Agriculture and Sustainability: a GIS Based Model to Appraise Incentive Policy

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Abstract. Agriculture is the major form of protection of local identities and sustainability and one of the most fragile Italian economic sectors, exposed to fluctuations of the financial/economic crisis. As a consequence, boosting agricultural policies should integrate conflicting objectives connected to preservation and innovation, effectiveness/efficiency, and landscape features and job opportunities. Referring to a large land area located in the central part of Sicily (Italy) the paper proposes an assessment/planning pattern aimed at providing some axiological items and a specific algorithm able to appraise each specific land parcel, generating different strategies and selecting the best format of funding allocation. The pattern combines some WebGIS tools helpful for spatial analysis and management of the big data amount coming from the Landscape Regional Plan and the cadastral vector database. The general approach integrates monetary and qualitative features, as well as land estate and landscape values within a multidimensional pattern providing the quantitative conditions for supporting qualitative and sustainable development.

Keywords: agricultural policy, GIS, appraisal model, sustainability.

1 Introduction

Agriculture is an economic sector that has suffered the effects of the economic crisis and has been growing slower due to the change of the relationship between the State and the market, the increasing international competition, the uncertainty of the large-scale investments (INEA, 2011) and the modification of the Common Agricultural Policy (CAP) that, in 2007-2013, produced "a notable impact on the Italian and Sicilian agriculture caused by the decreasing attention to the Mediterranean agricultural products" (Regione Siciliana, 2008, p. 16). These difficulties are confirmed by the low availability of financial facilities in agriculture compared to other economic sectors (4.2% in the south, 2.5% in the centre-north Italy) (Caprara *et al.*, 2010), and by the inability to accumulate economic wealth (over the decade 2000-2010 the added value increased by 2%).

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The preservation of the territory, in both its environmental and local dimensions, assumes the agricultural sector as a protection of economic wealth and a socio-economic whose activities have assumed a strategic importance because of the widespread a different demand in food and landscape. The new agricultural policy improves the nutritional behaviours by boosting the biological farms and promoting food education programmes (Pollan, 2007; Foer, 2010).

Despite the crisis, some important modifications have been improving the rural economic structure like the diffusion of environmental sustainability, the trust towards the responsibility of the local communities (European Commission 2011), a greater integration of land planning, economic investments and farm tourism reporting from 1998 to 2005 an increase of facilities of 58% in Italy and of 134% in Sicily (OSEAAS, 2007).

In this context, the change of the relationship among job, sustainability and territory is directed to the "degrowth, envelopes and maintenance" (Morin, 2012) and to some indications of the reformed CAP that invokes a strong public policy supporting those agricultural products whose production could not be guaranteed by the market, in order to prevent marginalisation, abandonment and degradation of the areas excluded from intensive farming and characterized by the permanence of fragile ecological and anthropic systems.

The conjugation of quantitative purposes (increase of 70% in agricultural products by 2050) to landscape and environmental sustainability (European Commission, 2010, pp. 2-3) asks for a global agricultural policy at a local scale which can be realized with a consistent amplification of a planning-oriented database and a territorial information system containing the data which allow to clearly and fairly appraise the economic, functional and landscape values of each territorial unit.

The Italian cadastre currently reports only dimensional and administrative data and the income from the land parcels, but its database is going to be improved with the development of orthophoto systems, cartographic modelling, GIS and WebGIS technologies to satisfy the ever-increasing demand for territorial data suitable for cognitive, appraising and planning purposes.

This study proposes a pattern for representing and appraising cadastral parcels; by applying GIS spatial calculation and by means of a great quantity of quality information, this model aims to improve tax equalisation and subsidy choice as well as to assess the redistributive effects of agricultural policy (Bernetti and Marinelli, 2010). These types of algorithms are common used to support the decision-making and improve the efficiency of multi-objective spatial planning (Cowen, 1988; Fotakis *et al*., 2012; Malczewski, 1999; Malczewski and Rinner, 2015).

2 Materials and methods

2.1 The cadastre: Information, Appraisal and Programming

The Cadastre has always represented the principal source of data used for an orderly representation of the territory and for planning economic activities. The quantitative and qualitative increase of its technical information base allows, therefore, to consolidate its primary vocation, i.e. tax equalisation, through the integration of territorial policies into economic planning (Coletta *et al*., 2009; Rizzo, 1986) within the sustainable development. Sustainability is a concept that encompasses a plethora of definitions (Trovato, 2012), but it tightly focuses on local development, which involves anthropological and landscape dimensions, and this leads to reconsider the relationship between global capital and income accumulated/provided from the social and territorial macro-system.

