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EMPIRICAL EVIDENCE ON AGRICULTURAL LAND-USE CHANGE IN SARDINIA (ITALY) FROM GIS-BASED ANALYSIS AND A TOBIT MODEL

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ABSTRACT

In this essay we study agricultural land-use change in the Region of Sardinia (Italy) in the time period 2003-2008, which is the period in which the European Agricultural Guidance and Guarantee Fund (EAGGF)-based part of the 2000-2006 Regional Operational Program of Sardinia (2000-2006 ROP-EAGGF) on regional agricultural land use was implemented.

What we deem of particular interest in this context, in terms of policy assessment, is that the 2000-2006 ROP-EAGGF is the most important program concerning agricultural land use implemented in Sardinia during the first decade of the new century, and quite similar in both strategy and structure to the other 2000-2006 ROP-EAGGF`s of several Regions of the European Union (EU) under the 2000-2006 Structural Funds. In Sardinia as elsewhere, investments were spread over almost all of the regional municipalities (only three Sardinian municipalities out of 377 did not receive funds under the 2000-2006 ROP-EAGGF), and represented an important effort to support local development based on the vitality of the traditional primary sector of production. Therefore, the methodological approach proposed and applied in this essay could be easily exported to other regional contexts in order to study agricultural land-use change.

The 2000-2006 ROP was a plurifund program based on the EAGGF, the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Financial Instrument for Fisheries Guidance (FIFG), and it was a fundamental pillar of the 2000-2006 cohesion policy of the European Union concerning Sardinia. The part of the program funded by the EAGGF amounted to around 770 million Euros, that is, approximately a 20 percent of the total investment expenditure of the program. More than 90 percent of the expenditure of the 2000-2006 ROP-EAGGF occurred in the period 2003-2008 (Regione Autonoma della Sardegna, 2009, pp. 18, 53, 56-57). The final executive report of the 2000-2006 ROP-EAGGF (ibid., p. 232) indicates that drastic measures aimed at simplifying payment procedures were adopted only starting from the year 2003, due to dramatic delays in the program implementation, and that only from that year did the program really start. Moreover, the European Commission stated that the expenditure of the 2000-2006 ROP had to be entirely realized and the official statements of account had to be made available to the European Commission by June 30, 2009, due to the impossibility of meeting the original deadline of December 31, 2006. It has to be put in evidence that what we feel really innovative in the comprehensive discussion of this paper is the intermixed use of Geographic information system (GIS) and econometric models in order to assess agricultural land-use processes related to the implementation of the cohesion policy of the European Union. More precisely, the results of a fairly standard censored regression (Tobit) model are spatially represented and implemented through GIS. The model is founded on, and motivated through, a GIS-based representation of its variables referred to Sardinian municipalities, and in particular of Sardinian agricultural land use, which is the focus of the assessment.

1. INTRODUCTION

In this essay we study agricultural land-use change in the Region of Sardinia (Italy) in the time period 2003-2008, which is the period in which the European Agricultural Guidance and Guarantee Fund (EAGGF)-based part of the 2000-2006 Regional Operational Program of Sardinia (2000-2006 ROP-EAGGF) on regional agricultural land use was implemented.

[1] This essay originates from the joint effort of the authors. Sabrina Lai has particularly taken care of the third section and concluding remarks; Corrado Zoppi has developed the discussions of the second and fourth sections; summary and introduction have been jointly defined by the authors.

The general objective is to assess whether, and to what extent, the 2000-2006 ROP-EAGGF was effective in maintaining agricultural land use compared to other physical, economic and social characteristics concerning local development.
What we deem of particular interest in this context, in terms of policy assessment, is that the 2000-2006 ROP-EAGGF is the most important program concerning agricultural land use implemented in Sardinia during the first decade of the new century, and quite similar in both strategy and structure to the other 2000-2006 ROP-EAGGF's of several Regions of the European Union (EU) under the 2000-2006 Structural Funds. In Sardinia as elsewhere, investments were spread over almost all of the regional municipalities (only three Sardinian municipalities out of 377 did not receive funds under the 2000-2006 ROP-EAGGF), and represented an important effort to support local development based on the vitality of the traditional primary sector of production. Therefore, the methodological approach proposed and applied in this essay could be easily exported to other regional contexts in order to study agricultural land-use change.
The 2000-2006 ROP was a plurifund program based on the EAGGF, the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Financial Instrument for Fisheries Guidance (FIFG), and it was a fundamental pillar of the 2000-2006 cohesion policy of the European Union concerning Sardinia. The part of the program funded by the EAGGF amounted to around 770 million Euros, that is, approximately a 20 percent of the total investment expenditure of the program. More than 90 percent of the expenditure of the 2000-2006 ROP-EAGGF occurred in the period 2003-2008 (Regione Autonoma della Sardegna, 2009, pp. 18, 53, 56-57). The final executive report of the 2000-2006 ROP-EAGGF (ibid., p. 232) indicates that drastic measures aimed at simplifying payment procedures were adopted only starting from the year 2003, due to dramatic delays in the program implementation, and that only from that year did the program really start. Moreover, the European Commission stated that the expenditure of the 2000-2006 ROP had to be entirely realized and the official statements of account had to be made available to the European Commission by June 30, 2009, due to the impossibility of meeting the original deadline of December 31, 2006.
For this reason, we consider the period 2003-2008 as the most suitable to assess if and to what extent the 2000-2006 ROP-EAGGF succeeded in maintaining agricultural land use. Objectives and operations of the 2000-2006 ROP-EAGGF are discussed in the following section, with reference to the Sardinian agricultural economy.
It has to be put in evidence that what we feel really innovative in the comprehensive discussion of this paper is the intermixed use of Geographic information system (GIS) and econometric models in order to assess agricultural land-use processes related to the implementation of the cohesion policy of the European Union. More precisely, the results of a fairly standard censored regression (Tobit) model are spatially represented and implemented through GIS. The model is founded on, and motivated through, a GIS-based representation of its variables referred to Sardinian municipalities, and in particular of Sardinian agricultural land use, which is the focus of the assessment. The Tobit model results make it clear that there is a strong relationship between agricultural land-use change and the other variables. These results entail some interesting insights concerning investment policies to maintain, reinforce and possibly expand agricultural land use, whose relevance can be clarified only through a spatial representation.
The third section defines a territorial taxonomy of Sardinian municipalities, by analyzing the spatial distribution of 2000-2006 ROP-EAGGF investment and of other characteristics which we believe are effective in describing the physical, economic and social environment of the Sardinian economy. The definition of this taxonomy is carried out by means of a GIS because it requires data integration from a number of sources, as it happens with many problems

in geographical analysis (Chrisman, 2002, p. 119). The ability both to integrate a wide variety of geographic data types and to develop new information building on available spatial and non-spatial data makes GIS a powerful support tool for modeling operations (Longley et al., 2001; p. 30); furthermore, GIS readily lends itself to combination with other technologies and techniques. In the fourth section we implement a censored (Tobit) regression model in order to discuss relations between the variables represented by means of the GIS. In this section, we explain why we choose the Tobit approach to implement our estimates in the context of the on-going literature on regression models. In the concluding section we discuss the implications of the results for the regional investment policy though a GIS-based representation and the exportability of the proposed methodological approach to other regional contexts.

