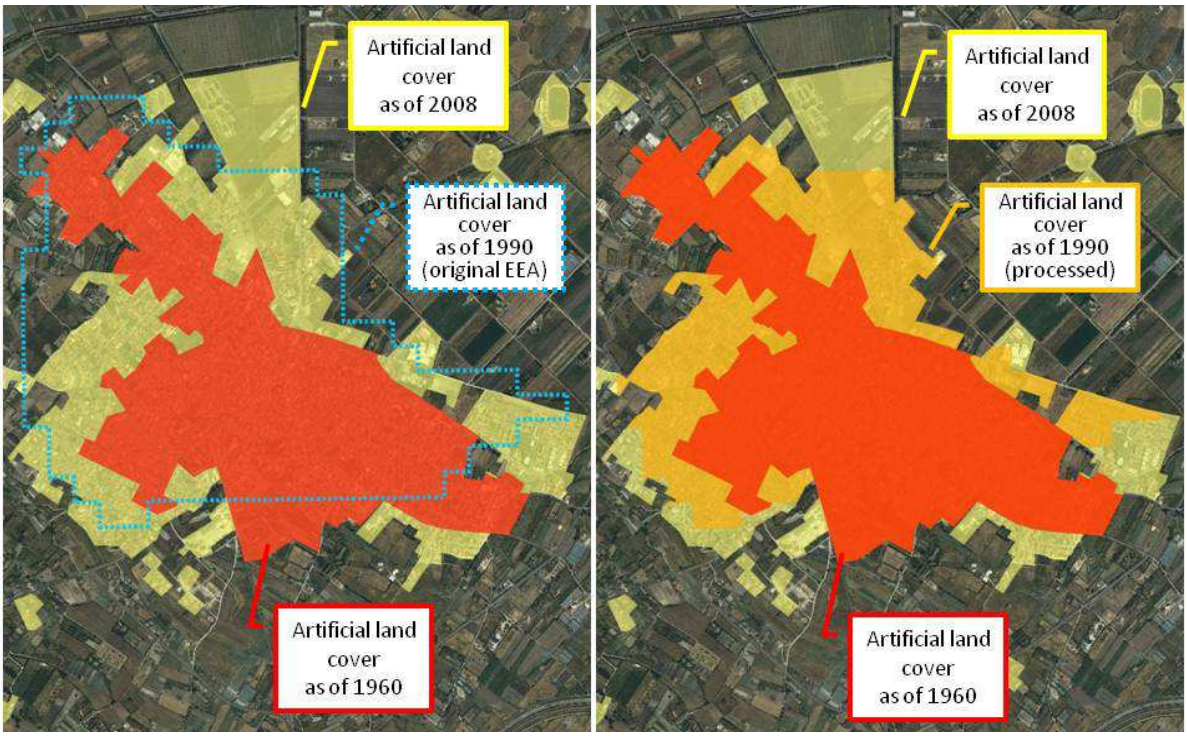

Figure 1: Analysis of changes in artificial land cover between 1960 and 2008: an example showing correction of inconsistencies due to differences in map resolutions.

The fifth section presents the results of regression models which use the land take variable and covariates in order to analyze if, and to what extent, these factors reveal similar, or different, effects in the two periods, and tries to identify consistencies concerning the covariates of land take. In the concluding section, we discuss consistencies related to the determinants of land take in order to identify factors that should 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.

3 FACTORS RELATED TO LAND TAKE

We consider land take as related to physical and planning code determinants, and to a social variable, that is residential density (Sklenicka et al., 2013; Huang et al., 2006), and as a possible consequence of pressure for future land development (CRCS, 2012).

We use the same covariates used by Zoppi and Lai (2014), classed as follows.

Variable	Definition	Mean	St.dev.
NURB1960	Municipality's non-urbanized areas in 1960 (ha) (source: RLP, Spatial Dataset of the Regional Geographic Information System of Sardinia, next SDRGISS[7])	6,353.51	6,157.73
NURB1990	Municipality's non-urbanized areas in 1990 (ha) (source: CLC, SDRGISS)	6,286.95	6,081.00
NURB2008	Municipality's non-urbanized areas in 2008 (ha) (source: Corine Land Cover Map of Sardinia – 2008 Edition, level 1, next CLCMS08, SDRGISS)	6,180.33	5,963.59
PLT6090	Percentage of municipal area whose land cover changed from non-urbanized to urbanized between 1960 and 1990	1.05	2.58
PLT9008	Percentage of municipal area whose land cover changed from non-urbanized to urbanized between 1990 and 2008	1.89	2.35

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

[7] Available from the Regional Geoportal, http://www.sardegnageoportale.it/index.html [accessed February 24, 2015].