Assuming a parcel[1] as the starting point, this research proposes to widen the cadastral database by integrating the economic and physical quantitative data with the aesthetic and qualitative data (geographical and landscape-related), so as to develop a territorial profile of each parcel through spatial calculation which is also suitable for the evaluation purpose. The new database can support the appraisal of the market values from the perspective of a cadastre founded on both incomes and values, for adjusting "the fiscal imposition to the asset recovery so that it can contribute to attenuate the effects of the crises and the speculative activities" (Rizzo, 2010), especially when the real estate becomes object of over-accumulation of capital with the aim of profiting from the differential market value.

The basic idea of this study is that public institutions can conduct virtuous hoarding activity by supporting the sustainable agricultural policies that raise the social value of the lands, thus promoting the traditional cultivation and making it competitive thanks to the introduction of innovations which not only increase the added value, but also tend to accumulate as farm improvement. The added value, defined as the difference between sales and purchases or as the remuneration of the productive factors (including amortization), "could be replaced in the fiscal survey by the social net product plus amortizations" (Rizzo, 2010, p. 146).

The recourse to GIS as a tool is consistent with the necessity to provide a value function containing the fundamental merit elements to have access to the incentive system as well as the territorial characteristics according to the policy for sustainable agriculture.

2.2 The GIS Model and the Methodology of the Georeferenced Cadastral Cartographic Database

The cartographic support has been achieved by integrating the necessary algorithms for a georeferenced cadastral cartographic database into a GIS; the object of the cartographic database and its spatial analyses apply the projection onto the geographic Cassini-Solder system, while territorial information is projected onto the geographic Gauss-Boaga system. In order to create a vector database, useful for accurate institutional calculation, the GIS database has been integrated with an algorithm using a rigorous methodology for the roto-translation (Di Filippo, 2004) (Figure 1). The methodology is divided in the following phases: 1. Acquisition of the cadastral cartography in numeric format; 2. Acquisition of the control points; 3.

[1] In the Italian land register, the parcel is a continuous part of land having the following characterizes: same owner, same type of cultivation and same ranking of productivity.

Translation from the plane coordinate system into the ellipsoidal coordinate system; 4. Transformation of the ellipsoidal coordinates; 5. Translation from the ellipsoidal coordinates into a new plane coordinate system (cartographic coordinates).

After correlating the two systems, the seven-parameter transformation is completed by calculating the translation parameters, two scale factors, the angular slide (S-band) and two rotation parameters according to the minimum quadratic difference. The algorithm runs using .XML file parameters and cadastral vector .CXF files, and creating a correlation between the *identification number* (*id*.) (cadastral code) of the parcel and the corresponding polygon, so that a geographic database in Shape format is developed (http://shapelib.maptools.org).

The database is built on the base of the *id*., by importing the cadastral data of the parcels following relational functions; besides, the fields *sheet* and *parcel* have been unified to build a specific field (KEY) and obtain a spatial join to the georeferenced cadastral map.

2.3 The Evaluation Model and the Spreadsheet

The proposed model is applied to a portion of land (Municipality of Piazza Armerina, Sicily, Italy) constituted by 31,254 parcels whose value has been represented from four points of view, 1. Landscape, 2. Environment, 3. Economy, 4. Functions. Each criterion is specified by indicators provided by a database that applies the spatial computation functions of the GIS and works out the criteria values by implementing specific utility functions.

The scores are assigned in an adimensional scale, ranging from 1 to 5, to each parcel, identified and described in quantitative and qualitative terms. The scores are positive when the characteristic constitutes an economic-monetary, functional, landscape or environmental value, and negative when it constitutes a disvalue (i.e. hydrogeological risk, high fire risk, etc.) (Table 1). The spatial analysis functions turn land characteristics into value function parameters. The relationship between characteristic and score is expressed by a utility function that associates the general value k – obtained by aggregating the scores by means of a Work Breakdown Structure – to each cadastral parcel.

$$k = \sum_i k_i' \lambda_i' . \qquad (1)$$

where: (i = 1, 2, 3, 4), k is the overall value of each parcel, k_i' is the value of criterion i (k_1' = landscape, k_2' = environment, k_3' = economy, k_4' = functions), k_{j_i}'' is the weight expressing the importance of criterion j compared to first-level criteria;

$$k_i' = \sum_{j_i} k_{j_i}'' \lambda_{j_i}'' \qquad (2)$$

where (j_1 = 1, 2,…, 6), (j_2 = 1, 2,…, 5), (j_3 = 1, 2,…, 4), (j_4 = 1, 2, 3), k_{j_i}'' is the value of subcriterion j of criterion i, λ_{j_i}'' is the weight defining the importance of subcriterion j – belonging to criterion i – compared to second-level criteria.