2. THE 2000-2006 ROP-EAGGF OF SARDINIA

The 2000-2006 ROP-EAGGF[2] is based on a set of measures that address several problems pertaining agriculture and rural development in Sardinia. Each measure contains several actions to be implemented through projects financed by the EAGGF.

A first concern of the program is to improve the use of water resources for agriculture in terms of efficiency, effectiveness and productivity, which implies investment in irrigation infrastructure and water resource management (measure 1.2, integrated cycle of water resource management: irrigation systems of agricultural zones; axis 1, natural resources). This is complementary to infrastructural and technological improvements, and capacity building, referred to other aspects of agricultural land use. These concern: i. reduction in production costs; ii. product quality; iii. a better environment for livestock; better living and working conditions for agricultural workforce; iv. conversion of current agricultural production into more profitable crops; v. rural aqueducts, electrical lines and roads. These issues are addressed by measures 4.9 (investment in agricultural firms; axis 4, local development systems), 4.19 (rural reparcelling), and 4.20 (development and improvement of rural infrastructure for agriculture).

Another important question is capacity building and quality of rural life. This is addressed by measure 1.2, in terms of capacity building concerning water resource management, and by measure 4.9, with reference to farm management. Moreover, measure 4.13 (essential services for the economy and the rural population) is concerned with actions aimed at making services available for the rural population, such as ICT-based network services (e.g., online request for documents from the public register's office), centralized laboratories for chemical and microbiological analyses of agricultural products, etc.

A third important issue is the marketing of the products of Sardinian agriculture. The lack of expertise in dealing with Italian, European and world markets is identified by the 2000-2006 ROP-EAGGF as a difficult obstacle for the future of Sardinian agriculture, and addressed through the tenth and eleventh measures of axis 4 (improvement of transformation and marketing of agricultural products; marketing of agricultural products characterized by a high qualitative level).

Moreover, the program invests (measure 1.9, prevention and control concerning forest fires, and reforestation; measure 4.12, diversification of agricultural activities and the like; measure 4.14, promotion of adaptation and development of rural areas; measure 4.17, restoration of the rural environment damaged by fire and natural disasters, and prevention; measure 4.18, professional education referred to all of the 2000-2006 ROP-EAGGF measures; 4.21, young farmers' start-up support) in: i. renovation and conservation of buildings and settlements identified as historical heritage of the rural environment; ii. construction of new rural buildings for

[2] The last version of the 2000-2006 ROP-EAGGF was established by Decision C 2007/1991 of the European Commission. This version is available on the Internet, in Italian only, at http://www.sardegnaprogrammazione.it/documenti/1_84_20080409115630.zip (accessed January 2, 2012).

exhibitions and conferences concerning rural civilization, recreation and educational activities; iii. conservation of traditional rural productive processes in order to prevent their loss (with particular reference to craftsmanship), even though they are not profitable any longer; iv. (recovered or new) rural paths for bikers, skaters, joggers, and hikers; v. professional edu cation as stated by measure 4.18 above.

Table 1. Measures of the 2000-2006 ROP-EAGG (Regione Autonoma della Sardegna, 2009a, pp. 300, 313, 367-391).

Measure	*Expenditure (million Euros)*	*Type of operations*
1.2 - Integrated cycle of water resource management: irrigation systems of agricultural zones	43.494	Public infrastructure and services
1.9 - Prevention and control concerning forest fires, and reforestation	11.000	Public infrastructure and services
4.9 - Investment in agricultural firms	183.092	Funds granted under the aid regime rules
4.10 - Improvement of transformation and marketing of agricultural products	137.848	Funds granted under the aid regime rules
4.11 - Marketing of agricultural products characterized by a high qualitative level	27.796	Funds granted under the aid regime rules
4.12 - Diversification of agricultural activities and the like	10.000	Funds granted under the aid regime rules
4.13 - Essential services for the economy and the rural population	15.659	Public infrastructure and services
4.14 - Promotion of adaptation and development of rural areas	31.740	Public infrastructure and services
4.17 - Restoration of the rural environment damaged by fire and natural disasters, and prevention	16.000	Public infrastructure and services
4.18 - Professional education referred to all of the 2000-2006 ROP-EAGGF measures	6.000	Education
4.19 - Rural reparcelling	59.957	Feasibility studies; funds granted under the aid regime rules
4.20 – Development and improvement of rural infrastructure for agriculture	143.626	Public infrastructure and services
4.21 - Young farmers' start-up support	84.325	Funds granted under the aid regime rules

It is evident that the thirteen measures of the 2000-2006 ROP-EAGGF show a comprehensive approach which entails addressing several aspects of rural development: conservation of natural resources and of rural cultural heritage, protection from fire and natural disasters, restoration and renovation of rural buildings and settlements, capacity building and professional education, tourism and tourism-related activities, reforestation, and support to agriculture, in terms of infrastructure and services.

Our objective here is not to evaluate the comprehensive impact and effectiveness of the program, but only to assess its impact on agricultural land use. We therefore consider only the subset of measures which finance public infrastructure and services for agricultural land use, that is measures 1.2, 1.9, 4.13, 4.14, 4.17, 4.20. We assume that the other measures, which are essentially funds granted to agricultural firms under the aid regime rules[3], and to promote professional education, do not influence agricultural land use, at least in the short run, even though they could possibly have an impact on rural economy. The investment expenditure referred to the six measures is about one third of the total investment of the 2000-2006 ROP-EAGGF (see Table 1).