ISBN: 978-3-9503110-8-2 (CD-ROM); ISBN: 978-3-9503110-9-9 (Print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C. BEYER

(1) Physical factors:

(a) average size, slope and distance from the closest urban center of a municipality's non-artificial-land areas in 1960 or in 1990, which became artificial in 1990 or in 2008 (Sklenicka et al., 2013; Cheshire and Sheppard, 1995; Palmquist and Danielson, 1989);

(b) accessibility, that is (Stewart and Libby, 1998), 1. endowment of roads which connect regional town and city centers, which 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;" 2. proximity to the regional administrative capital city, that is Cagliari, which is also the most important city center of the region; and, 3. proximity to the nearest province administrative center;

(c) distance from the coast, since in Sardinia the-so called "coastal-strip" (CS) is considered a "strategic resource, vital for the achievement of sustainable development in Sardinia, that requires integrated planning and management" by art. 19 of the Planning Implementation Code (PIC) of the Regional Landscape Plan of Sardinia[8] (RLP); due to particular restrictions in force in the CS, it was believed that land take would occur in the proximity of the CS, as 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.

(2) Planning-code-related factors:

(a) endowment of protected areas; it would be exptected that 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; from this perspective, land take is also driven by the availability of environmental amenities (Dewi et al., 2013);

(b) areas classed as "landscape components with an environmental value, defined as natural and seminatural areas" and as "agricultural and forestry areas" by the PIC of the RLP; it would be expected that it should be comparatively more difficult that such areas change their status from non-artificial to artificial land cover;

(c) areas located in the CS; these areas should be particularly unlikely to change their non-artificial land cover, as we have already discussed;

(d) areas which the planning code in force before the PIC, that is before 2006, classed as areas where land transformations and new developments were almost totally forbidden; it would be expected a positive influence of this variable on land take, at least in the 1990-2008, since 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.

(3) population density; several studies put in evidence a positive agglomeration effect of this variable on land tand take (Sklenicka, 2013; Guiling et al., 2009; Forster, 2006).

Variable	Definition	Mean 1960-1990	St.dev. 1960-1990	Mean 1990-2008	St.dev. 1990-2008
PSIZ6090 *PSIZ9008*	Municipality's average size of areas classed as non-urbanized in 1960/1990 and urbanized in 1990/2008 (PSIZ6090/PSIZ9008) (ha) (source: RLP, CLC, CLCMS08)	4.60	7.18	2.07	1.25
SLOP6090 *SLOP9008*	Municipality's weighted average slope of areas classed as non-urbanized in 1960/1990 and urbanized in 1990/2008 (SLOP6090/SLOP9008) (percent); weight = area size (source: RLP, CLC, CLCMS08, Digital Terrain Model of Sardinia[9])	6.99	7.08	9.56	6.19
PRS6090 *PRS9008*	Municipality's weighted average distance from the closest urban center to areas classed as non-urbanized in 1960/1990 and urbanized in 1990/2008 (PRS6090/PRS9008) (km); weight = area size (source: RLP, CLC, CLCMS08, SDRGISS)	0.96	1.54	2.43	1.51
ACCESS	Endowment of roads connecting regional town and city centers per unit of municipal land area (km/km^2) (source: SDRGISS)	**Mean**	0.96	**St.Dev.**	0.47
DISTCAPC	Distance of a municipality from the regional capital city, Cagliari (km) (source: Google Maps)	**Mean**	126.46	**St.Dev.**	71.27
DISTNEAC	Distance of a municipality from the closest province administrative	**Mean**	30.99	**St.Dev.**	16.70

[8] Available at: http://www.sardegnaterritorio.it/paesaggio/pianopaesaggistico.html [accessed February 24, 2015], which includes the PIC of the RLP, its cartography cartographical zoning classes and spatial dataset.
[9] Available at: http://www.sardegnageoportale.it/ [accessed February 24, 2015].

	center (km) (source: Google Maps)				
DISC6090 *DISC9008*	Municipality's weighted average distance from the shoreline to areas classed as non-urbanized in 1960/1990 and urbanized in 1990/2008 (DISC6090/DISC9008) (km); weight = area size (sources: RLP, CLC, CLCMS08, SDRGISS)	17.23	14.98	21.05	13.91
CONSAREA	Municipality's total protected area: parks, reserves, etc. (ha) (sources: SDRGISS)	**Mean**	1,342.74	**St.Dev.**	2636.12
NAT6090 *NAT9008*	Municipality's landscape components with environmental value, defined as natural and seminatural areas, that change from non-urbanized to urbanized between 1960/1990 and 1990/2008 (NAT6090/NAT9008) (ha) (sources: RLP, CLC, CLCMS08)	2.73	13.45	10.79	22.16
AGFO6090 *AGFO9008*	Municipality's landscape components with environmental value, defined as agricultural and forestry areas, that change from non-urbanized to urbanized between 1960/1990 and 1990/2008 (AGFO6090/AGFO9008) (ha) (sources: RLP, CLC, CLCMS08)	3.12	11.25	24.11	47.93
COASTRIP	Percentage of a municipality's area included in the CS (ha) (source: RLP; SDRGISS)	**Mean**	1.22	**St.Dev.**	2.41
OLPL6090 *OLPL9008*	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 changes from non-urbanized to urbanized between 1960/1990 (OLPL6090) and 1990/2008 (OLPL9008) (ha) (sources: RLP, CLC, CLCMS08, SDRGISS)	20.35	87.46	36.04	90.98
DENS1961 *DENS1990*	Municipality's population density in 1961 (DENS1961) and in 1990 (DENS1990) (people per square kilometer) (source: web site of the Italian Institute of Statistics http://demo.istat.it/dat81-91/COMUNI/ind_ pro.htm and website http://www.comuni-italiani.it/ [both accessed February 24, 2015])	70.02	170.80	74.73	213.84
AUTC6090 *AUTC9008*	Municipality's spatially lagged dependent variables 1960-1990 (AUTC6090, ref: PLT6090, Table 1 and Subsection 3.1) and 1990-2008 (AUTC9008, ref: PLT9008, Table 1 and Subsection 3.1)	0.99	1.56	1.82	1.27