Table 1. Part of the evaluation spreadsheet model. Our processing on data provided by the Land Registry Office and Forestry Corps of the Sicilian Region – Forestry Informatin System, Guidelines of the Regional Territorial Landscape Plan (Superintendence and DAU, 2008).

code	sheet	parcel	municipality	parcel code	cultivation type	ranking	hectare	are	centiare	rental income	agricultural income	owner code	variation code	area (m²)	code part 1	cultivation type of part 1	ranking part 1	hectare parte 1	are part 1	centiare part 1	area (m²) part 1
28784	230	118	T	419608	36	3	0	22	50	5,23	3,49	32994		2228							
28785	230	61	T	419551	993	0	1	21	82	25,67	15,52	0	26A	12768							
28786	232	53	T	419735	1	4	0	75	50	11,7	3,9	0	DEN	7506							
28787	265	10	T	425109	993	0	0	27	0	19,93	9,76	0	26A	2705	AA	36	2	0	11	26	1126
28788	214	469	T	416203	29	2	0	37	14	32,61	13,43	49571	FRZ	3678							
28789	121	246	T	383845	74	4	0	41	60	10,74	8,59	38635		4083							
28790	123	721	T	385228	91	3	0	6	40	0,66	0,2	31212	FRZ	640							
28791	169	85	T	404034	91	2	0	7	26	0,94	0,37	0	26A	758							
28792	277	228	T	427162	1	2	0	14	76	7,62	1,52	0	26A	1412	AA	36	1	0	4	61	461
28793	189	34	T	411573	74	3	0	23	20	8,39	4,79	30947		2237							
28794	219	275	T	416976	993	0	0	69	90	9,73	3,61	0	26A	6883							
28795	222	116	T	417864	993	0	0	99	80	22,31	5,15	0	26A	9939	AA	91	2	0	26	75	2675

					landscape						environment					economy				functions		
					0,1	0,2	0,1	0,2	0,2	0,2	0,2	0,2	0,4	0,1	0,1	0,25	0,25	0,2	0,3	0,2	0,4	0,4
					0,07	0,14	0,07	0,14	0,14	0,14	0,02	0,02	0,04	0,01	0,01	0,03	0,03	0,02	0,03	0,02	0,04	0,04
code	sheet	parcel	municipality	parcel code	geology	plants	forestry	river	building of archi-tectural interest	archeologic basin	geological risk	land use risk	forest fire (summer)	forest fire (winter)	road system constraint	rental income	agricultural income	average agricultural value	market value/m²	forest fire	land use	slope
28784	230	118	T	419608	3,0	3,0	3,7	2,7	5,0	-1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	2,5	2,3	3,8	1,4
28785	230	61	T	419551	3,0	3,0	3,9	1,8	5,0	-1,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	1,0	2,3	2,0		
28786	232	53	T	419735	3,0	3,0	1,2	3,8	5,0	-1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	2,1	1,2	2,7	1,2
28787	265	10	T	425109	3,0	3,0	3,0	2,0	5,0	-1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	3,6	3,1	4,5	1,5
28788	214	469	T	416203	3,0	3,0	3,8	2,8	5,0	-0,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0	3,8	3,1	4,5	2,7
28789	121	246	T	383845	3,0	3,0	3,8	7,7	5,0	-3,0	-2,1	5,0	0,0	0,0	0,0	0,0	0,0	1,0	2,6	2,6	3,2	2,2
28790	123	721	T	385228	3,0	3,0	4,0	3,0	5,0	-3,1	-3,0	1,0	0,0	-4,0	0,0	0,0	0,0	1,0	1,7	0,7	0,8	1,8
28791	169	85	T	404034	1,0	3,0	4,0	5,0	5,0	-2,0	-2,0	5,0	1,0	0,0	0,0	0,0	0,0	2,5	1,9	1,1	0,8	1,7
28792	277	228	T	427162	3,0	3,0	4,8	2,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0	3,3	1,9	2,7	1,8
28793	189	34	T	411573	2,5	3,0	0,6	5,0	5,0	-1,5	-1,2	2,0	1,0	0,0	0,0	0,0	0,0	1,0	3,0	2,6	3,2	1,9
28794	219	275	T	416976	3,0	3,0	3,1	3,4	5,0	-1,0	-0,9	2,0	0,0	0,0	-3,0	0,0	0,0	5,0	2,0	1,2		
28795	222	116	T	417864	2,5	3,0	0,2	5,0	5,0	-2,8	-2,0	0,0	5,0	0,0	0,0	0,0	0,0	2,0	2,5	1,2	1,2	1,3