Financial support referred to the aid-regime rules is granted to rural entrepreneurs on a small scale in order to accomplish several goals. For instance, these funds were used to increase the firms' physical capital (machinery, plants, buildings) and professional education, to help young farmers' start-ups, to develop rural tourism, to implement land improvement operations, and so on and so forth. In general, funds are granted to rural firms in order to deal with questions related to their present condition, whose improvement should not have generated a quantitative change in agricultural land use, during the period 2003-2008. However, a quan-

[3] Regulation n. 1999/1257 EC of the European Council, artt. 51 and 52.

titative impact could have possibly come from an income effect on agricultural land use (expansion) which we try to detect in the model discussed in the fourth section through an income-related explanatory variable. The reason is that an income increase could possibly drive an agricultural firm to buy or rent land suitable for agricultural production if it is available.

3. A GIS-BASED TAXONOMY OF SARDINIAN AGRICULTURAL LAND USE AND RELATED VARIABLES

Sections should be used to make it easier to follow the paper. Section and sub- In order to analyze agricultural land use in the time frame 2003-2008 and other physical, economic and social characteristics concerning local development, a descriptive table was needed. Since this analysis was to be carried out at the municipal level, by assuming cities as basic spatial units, such table had to have as many rows as Sardinian municipalities are, and as many fields as relevant attributes are. Data from various sources and in various digital formats were therefore collected; some data (e.g. those pertaining to demography, income, and levels of expenditure) were calculated by building on available spreadsheets; some others (e.g. spatial distribution of land uses, or delimitation of coastal landscape units) were derived from available spatial datasets. In other words, integration of available (both spatial and non-spatial) information was required to develop new knowledge and obtain new layers of either spatial or non-spatial information, which called for a GIS-based analysis.

As far as the geographic description of municipalities is concerned, only one shapefile ("Municipal Administrative Boundaries", MAB) was used to implement the GIS. Produced by the Regional Administration of Sardinia and freely downloadable from the Internet[4], this shapefile contains 377 polygons and multi-part polygons, each corresponding to the area included within the administrative boundary of a given municipality. This section aims at explaining how variables relevant to the analysis were identified, and their values calculated for each municipality, by means of GIS.

Data concerning land cover and land-cover changes in the time frame 1990-2006 are provided, at the European level, by the European Environmental Agency[5]. Of particular interest for a study of land-cover changes are two datasets, showing changes between 1990 and 2000 and between 2000 and 2006 (Figure 1), since authors claim to have been able to draw a distinction between real evolution processes and different interpretations of the same subject, and therefore to expunge the latter from the datasets. However, the above data were not used here because their level of detail (e.g. scale of the maps produced and minimum mapping units) did not appear to be appropriate for this study; moreover, the date of production of the datasets would have not allowed for the best possible study of the effects of the ROP-EAGGF in maintaining agricultural land uses, since, as explained earlier in the introduction, the most part of the 2000-2006 program was actually implemented between 2003 and 2008.

We therefore chose to study variables related to land uses on the basis of the 2003[6] and the 2008[7] regional land-use maps, in which land uses are organized according to a four-level hierarchical[8] nomenclature, in compliance with the European project "CORINE Land Cover".

[4] The shapefile is available at: http://webgis.regione.sardegna.it/scaricocartografiaETL/ limitiAmministrativi/limitiAmministrComunali/limitiAmministrComunali.zip (accessed January 10, 2012).

[5] http://www.eea.europa.eu/data-and-maps/data#c11=landuse (accessed January 10, 2012).

[6] Completed in 2003, the "Land Use Map of the Region of Sardinia - 2003 Edition" is a spatial dataset that covers the whole island. Data were mainly obtained from photo interpretation of aerial photographs dating 1997-1998, satellite images and orthoimages, but other vector datasets (e.g. regional digital cartography) were also used; on-site surveys were carried out between 2002 and 2003. The map has a scale of 1:25,000, and it can be freely downloaded from: http://www.sardegnageoportale.it/index.php?xsl=1598&s=141401&v= 2&c=8831&t=1 (accessed January 10, 2012).

[7] The so-called "New Land Use Map of the Region of Sardinia" was completed in 2008 building upon the 2003 land-use map and photo interpretation of satellite images, orthoimages, and ancillary vector datasets. On-site

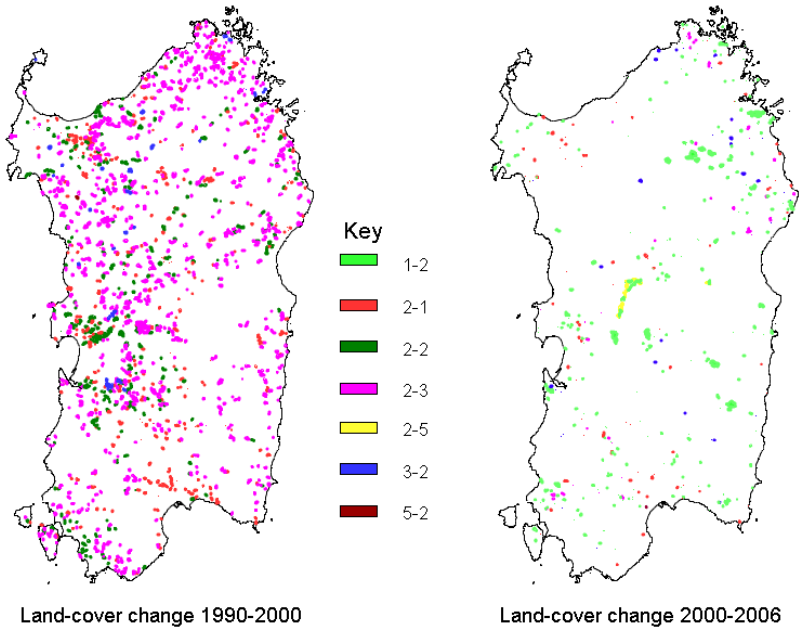

Figure 1. The land-cover changes involving areas classed as agricultural between 1990 and 2000 and between 2000 and 2006 (data from www.eea.europa.eu)

Strictly speaking, the so-called "regional land-use map" is therefore actually a land-cover map, although, thanks to its level of detail, it does also provide reliable information on how land is used by humans, especially as far as agricultural areas and forests are concerned. In the remainder of this paper, the expression "land use" will therefore be used.

According to the two datasets, in Sardinia the amount of land occupied by agriculture has globally increased: Table 2 shows both the nomenclature of agricultural land uses according to the 2003 and the 2008 regional land-use maps and their corresponding area.

In the MAB shapefile, a number of descriptive attribute fields characterizing each Sardinian municipality and related to land uses or land-use changes were at first introduced, and their values were calculated for each municipality. We will however present here only two of these attributes, that is the dependent variable (percentage change in a municipality's agricultural land use between 2003 and 2008) and another land-use related variable that was discovered to have an impact on the dependent variable by running the model presented in the next section.