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

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

3.1 Autocorrelation-related spatially-lagged dependent variable

If the value of a variable defined with reference to a spatial unit, such as a municipality, is correlated to the values it takes in the closest units, the variable is characterized by spatial autocorrelation. Spatial autocorrelation of the dependent variable in spatial regressions produces biases in the model's estimates. This issue can be addressed by adding a spatially-lagged dependent variable to the set of covariates (Anselin, 1988; 2003).

The presence of spatial autocorrelation of the dependent variable of our model, that is municipality's 1960-1990 and 1990-2008 percent change from non-artificial to artificial land cover (PLT6090 and PLT9008) is detected through the Moran's test (Moran, 1950; Anselin, 1988).

The Moran's test concerning the spatial autocorrelation of a variable X which takes values over a finite number of spatial units i, i = 1, …, N, is based on a statistic I defined as follows:

$$I = \frac{N}{S}\frac{\sum_{ij} W_{ij}(X_i - \boldsymbol{X})(X_j - \boldsymbol{X})}{\sum_i (X_i - \boldsymbol{X})} \quad (1)$$

where j = 1, …, N, **X** is the mean of the components of vector X, W_{ij} is equal to 1 if spatial unit i is spatially related to spatial unit j, 0 otherwise, and S is equal to $\sum_i \sum_j W_{ij}$. The test assumes that I is normally distributed with a zero mean in case no spatial autocorrelation occurs, which is the null hypothesis of the Moran's test. If the p-value of the test is lower than 5-10%, a spatially-lagged dependent variable should be added to the set of the covariates in order to make the model unbiased, since it is very likely that the values of the dependent variable are spatially autocorrelated. The spatially-lagged dependent variables, named AUTC6090 and AUTC9008 in Table 2, are defined through the following procedure, where AUTOCORR represents a spatially-lagged dependent variable (Anselin, 1988; 2003):

ISBN: 978-3-9503110-8-2 (CD-ROM); ISBN: 978-3-9503110-9-9 (Print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C. BEYER

$$AUTOCORR_i = \sum_j W_{ij} \quad (2)$$

where i, j = 1, …, N.

The application of the procedure described so far to our study implies the implementation of the Moran's test. We implement a set of Moran's tests using GeoDa[10] by assuming, alternatively, that W_{ij} of (1) is equal to 1 if: i. municipality i's and j's boundaries overlap each other, at least to some extent (Order 1 in Table 3); ii. municipality j's boundary overlaps the boundary of municipality z, at least to some extent, which in turns overlaps municipality i's boundary (Order 2 in Table 3); iii. municipality j's boundary overlaps the boundary of municipality z, at least to some extent, which overlaps municipality y's boundary, which overlaps municipality i's boundary (Order 3 in Table 3).

Contiguity order	Moran's I statistic	Stand.error	z-statistic	P-value: I=0
AUTC6090				
Order 1	0.422	0.022	18.990	7.27E-57
Order 2	0.280	0.018	15.229	3.92E-41
Order 3	0.142	0.017	8.149	5.51E-15
AUTC9008				
Order 1	0.341	0.022	15.859	9.88E-44
Order 2	0.237	0.020	11.666	4.74E-27
Order 3	0.145	0.018	8.230	3.11E-15

Table 3. Moran's test concerning spatial autocorrelation of variables AUTC6090 and AUTC9008.

Table 3 shows the results of the six Moran's tests carried out, which are always significant. The most significant is the first case (Order 1), so we add a spatially-lagged dependent variable defined by (2) to the set of covariates of our model, where W_{ij} is equal to 1 if municipality i's and j's boundaries overlap each other, at least to some extent. Descriptive statistics of AUTOCORR are shown in Table 2.

4 LAND TAKE AND ITS COVARIATES: SPATIAL REPRESENTATION AND CORRELATIONS

Once three shapefiles describing urbanized areas as of (i) 1960, (ii) 1990, and (iii) 2008 were obtained (as previously stated in Section 2, from the Sardinian CLC-based land-cover maps for 2008, the EEA's UMZ for 1990, and from selected layers of the RLP spatial dataset for the end of the 1950's), it was possible to derive two further shapefiles describing those parcels of land whose land cover changed from non-artificial to artificial respectively between 1960 and 1990 and between 1990 and 2000; this in turns made it possible to calculate, for each Sardinian municipality and in the two selected time periods, the magnitude of land-take (PLT6090, PLT9008), as well as the average size of parcels whose land cover had changed from non-artificial to artificial (PSIZ6090, PSIZ9008).