The economic criterion is based on the cadastral incomes (landowners and firms), the agricultural standard value and market value, productivity, acclivity, location. The pattern integrates spatial and appraisal calculation functions by a specific algorithm allowing both the numerical and the graphical implementation, and recording both the cartographic changes in the charts, and the numerical changes in the mapping. A WebGIS interface allows displaying the distribution of the parcels boosted according to a fixed budget and a specific strategy (Sani and Rinner, 2011; Torre, 2007).

2.4 Incentive Policy

The incentive policy takes into account sustainability principles as declined by integrating firm economic performances in local identity and culture. In the Enna district low urbanization, demographic drop, intense migration flowing towards external labour markets, a weak economic system mostly depending on agriculture and high unemployment rate on the one hand, and the vitality of traditional handicrafts and the construction sector on the other, should be of great interest to an incentive policy for the creation of added value, diversification in household consumption and improvement of life quality.

In Sicily, the CAP is inspired by the European support strategy that intends to integrate market, local rural development, sustainability and innovation. With reference to some key thematic areas – economy of the agri-food sector, environment, rural economy and population – the development programs individuate four axis: 1. Improving the competitiveness of the agricultural and forestry sector; 2. Improving the environment and the countryside; 3. Quality of life in rural areas and diversification of the rural economy; 4. Leader, (ENRD, 2007).

The proposed pattern is a decision-making support helpful for determining the financial requirement of the firms involved in the incentive program. Measure 112 of CAP 2007-2013 is supposed to be applied: it concerns the renewal process of the entrepreneurial culture in terms of economic actors and farm competitiveness. The overall financial envelope of the measure is 90 mln € and is conditional upon the execution of at least another investment measure among the following: a) Modernisation of agricultural holdings (M.121); b) Improvement of the economic value of forests (M.122); c) First afforestation of agricultural land (M.221); d) Diversification into non-agricultural activities (M.311).

The financeable amount, assumed as a base for determining the requirement, is established by adopting the current practices among local operators, that is, the standard amount of 40,000 euros (M.112) plus further 60,000 euros for any additional measure. The access to the funding depends on the dimension of the farm that has to correspond to 10 ESUs (Economic Size Unit), reduced to 8 ESUs in case of disadvantaged areas (e.g. where the municipality of Piazza Armerina is located).

3 Results of Appraisal and Programmatic Indications

The economic appraisal and spatial calculation of the area have shown the spatial distribution of the parcels which most deserve an incentive based on a hypothetical budget. The selection is made on the following algorithm:

$$\forall p \exists f_1(p) = k : k \geq g_W ; \; 1 \leq k \leq 5 ; \; \sum_i^n f_2(p_i) = W ; \; (n = 31.254) \tag{3}$$

where p is the generic parcel selected if the value k overcomes the threshold g_w; the threshold is set so that the potential funding sum of all the selected parcels will be equal to the total budget W (Fig. 1)

Eight different strategies have been hypothesized; each of them is defined by a specific weight system λ_j (respecting the constraint $\sum_j \lambda_j = 1$) placing primary importance on two of the four different qualitative dimensions (Landscape, Environment, Economy and Functions) (strategies 1-4) or on each dimension (strategies 5-8) (Table 2).

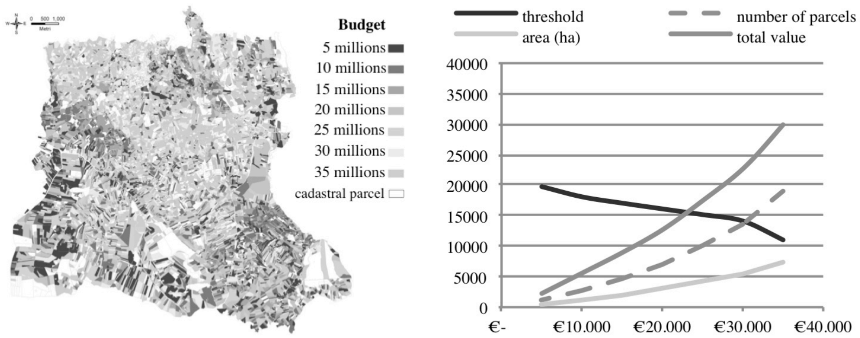

Fig. 1. Funding distribution of the budget increasing from EUR 5 to 35 million.