The attribute "Percentage change in a municipality's agricultural land use between 2003 and 2008" (label: PLUAA3_8) accounts for the increase or decrease in size of a municipality's total agricultural area, which consists of polygons whose codes start with "2", according to the Corine nomenclature. To fill in the values in this field, a series of basic operations (filtering, intersecting, area calculations, dissolving, summarizing) were performed in gvSIG[9] by using

surveys were carried out between 2005 and 2007. Minimum mapping unit (Longley et al., 2001; p.151) of the map equals 0.5 hectares in urban areas and 0.75 hectares in the countryside. The dataset can be freely downloaded from: http://www.sardegnageoportale.it/index.php?xsl=1598&s=141401&v= 2&c=8831&t=1 (accessed January 10, 2012).

[8] This means that the first letter of the code corresponds to a general land use, which is described in greater detail by means of a second letter, and further by means of a third letter, and so on. General class 1 corresponds to "artificial surfaces", class 2 to "agricultural areas", class 3 to "forest and semi-natural areas", class 4 to "wetlands", and class 5 to "water bodies".

[9] gvSIG is an open source desktop application, freely available at http://www.gvsig.org (accessed January 10, 2012).

three datasets: the 2003 land-use map, the 2008 land-use map and the MAB layer. In Figure 3.a, Sardinian municipalities are classed according to the values of PLUAA3_8.
The attribute "Percentage change in a municipality's urbanized land between 2003 and 2008" (label: VARUU3_8) accounts for the increase or decrease in size of a municipality's artificial surfaces, which, according to the Corine nomenclature, are characterized by codes starting with "1". A series of basic operations (filtering, intersecting, area calculations, dissolving, summarizing) were performed separately on the 2003 and the 2008 land-use maps so as to obtain the value of the attribute "urbanized land area" for each municipality in the two datasets; next, land-use maps attribute tables were joined to the MAB layer's attribute table and the percentage change was finally calculated for each municipality. In Figure 3.c, Sardinian municipalities are classed according to the values of VARUU3_8.

Table 2. Agricultural land uses in Sardinia according to the 2003 and 2008 land-use maps

2nd level	*3rd level*	*4th level*	*Total area in 2003 [hectares]*	*Total area in 2008 [hectares]*
21 Arable land	211 Non-irrigated arable land	2111 Non-irrigated arable land	144,537.8	251,181.45
		2112 Artificial meadows	142,587.2	164,575.47
	212 Permanently irrigated land	2121 Arable land and horticultural crops in open fields	346,524.70	205,735.63
		2122 Rice fields	4,584.17	4,660.69
		2123 Nurseries	240.08	341.00
		2124 Crops in greenhouses	1,184.98	1,769.04
22 Permanent crops	221 Vineyards		15,957.87	24,686.43
	222 Fruit trees and berry plantations		10,268.18	11,907.84
	223 Olive groves		43,790.91	48,777.62
23 Pastures	231 Pastures		9,517.21	10,316.08
24 Heterogeneous agricultural areas	241 Annual crops associated with permanent crops	2411 Annual crops associated with vineyards	9,608.73	11,714.50
		2412 Annual crops associated with vineyards	163.70	296.13
		2413 Annual crops associated with other permanent crops	53,164.42	58,067.58
	242 Complex cultivation patterns		43,107.79	42,206.07
	243 Land principally occupied by agriculture, with significant areas of natural vegetation		27,271.17	29,282.01
	244 Agro-forestry areas		50,493.25	57,429.67
		TOTAL	***903,002.15***	***922,947.21***

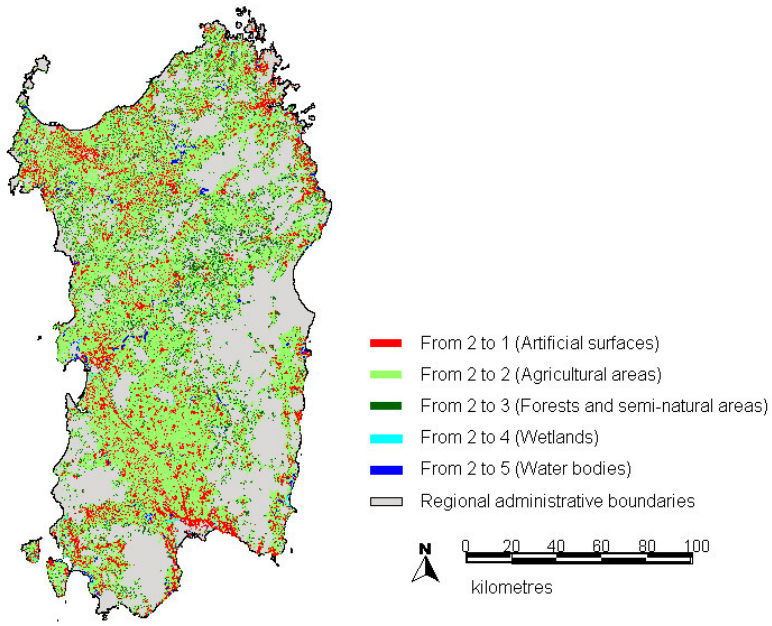

Figure 2. Land-use changes in the 2003-2008 time frame, taking into account only areas that in 2003 were classed as agricultural (Corine land cover first-level code = 2) according to the regional land-use maps (data from http://www.sardegnageoportale.it/)

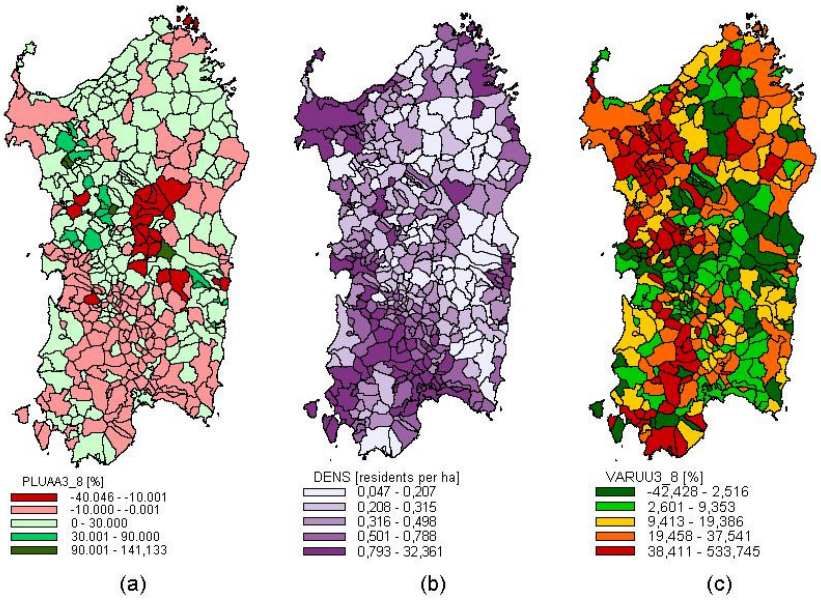

Figure 3. A classification of Sardinian municipalities based on: percentage change in a municipality's agricultural land use between 2003 and 2008 (a); residential density in 2008 (b); percentage change in artificial surfaces between 2003 and 2008 (c)

The four remaining attributes do not deal with land uses, but, respectively, with demography, regional planning, income and implementation of agricultural policy.