Through GIS-based analyses consisting either of combinations of basic geoprocessing operations or of more advanced techniques (e.g. to estimate the values of SLOP6090 and SLOP9008, PRS6090 and PRS9008, DISC6090 and DISC9008), a geographic dataset was developed and the value of each variable for each of the 377 Sardinian municipalities was calculated, which made it possible to analyze the spatial distribution of the variables.

The values of the correlation coefficients (ρ) measuring the linear dependence between the dependent variables PLT6090 and PLT9008 (accounting for land take at the municipal level in the two time periods taken into account) and their respective sets of covariates are shown in Table 4, where some high and positive correlations are highlighted: PLT6090 is correlated to DENS1961 (ρ=0.7185) and to PSIZ6090 (ρ=0.5259), while PLT9008 is correlated to PSIZ9008 (ρ=0.6068) and to DENS1990 (ρ=0.4951). 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 in the given time period, and the larger the population at the beginning of the interval under examination.

[10] Version 1.4.6. Available at https://geodacenter.asu.edu.

Dependent variable: PLT6090				Dependent variable: PLT9008			
	ρ		ρ		ρ		ρ
PSIZ6090	0.5259	*CONSAREA*	0.0405	*PSIZ9008*	0.6068	*CONSAREA*	-0.0704
SLOP6090	-0.1316	*NAT6090*	0.3361	*SLOP9008*	-0.3039	*NAT9008*	0.1846
PRS6090	0.2664	*AGFO6090*	0.3955	*PRS9008*	0.0884	*AGFO9008*	0.2476
ACCESS	0.1442	*COASTRIP*	0.4328	*ACCESS*	0.2869	*COASTRIP*	0.3823
DISTCAPC	-0.1464	*OLPL6090*	0.2904	*DISTCAPC*	-0.1901	*OLPL9008*	0.1972
DISTNEAC	-0.2438	*DENS1961*	0.7185	*DISTNEAC*	-0.3402	*DENS1990*	0.4951
DISC6090	-0.1827			*DISC9008*	-0.3408		

Table 4. Pearson product-moment correlation coefficients between the two dependent variables (PLT6090 and PLT9008) and all of their covariates listed in Table 2.

Lower, and yet relevant (between 0.30 and 0.45), are the positive correlation coefficients on the one hand between PLT6090 and COASTRIP, AGFO6090, NAT6090, and on the other hand between PLT9008 and COASTRIP. This means that, usually, higher values of land take occured in municipalities whose territory overlaps the coastal strip as defined within the 2006 RLP, and that between 1960 and 1990 land take occurred in municipalities having larger areas classed by the RLP either as natural and seminatural areas or as agricultural and forestry areas. The highest negative values of the correlation coefficient can be found on the one hand between PLT6090 and DISTNEAC and on the other hand between PLT9008 and the variables DISTNEAC and DISC9008, although the linear correlation is not as relevant as the above mentioned positive ones (ρ takes values between -0.24 and -0.34).

Maps in Fig. 2 and 3, where polygons represent Sardinian municipalities, depict the spatial distribution of the variables PLT6090, PLT9008 and of their two covariates having the highest positive values of the correlation coefficient, that is, respectively, PSIZ6090 and DENS1961 for the first, and PSIZ9009 and DENS1990 for the second.

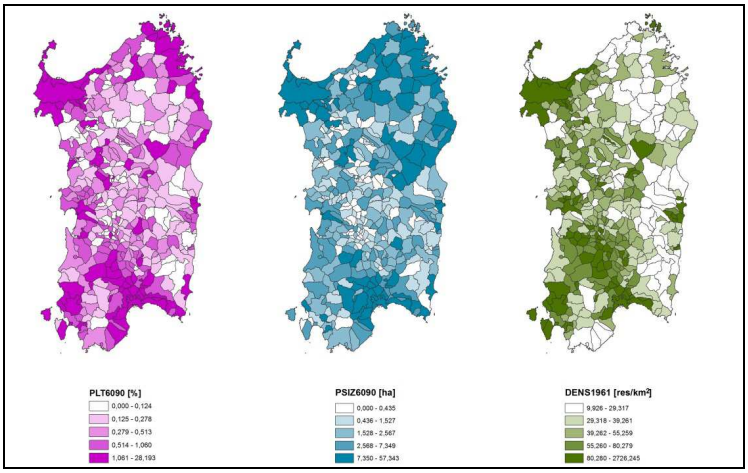

Figure 2: Spatial representation of the variables PLT6090, PSIZ6090 and DENS1961 at the municipal level (quantiles).