Table 2. Weight system of the eight strategies.

	Strategies							
Criteria	1	2	3	4	5	6	7	8
Landscape	0,1	0,5	0,1	0,4	0,7	0,1	0,1	0,1
Environment	0,1	0,1	0,4	0,1	0,1	0,7	0,1	0,1
Economy	0,5	0,3	0,4	0,1	0,1	0,1	0,7	0,1
Functions	0,3	0,1	0,1	0,4	0,1	0,1	0,1	0,7

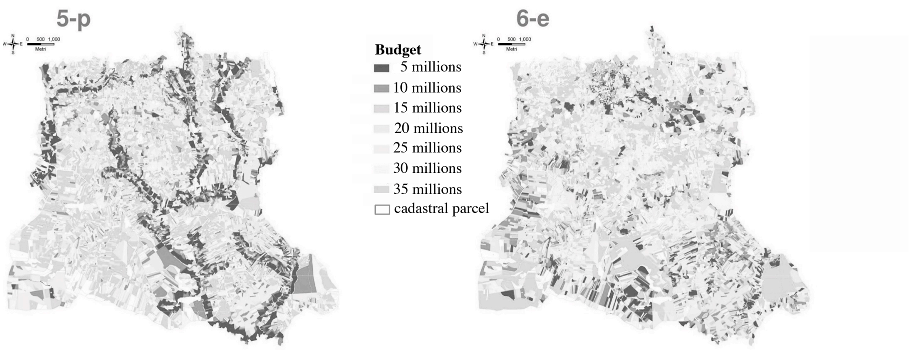

Fig. 2. Distribution of the parcels selected according to the budget and strategies 5 and 6.

The varied results produced by the different strategies raise issue of fairness in funding (Fig. 2). To this end, every strategy should analyse the relationships among the increasing budget and: the number of the selected parcels; the area receiving funding (index of efficient and fair funding allocation); the threshold level which is reduced for selecting the parcels (indicating the relationship between funding amount and quality of the selected parcels); the overall evaluation (index summing all the scores of the selected parcels).

These characteristics are normalized on a scale from 0 to 2 (Tab. 3, Fig. 3). On the same budget one strategy is preferred if: a greater number of parcels and a greater area are financed; a higher total value is obtained (when the best parcels or a much greater number of less valuable parcels are financed); the same number of parcels is selected on the same budget but a higher threshold is imposed (index of higher-quality parcels along the main criteria of a specific strategy).

Table 3. Weight system of the eight strategies.

strategy	location threshold	slope threshold	width threshold	location parcel	slope parcel	width parcel	location area	slope area	width area	location value	slope value	width value
str 1	1,94	-0,09	1,27	6793	4,02	18134	2563	4,76	7222	14941	2,69	33002
str 2	1,65	-0,06	0,69	6556	3,21	16963	2540	2,84	7118	11818	2,40	26922
str 3	1,54	-0,10	1,12	6948	5,28	18178	2383	5,09	7222	11989	3,50	26212
str 4	1,65	-0,07	0,91	8850	1,67	17868	3953	1,26	6759	17013	1,18	28964
str 5	1,46	-0,04	0,44	7686	1,53	16498	3740	1,04	6562	12595	1,13	23687
str 6	1,12	-0,12	1,02	9113	1,68	18233	3470	2,08	7122	11943	1,13	18869
str 7	1,98	-0,09	1,37	6246	5,02	18112	2007	5,15	7242	13888	3,12	32954
str 8	1,83	-0,11	1,78	9165	1,68	18200	4016	1,20	6712	20763	1,02	32536