The first of these descriptive attributes is the residential density (label: DENS) measured, for each municipality, in residents (as of 2008[10]) per hectare. A choropleth map in which municipalities are categorized into according to their values of residential density in 2008 is provided in Figure 3.b.

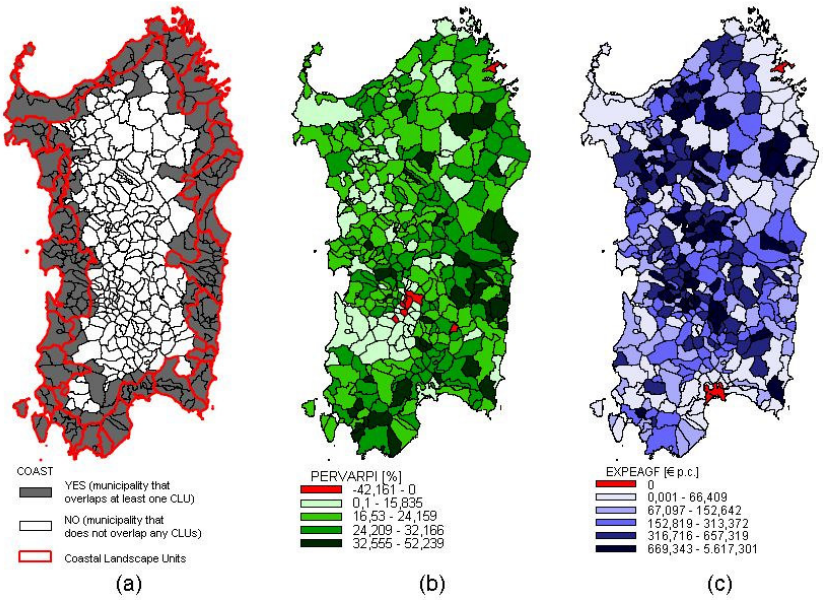

Figure 4. A classification of Sardinian municipalities based on: whether a municipality overlaps at least one coastal landscape unit (a); percentage change in per-capita income in the time frame 2003-2008 (b); 2000-2006 ROP-EAGGF per-capita investment on public infrastructure and services for agriculture (c)

The second attribute (label: COAST) is a dichotomous one (taking only "yes" and "no" values), and it accounts for whether a municipality overlaps at least one coastal landscape unit (CLU), as defined in the Regional Landscape Plan (RLP). Approved in 2006 and currently under revision, the RLP is the first statutory landscape plan with regional dimensions produced in Italy under the National Code of Cultural Heritage and Landscape. The Regional Administration of Sardinian initially focused on coastal areas only, in order to protect a part of the island considered both economically strategic and environmentally fragile, and therefore identified 27 coastal landscape units (Figure 4.a). General rules and restrictions on building activities and transformation of land are in force in those municipalities whose land area overlaps, or is completely contained in, the CLUs. For the remaining municipalities only specific rules concerning preservation of specific and precisely identified landscape features or assets are in force. Whether or not a municipality overlaps a CLU thus directly affects the possibility of producing changes in land uses. In Figure 4.a, Sardinian municipalities are classed according to the value of COAST.

The third attribute is the percentage change in a municipality's per-capita income in the period 2003-2008 (label: PERVARPI). Raw data on per-capita income in 2003 and 2008 were collected from two websites[11] and reorganized into a spreadsheet, later joined to the attribute table of the MAB shapefile. In Figure 4.b, Sardinian municipalities are classed according to the values of PERVARPI.

Finally, the fourth attribute is the 2000-2006 ROP-EAGGF per-capita investment for each municipality on public infrastructure and services for agriculture (label: EXPEAGF). Implementation of projects co-financed through European funds in Italy was monitored, at the na-

[10] Data available at http://www.sardegnastatistiche.it (accessed January 10, 2012).
[11] http://www.sardegnastatistiche.it and http://www.comuni-italiani.it.

tional level, by means of a web database called MONIT, from which we selected only those records for which all of the following conditions held true: (i) projects were carried out in Sardinia, (ii) they were funded through the EAGGF, and (iii) funds were granted for public services and infrastructure. Only projects funded through measures 1.2, 1.9, 4.13, 4.14, 4.17, 4.20 of the ROP were therefore selected for the reasons explained in the previous section. A total of Euros 220,793,919.07 had been spent, on these projects, by June 30th 2009. The resulting table had 374 rows, meaning that three of the 377 Sardinian municipalities were not granted any funds for public services and infrastructures through the EAGGF. In Figure 4.c, Sardinian municipalities are categorized into according to the values of EXPEAGF.

4. AGRICULTURAL LAND USE CHANGE IN THE CONTEXT OF THE 2000-2006 ROP-EAGGF

This section is organized as follows. In the first paragraph, the censored regression (Tobit model) methodology is presented in the context of the case study discussed in this paper. In this paragraph, we explain why we choose the Tobit approach to implement our estimates and which part of the methodology is already used in other papers. Secondly, the results concerning the analysis of the impact of the 2000-2006 ROP-EAGGF on agricultural land use are discussed, in a context characterized by other physical, economic and social variables concerning local development.

4.1. Methodology

We use a censored regression model since the dependent variable of our analysis, that is the percentage change in Sardinian municipalities' agricultural land use in the period 2003-2008, is continuous in the interval between about -40% percent and about 140 percent, while it is not observable below -40 percent. This is the standard technique to deal with phenomena represented by inherently continuous variables that for some reasons are not observable (censored) in a region of their variation range.