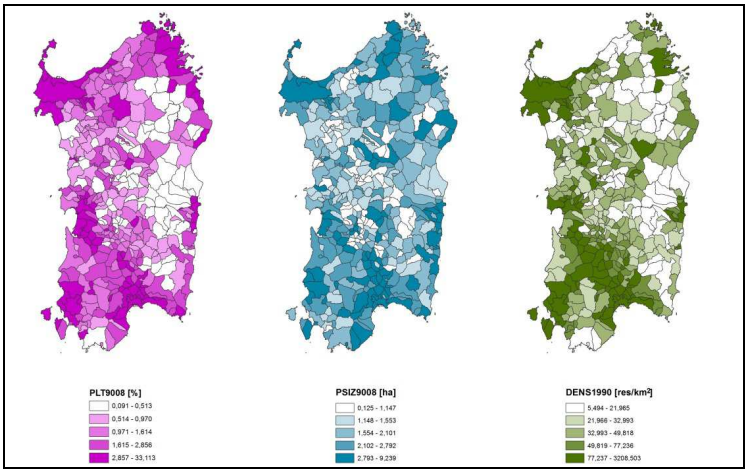

Figure 3: Spatial representation of the variables PLT9008, PSIZ9008 and DENS1990 at the municipal level (quantiles).

ISBN: 978-3-9503110-8-2 (CD-ROM); ISBN: 978-3-9503110-9-9 (Print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C. BEYER

5 RESULTS

We use an ordinary-least-squares (OLS) model to analyze if and to what extent each factor, which the literature quoted in the third section identifies as a possible determinant, is correlated to land take, in the two periods 1960-1990 and 1990-2008. Preliminarily, we estimate two OLS regressions for each period. The first includes the actual values of the explanatory variables described in Table 2, while the second uses their logarithms. By doing so, we assess whether the linear or the log-linear models shows the best fit. The estimates of coefficients of the variables from the two models are consistent with each other, even though the linear models' fitness is quite greater than that of the log-linear, since the values of adjusted Rs-squared related to the 1960-1990 period are about 80 percent for the linear model and about 73 percent for the log-linear, and the values of adjusted Rs-squared related to the 1990-2008 period are about 63 percent for the linear model and about 55 percent for the log-linear. Therefore, our discussion is based on the linear models' estimates.

The estimates related to the 1960-1990 period, reported in Table 5, show significant correlations (p-values less than 0.1 percent) for: (i) the average size of areas classed as non-artificial in 1960 and artificial in 1990 (PSIZ6090, positive); (ii) the landscape components with an environmental value (agricultural and forestry areas) that change from non-artificial to artificial land cover (AGFO6090, negative); (iii) the size of a municipality's environmentally-valuable landscape components (NAT6090, positive); (iv) the percentage of a municipality's area included in the CS (COASTRIP, positive); (v) 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 changes from non-urbanized to urbanized between 1960 and 1990 (OLPL6090, positive); (vi) the residential density in 1961 (DENS1961, positive); and (vii) the spatially-lagged dependent variable (AUTC6090, positive).

Moreover, less significant estimates are reported for: (i) the distance of a municipality from the regional capital city (DISTCAPC, negative, p-value: 6 percent); (ii) the distance of a municipality from the closest province administrative center (DISTNEAC, positive, p-value: 7 percent); (iii) the endowment of roads connecting regional town and city centers per unit of municipal land area (ACCESS, positive, p-value: 11 percent); (iv) the municipality's total protected area; (v) the municipality's weighted average distance from the closest urban center to areas classed as non-urbanized in 1960 and urbanized in 1990 (PRS6090, negative, p-value: 14 percent); (vi) the municipality's weighted average distance from the shoreline to areas classed as non-urbanized in 1960 and urbanized in 1990 (DISC6090, positive, p-value: 20 percent).

Finally, the municipality's weighted average slope of areas classed as non-urbanized in 1960 and urbanized in 1990 does not seem to influence land take in the period.

The estimates related to the 1990-2008 period, reported in Table 5 as well, are consistent with the 1960-1990 estimates for variables PSIZ9008, PRS9008, ACCESS, DISTNEAC, CONSAREA, COASTRIP, OLPL9008, DENS1990 and AUTC9008. Variables DISTCAPC, DISC9008, NAT9008 and AGFO9008 do not seem to impact on land take. SLOP9008 does not seem to influence land take in the 1990-2008 time period as well.

6 DISCUSSION AND CONCLUSION

This paper analyzes the Sardinian land-taking processes through OLS regression models in two time periods, 1960-1990 and 1990-2008, as related to factors that are identified as relevant variables in several studies concerning land take in the mainstream literature. We tentatively consider a set of variables which includes location-related and physical determinants, and planning code-related factors. Findings are consistent with a previous study (Zoppi and Lai, 2014) concerning Sardinian land-taking processes in the 2003-2008 period.

The outcomes of both time periods show 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 that changes its status from non-artificial to artificial. This indicates that saving non-artificial 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.