strategy	location threshold	slope threshold	width threshold	location parcel	slope parcel	width parcel	location area	slope area	width area	location value	slope value	width value
str 1	1,91	1,08	1,23	0,37	1,33	1,89	0,55	1,81	1,94	0,70	1,34	2,00
str 2	1,23	0,38	0,37	0,21	0,90	0,54	0,53	0,88	1,64	0,00	1,11	1,14
str 3	0,99	1,35	1,02	0,48	2,00	1,94	0,37	1,97	1,94	0,04	2,00	1,04
str 4	1,25	0,74	0,71	1,78	0,08	1,58	1,94	0,11	0,58	1,16	0,13	1,43
str 5	0,80	0,00	0,00	0,99	0,00	0,00	1,73	0,00	0,00	0,17	0,09	0,68
str 6	0,00	2,00	0,86	1,96	0,08	2,00	1,46	0,51	1,65	0,03	0,08	0,00
str 7	2,00	1,26	1,39	0,00	1,86	1,86	0,00	2,00	2,00	0,46	1,69	1,99
str 8	1,65	1,74	2,00	2,00	0,08	1,96	2,00	0,08	0,44	2,00	0,00	1,93

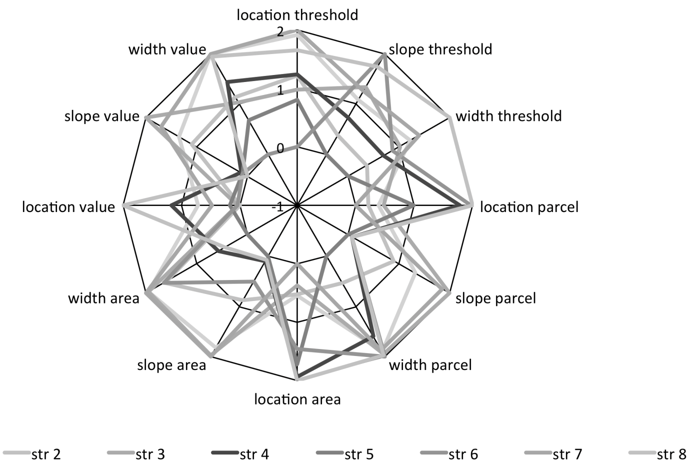

Fig. 3. Evaluation of the strategies according to the efficiency/effectiveness of the budget allocation

The model allows a further evaluation concerning the distribution of the financed land units with reference to land qualification. The whole financed parcels are overlapped with eight *qualified sectors* (for a budget of EUR 20 million) implementing one by one the eight strategies (64 combinations) and selecting the parcels inside (dark grey) and outside (light grey) the *sector*: the indexes of effectiveness of each strategy can be achieved by connecting the area of each *sector with* the whole financed area and the financed area inside the *sector* (Fig. 4).

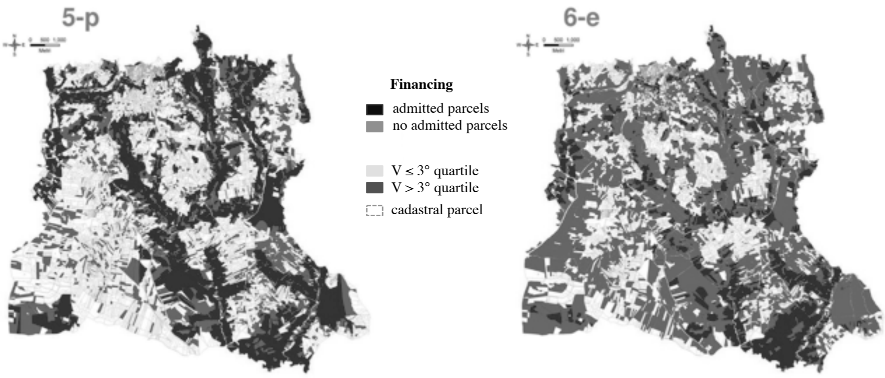

Fig. 4. Effectiveness evaluation of strategies 5 and 6 with reference to the qualified area

4 Conclusion

The proposed model allows testing how a representation and evaluation model (through functions of spatial calculation and economic appraisal) can address the incentive policy of the agricultural sector.

The results underlined the conditions, which justify and prefer a policy aimed at encouraging lands with greater landscape value and lower productivity. A coherent economic and land planning in agriculture imposes itself with some urgency and asks for a methodology of analytical representation and evaluation of the territory which assumes minimum units of study described by detailed spatial information, and accurately stored and managed by spatial informative systems.

The paper has also underlined some criticalities of these procedures, due to very poor standardised geo-spatial data; thus, a specialist competence is required for building an evaluation database. Potentially, this model can be developed by overcoming the additive approach and pushing the artificial intelligence to represent complex relationships.

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