Censored regression models are also named "Tobit models" with reference to Tobin (1958), who discussed this type of models in the first place. Tobit models have a widespread use in empirical analysis concerning land use and land-use choice. A very interesting application is proposed by Gebremedhin and Swinton (2003), who assess the impact of public intervention and security of tenure rights on the attitude of farmers toward soil conservation in the Tigray region (Northern Ethiopia). Another important essay concerning Ethiopian agriculture (West Shoa Zone, Central Highlands) is discussed by Alene et al. (2000), who apply a Tobit model to estimate the relationship between adoption and intensity of utilization of improved maize varieties, and education, household labour, farm size, extension services, farm income, and timely availability of improved maize seeds. Coomes et al. (2000) apply a Tobit regression to analyze the relationships between non-market mediated access to land and labor, and forest fallow management and duration in the Peruvian Amazon. Pfaffermayr et al. (1991) assess the labor-supply decisions of farm workers between part-time off-farm and full-time in-farm options through probit and Tobit models as possibly dependent on farm size, household characteristics and education. Baidu Forson (1999) applies a Tobit model to analyze the determinants of level and intensity of adoption of innovative technologies for soil conservation and water resource management in Niger, and finds that a very important role is played by degraded farmland, education, risk aversion, and availability of short-term profits. Rajasekharan and Veeraputhran (2002) use Tobit regressions to study the relationship between intercropping decisions and availability of family labor and the type of intercrops during the initial gestation periods of natural rubber cultivation in the Kerala region (India); they find that very important determinants are banana, cassava and pineapple crops.

The aforementioned studies are a very small share of hundreds of published papers that constitute the vast literature related to questions concerning physical, economic and social determinants of agricultural land use analyzed through censored regression models. Common features of these case studies are the continuous and censored nature of the variables representative of the issues, the intermix of physical, economic, social, and agricultural land use phenomena, the identification of spatial units as points of reference for the representation and the assessment of the variables and of their relationships.

In this paper we use a Tobit model to analyze the relation between a censored variable, the percentage change in Sardinian municipalities' agricultural land use in the period 2003-2008, and a set of variables representing physical, economic and social characteristics concerning Sardinian local development. We use a standard Tobit model, based on Greene's (1993, pp. 694-700). For this reason, we think worth proposing just a synthetic description on its implementation, as described below.

We consider a censored or latent dependent variable, y*, which is related to an observable variable, y, as follows:

$$\begin{aligned} y &= L && \text{if } y^* \leq L; \\ y &= y^* && \text{if } y^* > L. \end{aligned} \qquad (1)$$

The model operationalizes by assuming that y* is linearly dependent on a vector of explanatory variables, $x = (x_1,\ldots, x_m)$, through the following relation:

$$y^* = \boldsymbol{\beta}'\mathbf{x} + \varepsilon, \qquad (2)$$

where $\beta = (\beta_1,\ldots, \beta_m)$ is a vector of coefficients.

If we substitute (2) in (1) we obtain the following model, which, under the usual hypotheses of ordinary least-squares models concerning the mean, variance and covariance of the ε term12, can be estimated by the maximum likelihood estimator (MLE), which is unbiased and efficient, even though non-linear (Greene, ibid.):

$$\begin{aligned} y &= L && \text{if } y^* \leq L; \\ y &= \boldsymbol{\beta}'\mathbf{x} + \varepsilon && \text{if } y^* > L. \end{aligned} \qquad (3)$$

The MLE for β is the vector $b = (b_1,\ldots, b_m)$ that maximizes the following maximum likelihood function:

$$\ln L = \sum_{y>L} \frac{1}{2}\left[\ln(2\pi) + \ln(s^2) + \frac{(y-\mathbf{b}'\mathbf{x})^2}{s^2}\right] + \sum_{y=L} ln\left[1 - \phi\left[\frac{(y-\mathbf{b}'\mathbf{x})}{s}\right]\right] \qquad (4)$$

where s2 is the MLE estimator for the variance of the error term13 and ϕ is the cumulative normal distribution operator (Greene, ibid.).

The values of the vectors of coefficients bj's which maximize (4) are the solution of the system which comes from equalizing to zero the derivatives of ln L with respect to the m components of vector b.

[12] The model assumes that the error term ε is normally distributed and: i. $E(\varepsilon|x) = 0$ (i.e., the error terms in the regression have a 0 conditional mean), ii. $Var(\varepsilon) = \sigma^2$ (i.e.: the error term has the same variance at each observation), and iii. $E[\varepsilon_i\, \varepsilon_j|X] = 0$ (i.e.: the error terms are uncorrelated between observations).

[13] $s^2 = \frac{(y-xb)'(y-xb)}{n}$, where y is the vector of observations of the censored variable y and x is the matrix (n,m) of the n observations of the m explanatory variables.

The values of the estimates bj's of the vector of coefficients βj's make it possible to estimate the marginal effects of a change of the vector of explanatory variables x on the censored variable y as follows (Greene, ibid.):

$$\frac{\partial E(y|\boldsymbol{x})}{\partial \boldsymbol{x}} = \boldsymbol{b}\phi\left(\frac{\boldsymbol{b}'\boldsymbol{x}}{s}\right). \quad (5)$$

4.2. The impact of the 2000-2006 ROP-EAGGF on agriculture land use

The analysis of the change in Sardinian municipalities' agricultural land use in the period 2003-2008 is based on the model described in the second part of the first paragraph of this section. The characteristics of vector x = (x1,…, xm) and their measures are defined, and the results of the model application are reported with reference to: i. the estimates b = (b1,…, bm) of the components of vector β, and ii. the marginal effects from (5).

Dependent and explanatory variables, referred to spatial units identified with the 377 municipalities of Sardinia, which correspond to variables y and x = (x1,…, xm) of model 1-5, are reported in Table 3. The spatial taxonomy of these variables is described in the preceding section.

The dependent variable is the percentage change of agricultural land use in 2008 with respect to agricultural land use in 2003 and labeled PLUAA3_8. This is a precise quantitative measure concerning the impact of the 2000-2006 ROP-EAGGF on agricultural land use, which is referred, as we put in evidence above, only to the subset of measures which finance public infrastructure and services for agricultural land use, that is measures 1.2, 1.9, 4.13, 4.14, 4.17, 4.20 of the 2000-2006 ROP-EAGGF.

The choice of the explanatory variables that characterize the 377 Sardinian municipalities is motivated as follows. Residential density, which is almost constant between 2003 and 2008, is considered as an important characteristic, since it makes it possible to control for an agglomeration effect which could possibly entail evidence of investment attraction to municipalities where people are more concentrated.