1960-1990 period				
Variable	Coefficient$_i$	Stand.error	t-statistic	Hypothesis test: coefficient=0
Constant	-0.9315	0.2730	-3.413	0.0007
PSIZ6090	0.1122	0.0106	10.627	0.0000
SLOP6090	0.0018	0.0101	0.174	0.8621
PRS6090	-0.0740	0.0495	-1.494	0.1361
ACCESS	0.2315	0.1431	1.618	0.1065
DISTCAPC	-0.0018	0.0009	-1.944	0.0527
DISTNEAC	0.0073	0.0039	1.867	0.0627
DISC6090	0.0066	0.0051	1.299	0.1947
CONSAREA	-4.1E-05	2.5E-05	-1.624	0.1053
NAT6090	0.0337	0.0063	5.359	0.0000
AGFO6090	-0.0290	0.0082	-3.517	0.0005
COASTRIP	0.1483	0.0330	4.499	0.0000
OLPL6090	0.0037	0.0008	4.397	0.0000
DENS1961	0.0075	0.0004	17.616	0.0000
AUTC6090	0.4777	0.0547	8.727	0.0000
Adjusted R-squared = 0.8024				
1990-2008 period				
Constant	-1.7298	0.4922	-3.514	0.0005
PSIZ9008	0.8553	0.0679	12.588	0.0000
SLOP9008	-0.0150	0.0139	-1.073	0.2839
PRS9008	-0.0232	0.0691	-0.336	0.7372
ACCESS	0.7924	0.1869	4.239	0.0000
DISTCAPC	0.0011	0.0012	0.890	0.3741
DISTNEAC	0.0050	0.0054	0.917	0.3596
DISC9008	-0.0023	0.0076	-0.302	0.7626
CONSAREA	-7.0E-05	3.2E-05	-2.189	0.0293
NAT9008	-0.0024	0.0053	-0.450	0.6532
AGFO9008	0.0018	0.0021	0.841	0.4011
COASTRIP	0.1201	0.0443	2.712	0.0070
OLPL9008	0.0006	0.0013	0.447	0.6553
DENS1990	0.0026	0.0004	6.261	0.0000
AUTC9008	0.4222	0.0941	4.489	0.0000
Adjusted R-squared = 0.6289				

Table 5. OLS results, dependent variables PLT6090 (1960-1990 period) and PLT9008 (1990-2008 period): the regression models include the covariates of Table 2.

Secondly, the more a municipality is accessible, the more it is suitable to land-taking processes, which indicates that balancing 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 in small municipalities, giving particular care to road connections to the regional capital and province cities. Moreover, the lower a municipality's proximity to the nearest province administrative center (DISTNEAC) , the less the municipality is suitable to land take, which is an argument in favor of balancing accessibility as well.

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 of strategical importance in order to deal with land-taking processes, and to influence their territorial layout. This is also confirmed by the estimates of both regressions related to the covariates OLPL6090 and OLPL9008, which are 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 covariates NAT6090 and NAT9008, which are positively, even though significantly only in the case of 1960-1990 model, correlated to the change of land from non-artificial to artificial. This suggests, as before, that the more conservative planning rules are weakened, the more land-taking processes occur: in the case of NAT6090 and NAT9008 it is evident that the conservation character of the RLP PIC and of previous regional plans was weak if non-artificial areas defined as landscape

ISBN: 978-3-9503110-8-2 (CD-ROM); ISBN: 978-3-9503110-9-9 (Print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C. BEYER

components with an environmental value were allowed to change their status from non-artificial to artificial land between 1960 and 1990, and between 1990 and 2008.

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 variable DISC9008, in the 1990-2008 time period, and the evidence of an impact of the variable DISC6090 on land take in the 1960-1990 time period. Since in the Sixties, Seventies and Eighties regional land-taking processes in Sardinia were almost exclusively concentrated in coastal municipalities, as the positive correlations between the variable COASTRIP and land take put in evidence in both periods, the non-coastal characterization of land take in the 1990-2008 period could only be related to the conservative planning rules that the regional landscape plans in force from 1990 to 2006 and the RLP, from year 2006 on, have implemented.

In this paper, we tentatively consider a set of variables which includes location-related and physical determinants, and planning code-related factors. Our analysis does not assume 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, which are consistent with statements proposed in the study quoted above (Zoppi and Lai, 2014). Agglomeration effect (both in terms of land which becomes artificial being non artificial in the first place, and of residential concentration) increases the intensity of land take. As a consequence, extensive urbanization processes and planning codes that 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 restrictive planning rules concerning new development in the CS helps to counter and limit land take.

In the rest of these concluding remarks we use GIS to comment and discuss policy implications of our results through some spatial representations. Such GIS-based representations are easily reproducible with reference to other contexts of the EU NUTS 2 regions, and they allow for a pretty straightforward spatial interpretation of the results.

We started by simulating a “what-if” scenario by building upon the results of the OSL model, and more precisely upon marginal effects presented in Table 5: for each municipality, we estimated the magnitude of the impact either on the 1960-1990 or on the 1990-2008 percent change from non-artificial to artificial land cover (respectively, PLT6090 and PLT9008) that would occur if a single explanatory variable (among those taking the highest values of the t-statistic, that is, for PLT6090: DENS1961, PSIZ6090, ACCESS, CONSAREA, and for PLT9008: DENS1990, PSIZ9008, ACCESS, CONSAREA) had increased by a given quantity – that is, ten percentiles in that variable’s distribution.

Figure 4 and Figure 5 present visually some of the results. As for the time period 1960-1990, the greatest change in artificial land cover is produced by implementing policies that increase the variable PSIZ6090, as up to 2.089 percent of the 1960 non-artificial land cover would have changed into artificial, if the value of the variable had increased by ten percentiles (Figure 4, left-center). The impact of the variable DENS1961 comes second, as it can amount to 1.559 percent (Figure 4, left), closely followed by the impact of the variable ACCESS, which can get as high as 0.123 percent (Figure 4, right). Impacts associated with the variable CONSAREA are always negative (Figure 4, right-center) and their peak is at 0.25 percent in absolute value.

With reference to the time period 1990-2008, the greatest change in artificial land cover is produced by implementing policies that increase the variable PSIZ9008, as up to 1.896 percent of the 1990 non-artificial land cover would have changed into artificial, if the value of the variable had increased by ten percentiles (Figure 5, left-center). The impact of the variable ACCESS comes second, as it can amount to 0.422 percent (Figure 4, right), closely followed by the impact of the variable DENS1990, which takes 0.397 percent as its the maximum value (Figure 4, left). Impacts associated with the variable CONSAREA are always negative here as well (Figure 4, right-center) and and their peak is at 0.426 percent in absolute value.

The maps also unveil a clear spatial agglomeration of municipalities taking the highest impact values associated with the variables DENS1961, ACCESS and CONSAREA (the latter, in absolute value) for the time period 1960-1990 (Figure 4) and with the variables DENS1990, ACCESS and CONSAREA (the latter, in absolute terms) for the time period 1990-2008 (Figure 5); moreover, these clusters show similar spatial patterns in the two time periods. Such a clear spatial agglomeration does not emerge, on the other hand, for

municipalities having either the lowest impact values associated with PSIZ6090 (Figure 4) or the highest impact values associated with PSIZ9008 (Figure 5).

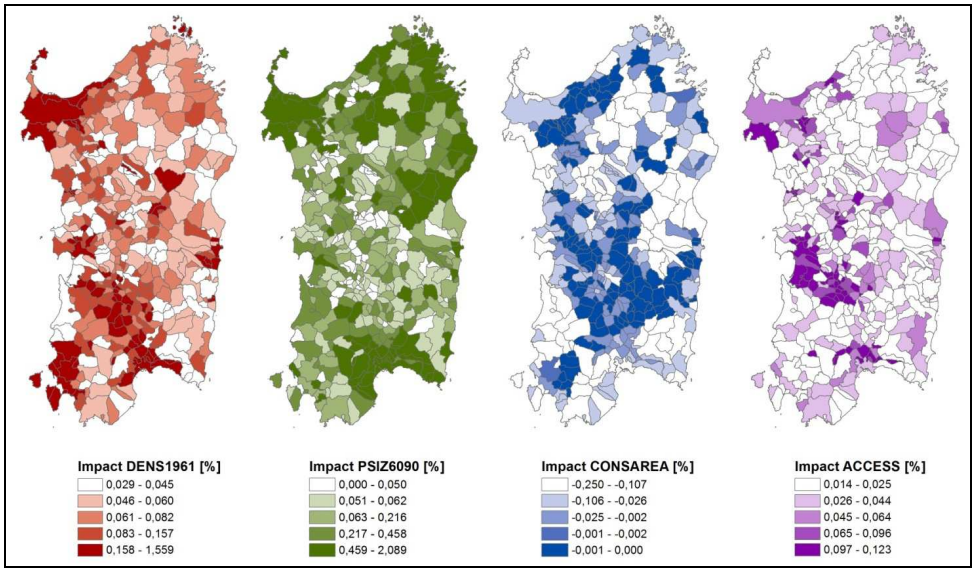

Figure 4: Spatial representation of policy implications at the municipal level: impacts on land-cover change (from non-artificial to artificial) in the 1960-1990 time period stemming from policies that increase: residential density in 1961 (left); or average size of areas whose land cover changes from non-artificial to artificial between 1960 and 1990 (left-center); or a municipality's total protected area (right-center); or its endowment of roads connecting regional town and city centers per unit of municipal land area (right) (all quantiles).