The change in the area of urbanized land after the program's implementation (VARUU3_8) could impact agricultural land-use change. Increasing urbanization could possibly make a municipality comparatively more attractive for investment, and for investment in agriculture, even though new urbanized land could be a detriment to agricultural land use. Therefore, the change in urbanized land should be considered a significant aspect, although the expected impact is fuzzy.

Table 3. Definition of variables and descriptive statistics

Variable	Definition	Mean	St.dev.
PLUAA3_8	Percentage change in a municipality's agricultural land use between 2003 and 2008	4.6660	17.2699
DENS	Residential density of a municipality in 2008 (residents per hectare)	0.7744	2.0981
VARUU3_8	Percentage change in a municipality's urbanized land between 2003 and 2008	22.8301	41.1650
COAST	Dummy - A municipality overlaps a coastal landscape unit as defined by the Regional Landscape Plan	0.4430	0.4974
PERVARPI	Percentage change in a municipality's per-capita income in the period 2003-2008	21.8675	9.5568
EXPEAGF	2000-2006 ROP-EAGGF per-capita expenditure for measures 1.2, 1.9, 4.13, 4.14, 4.17, 4.20 concerning a municipality (Euros per resident)	456.1207	669.9753

The variable that indicates if a municipality is coastal or non-coastal, labeled COAST, aims at assessing if agricultural land-use change is influenced by this characteristic, which is relevant because, since November 2004, when Regional Law no. 8 was approved, Sardinian coastal municipalities have had to make their planning policies consistent with very strict planning

rules, especially for areas included in the coastal zone (Zoppi, 2008)14. In particular, new urbanization was almost totally prevented in coastal municipalities, which could eventually have become more attractive for investment in agriculture. We assume that a municipality is coastal if it overlaps a coastal landscape unit as defined by the zoning cartography and implementation rules of the Regional Landscape Plan (ibid.).

We use the change in per-capita income from 2003 to 2008 (PERVARPI) as the variable that controls for a possible income effect. As with VARUU3_8, change in per-capita income should be considered a significant aspect, although we do not have a definite expectation on the sign of the coefficient, since increasing per-capita income could possibly make a municipality more willing to invest in agriculture, or displace agriculture if the available investment, coming from increased income, is diverted elsewhere.

The variable that represents the per-capita investment concerning a municipality from the 2000-2006 ROP-EAGGF (EXPEAGF) characterizes the relative importance that the ROP recognizes to a particular municipality's territory, and the level of trust of the regional administration in the capability of generating a positive impact on agricultural land use. This variable's impact on the dependent variable is expected to be positive, since we expect that investment in public infrastructure and services for agricultural land use would help maintaining and possibly increasing a municipality's agricultural land use.

The estimates of the components of vector β, that is the vector $b = (b_1,\ldots, b_m)$ of (4), and the marginal effects of explanatory variables x's on the dependent variable y of (5) are reported in Table 4 and Table 5. The decomposition-based fit measure, which indicates the share of the total variance of the censored variable explained by the model, is about 50%.

The results are significant at 2.5 percent with the exception of VARUU3_8, which is slightly less significant (7.5 percent) and show the expected sign when there is one.

Table 4. Estimates of coefficients of the components of vector β, b = (b1,…, bm), calculated by solving the maximization problem expressed by (4)

Variable	Coefficient b_i	Standard error	z-statistic	Hypothesis test: $\beta_i=0$
DENS	0.3479	0.0680	5.116	0.0000
VARUU3_8	0.0394	0.0220	1.791	0.0732
COAST	4.1603	1.8525	2.246	0.0247
PERVARPI	0.2073	0.0737	2.812	0.0049
EXPEAGF	0.0070	0.0007	10.434	0.0000
Decomposition-based fit measure = 0.466				

The marginal effect of residential density (DENS) indicates that an increase of about 3.5 percent of the agricultural land use extension would occur if DENS increased by 10 residents per hectare, which puts in evidence a significant agglomeration effect.

Table 5. Estimates of the marginal effects of the explanatory variables on the censored variable from (5)

Variable	Marginal effect	Standard error	z-statistic	Hypothesis test: $\beta_i=0$
DENS	0.3470	0.0678	5.119	0.0000
VARUU3_8	0.0393	0.0219	1.791	0.0732
COAST	4.1498	1.8466	2.247	0.0246
PERVARPI	0.2067	0.0736	2.809	0.0050
EXPEAGF	0.0070	0.0007	10.429	0.0000

The dichotomous variable COAST indicates if a municipality belongs to a coastal landscape unit. This variable has a positive and significant marginal effect, which puts in evidence that investment in infrastructure and services to improve agricultural land use is more effective in coastal areas than in

[14] This law (named "The saving-coast law") identifies the coastal areas as those included in a 2-km belt from the coastal line. The definition of the coastal zone changed after the Regional Landscape Plan (RLP) approval (through Deliberation of the Sardinian Regional Government no. 36/7 of September 5, 2006), which established a new and generally wider limit for the coastal zone.

inner ones. The results imply, *ceteris paribus*, a 4 percent positive differential in agricultural land use.

The change in a municipality's urbanization also reveals a positive marginal effect, even though not quantitatively strong: approximately only a 3.9 percent of a percentage point for a one percent increase. However, this is important since it shows that increasing urbanization does not seem to prevent conservation or expansion of agricultural land use. From this point of view, the results of the estimates suggest that municipalities characterized by urban expansion should be targeted for agricultural land-use investment.

A positive marginal effect is put in evidence by the variable concerning the percentage increase in real per-capita income as well (a 0.2 percent increase in agricultural land use per a one-percent increase of per-capita income). This observation indicates that, everything else being equal, a positive income effect is supported by the estimates of the model. This implies not only that there is an income effect that does not displace at all agricultural activities, but also that, in principle, whichever policy aiming at increasing local people's income can be considered an indirect support to maintaining and possibly increasing agricultural land use. In other words, we can state that our results suggest that all of the measures of the 2000-2006 ROP-EAGGF have positive impacts on agricultural land use: i. direct measures, that is those here taken into account to define the variable EXPEAGF (measures 1.2, 1.9, 4.13, 4.14, 4.17, 4.20), as we see below; ii. all the other measures, which grant funds to farmers and rural entrepreneurs under the regime of state aids, and, by doing so, increase their income.

Finally, the marginal impact of the investment concerning a municipality from the 2000-2006 ROP-EAGGF is positive, as expected, and highly significant. However, this impact is quantitatively weak, since it indicates that a hundred-Euro increase of per-capita investment implies approximately a 0.7 percent increase in agricultural land use. In other words, this means that an investment of nearly 165 million Euros, that is more than one fifth of the total 2000-2006 ROP-EAGGF expenditure, would have been required to increase the agricultural land use extension in 2008 with respect to 2003 by approximately 63 km^2.

5. CONCLUDING REMARKS: A SPATIAL REPRESENTATION OF POLICY IMPLICATIONS FROM THE MODEL RESULTS

This paper proposes a discussion on quantitative change in agricultural land use at the municipal level as a phenomenon influenced by physical, economic, social and investment policy variables. The methodological approach is based on the intermixed use of GIS techniques and econometric models. We feel that the use of a Tobit model based on a GIS-based taxonomy of dependent and explanatory variables could be easily and effectively exported to other European Union regional contexts, since the 2000-2006 ROP's of the European regions at the NUTS 2 level were fairly standard. The reproducibility of the proposed approach makes it possible to assess the results concerning the impact of ROP-EAGGF's on agricultural land-use change and to compare such impacts across regions, at the intra-national and inter-national levels. Moreover, the results are useful not only in terms of ex-post assessment, but also with reference to the definition and implementation of regional policies concerning investment aimed at maintaining and increasing agricultural land use, that is in terms of ex-ante and on-going assessment.

In the rest of this concluding remarks we use GIS to comment and discuss policy implications of our results through a spatial representation. The GIS-based representation is easily reproducible with reference to other contexts of the EU NUTS 2 regions, and it allows for a pretty straightforward spatial interpretation of the results. As we put in evidence above, the impacts of the policy (explanatory) variables on agricultural land-use change do not always have an *a priori* expectation on the sign of the impact; therefore, a comparative analysis of spatial interpretation of results across regions may eventually indicate different policy approaches at the regional level.

Background policy implication for the GIS-based discussion on policy variables that follows is that, as we discussed at the end of previous session, it should be more effective to invest in agriculture in those municipalities characterized by significant values of residential density and in those municipalities whose territory overlaps a coastal landscape unit.

We started by simulating a "what-if" scenario by building upon the results of the Tobit model, and more precisely upon marginal effects presented in Table 5: for each municipality, we estimated the magnitude of the impact on the percentage change in a municipality's agricultural land use between

2003 and 2008 that would be produced if a single explanatory variable increased by a given quantity (that is, ten percentiles in the distribution of that variable). Next, since the values of one explanatory variable (namely, COAST) is fixed, we estimated the magnitude of the impact that would be produced by implementing simultaneously policies that increase the four remaining variables (DENS, VARUU3_8, PERVARPI, EXPEAGF).

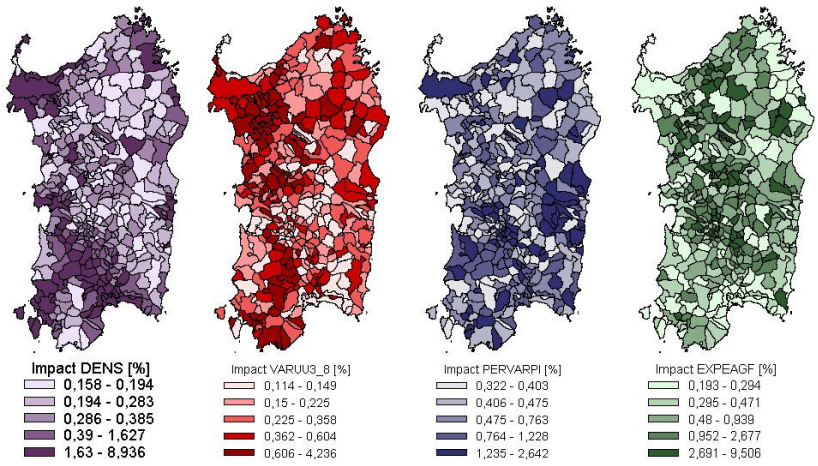

Figure 5. Spatial representation of policy implications: impacts on agricultural land use stemming from policies that increase: a municipality's residential density (a); percentage change in a municipality's urbanized land between 2003 and 2008 (b) per-capita income at the municipal level (c); per-capita investment on public infrastructure and services for agriculture (d)

Figure 5 presents some of the results of the first process: by implementing policies that increase per-capita income, a positive change in agriculture land use between 0.322 percent and 2.642 percent is produced (Figure 5.c); this percentage rises to 0.114 to 4.236 percent when policies that augment the amount of a municipality's urbanized land are put in place (Figure 5.b), and takes the highest values (0.158 to 8.936 percent and 0.193 to 9.506 percent) if policies that intensify residential density or per-capita investment funded through the ROP-EAGGF are implemented (Figures 5.a and 5.d respectively). Some clusters of municipalities taking either the highest or the lowest values are clearly identifiable in these maps, which could provide regional decision-makers with useful insights on the spatial dimension of regional policies aimed at strengthening the above policy variables, if agricultural land uses are to be preserved and increased.

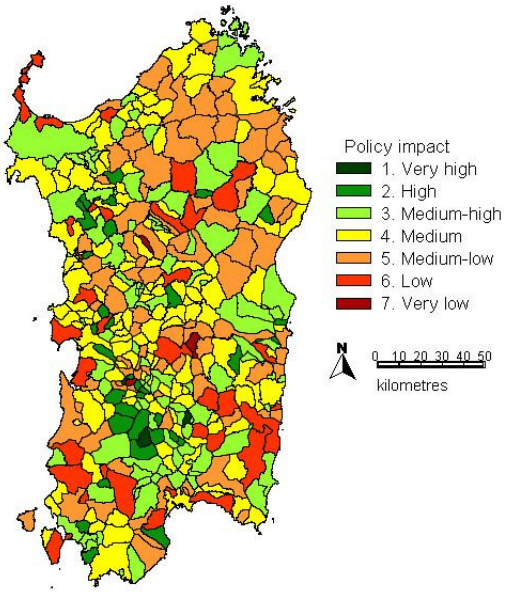

Figure 6. Spatial representation of policy implications: impacts on agricultural land use stemming from policies that increase simultaneously, at the municipal level: residential density, urbanized land, per-capita income, per-capita investment on public infrastructure and services for agriculture

An ever more powerful suggestion for policy makers is provided in Figure 6, which spatially represents, in qualitative terms, impacts on preservation of agricultural land uses produced by implementing policies that increase residential density, urbanized land, per-capita income, per-capita investment on public services and infrastructure for agricultural areas.

Such spatial representations provide decision-makers with clear indications on which are the "best" possible areas that policies should target in order to preserve, and where possible and appropriate to reinforce, agricultural land uses.

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