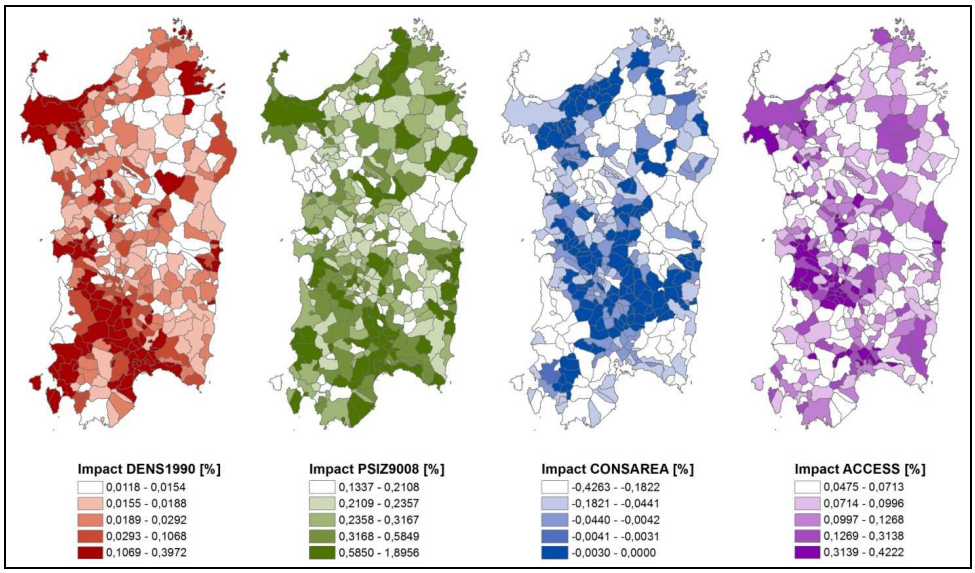

Figure 5: Spatial representation of policy implications at the municipal level: impacts on land-cover change (from non-artificial to artificial) in the 1990-2008 time period stemming from policies that increase: residential density in 1990 (left); or average size of areas whose land cover changes from non-artificial to artificial between 1990 and 2008 (left-center); or a municipality's total protected area (right-center); or its endowment of roads connecting regional town and city centers per unit of municipal land area (right) (all quantiles).

7 REFERENCES

CHESHIRE P., Sheppard S.: On the price of land and the value of amenities. In: Economica, Vol. 62, Issue 2, pp. 247-267. Wiley-Blackwell: London, United Kingdom, 1995.

EUROPEAN COMMISSION: Report on best practices for limiting soil sealing and mitigating its effects. 2011. Available at http://ec.europa.eu/environment/soil/pdf/sealing/Soil%20sealing%20-%20Final%20Report.pdf [accessed February 24, 2015].

EUROPEAN COMMISSION, EUROSTAT: Land cover/use statistics (LUCAS). Available at http://epp.eurostat.ec.europa.eu/portal/page/portal/lucas/introduction [accessed February 24, 2015].

EUROPEAN ENVIRONMENT AGENCY. Land take, 2013a, Available at: http://www.eea.europa.eu/data-and-maps/indicators/land-take-2/ [accessed February 24, 2015].

EUROPEAN ENVIRONMENT AGENCY: CORINE Land Cover, 2013b. Available at: http://www.eea.europa.eu/publications/COR0-landcover [accessed February 24, 2015].

ISBN: 978-3-9503110-8-2 (CD-ROM); ISBN: 978-3-9503110-9-9 (Print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C. BEYER

DEWI, S., van Noordwijk, M., Ekadinata, A., Pfund, J.L.: Protected areas within multifunctional landscapes: squeezing out intermediate land use intensities in the tropics? In: Land Use Policy, Vol. 30. Issue 1, pp. 38–56. Elsevier: Amsterdam, The Netherlands, 2013.

FORSTER D.L.: An overview of U.S. farm real estate markets. Working Paper of Agricultural, Environmental and Development Economics, Ohio State University: AEDE-WP-0042-06. 2006. Available at http://ageconsearch.umn.edu/bitstream/28319/1/wp060042.pdf [accessed February 24, 2015].

GUILING P., Brorsen B.W., Doye D.: Effect of urban proximity on agricultural land values. In: Land Economics, Vol. 85, Issue 2, pp. 252-264. University of Wisconsin Press: Madison, WI, United States, 2009.

HUANG H., Miller Y., Sherrick B.J., Gòmez M.I: Factors influencing Illinois farmland values. In: American Journal of Agricultural Economics, Vol. 88, Issue 2, pp. 458-470. Oxford University Press, Oxford Journals: Oxford, United Kingdom, 2006.

ISPRA: Annuario dei dati ambientali 2011 – Tematiche in primo piano [Yearbook of 2011 environmental data – Mainstream themes]. Available at http://www.isprambiente.gov.it/files/pubblicazioni/statoambiente/tematiche2011 [accessed February 24, 2015].

MORAN, P.A.P.: Notes on continuous stochastic phenomena. In: Biometrika Vol. 37, pp. 17-33. Oxford University Press: Oxford, United Kingdom, 1950.

PALMQUIST R.B., Danielson L.E.: A hedonic study of the effects of erosion control and drainage on farmland values. In: American Journal of Agricultural Economics, Vol. 71, Issue 1, pp. 55-62. Oxford University Press, Oxford Journals: Oxford, United Kingdom, 1989.

SKLENICKA P., Molnarova K., Pixova K.C., Salek M.E.: Factors affecting farmlands in the Czech Republic. In: Land Use Policy, Vol. 30. Issue 1, pp. 130-136. Elsevier: Amsterdam, The Netherlands, 2013.

STEWART P.A., Libby L.W.: Determinants of farmland value: the case of DeKalb County, Illinois. In: Review of Agricultural Economics, Vol. 20. Issue 1, pp. 80-95. Oxford University Press, Oxford Journals: Oxford, United Kingdom, 1998.

ZOPPI C., Lai S.: Land-taking processes: An interpretive study concerningan Italian region. In: Land Use Policy, Vol. 36. pp. 369-380. Elsevier: Amsterdam, The Netherlands, 2014.