A Spatial Integrated Database for the Enhancement of the Agricultural Custodianship Role (SIDECAR) – some preliminary tests using Tuscany as a case-study Region.

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Abstract

Agriculture plays a fundamental role in the provision and regulation of Ecosystem Services. As a result, the loss of farmland or its mismanagement may consistently reduce community well-being. This problem is particularly felt in the Mediterranean area, where pedoclimatic conditions and high anthropic pressure on scarce resources are making rural systems more fragile. Policy is a very important driver in the promotion of sustainable agriculture and soil protection. However, it would appear that policy does not adequately address the scale and urgency of soil and environment protection issues. The complexity of factors that influence the role played by agriculture in territorial custodianship and Ecosystem service provision demands dynamic management tools, where information and territory are closely intertwined in providing adequate knowledge for intervention.

This paper presents SIDECAR (Spatial Integrated Database for the Enhancement of the Agricultural Custodianship Role[1]), a decision support system (DSS) which aims to promote an integrated approach to planning, programming and design. SIDECAR is a database where several georeferenced data were merged and developed using a Geographic Information System (QGIS). It allows for the integration of spatialized information on land use, territorial biophysical characteristics, farm socio-economic characteristics, Common Agricultural Policy aid distribution, etc. SIDECAR has been tested in the Italian region of Tuscany where there is a high level of multifunctionality in agriculture and a great variety of contexts.

Results show that the effectiveness of agricultural and spatial planning policies and their positive role for community well-being can be improved by considering: a) spatialized information; b) farm data used for forecasting agricultural trends at territorial level; c) the provision of ecosystem services by agriculture.

1. Introduction

The seminal work of Costanza et al. (1997) highlighted the role of nature in providing Ecosystem Services (ESs). Following an initial period when agriculture was considered as an activity which reduces the provision of ESs compared to natural un-anthropized areas, a growing awareness of the multifunctional role of agriculture and of the importance of well managed agro-ecosystems in providing ESs arose (OECD, 2001, Durand and van Huylenbroeck, 2003, van Huylenbroeck et al. 2007).

At present, in European countries, agriculture and forestry still cover the major part of the territory. Nevertheless, this share is steadily decreasing because of two major phenomena: economic and urban development and land abandonment (see, e.g. Verburg et al., 2006). Economic development has led to a loss in the importance of agriculture in terms of share of GDP and of employment in favor of industry and services which require a large amount of artificialized surfaces. Furthermore, the movement of population from rural to urban areas (Hall, 1997, Angel et al., 2011) has determined a sharp increase in built-up areas for residential purposes. At the same time, agriculture is

[1] SIDECAR has been described in a first contribution in Italian under the name DISPAT.

gaining importance for urban populations because of the wide spectrum of ESs it produces (Gutman, 2007; La Rosa et al., 2014). The demand for ESs, such as the provision of food and amenities, by urban populations may constitute the basis for a new covenant between urban and rural areas (Gutman, 2007). Urbanization processes, in many cases, have not followed a clear vision but have assumed confused forms (Scott et al., 2013), as the result of a lack of proper regulation by public institutions. Salvati and Gargiulo Morelli (2014) provide an analysis of the urban sprawl in the Mediterranean Region and highlight that, in recent years, several cities have assumed a polycentric structure, characterized by dispersed low- and medium-density settlements. These settlements are located around urban centers and lead to the fragmenting of fertile rural areas which are suitable for agriculture and are often of high environmental quality. Salvati (2013) and Ferrara et al. (2014) confirm that the loss of productive soil caused by urbanization often affects the most productive agricultural land. Indeed, the lack of proper regulation and land use choices mainly based on private interests might determine an underestimation of the importance of agriculture, as a result of the greater economic profitability and lobbying power of other economic activities. This, in turn, could result in future costs for the collectivity.

In fertile areas, the need to cope with a global competition may result in an agricultural intensification where disservices, rather than services, may be produced (Stoate et al., 2001; Huang et al., 2015). However, in most rural areas, negative impacts are mainly caused by land abandonment (Cooper et al., 2006; García-Ruiz and Lana-Renault, 2011, Pelorosso et al., 2011, Haddaway et al., 2013). The process of land abandonment is particularly important in the European Mediterranean countries which are characterized, from the one hand, by a great number of small households unable to cope with competition in a global arena, and from the other hand, by pedoclimatic conditions, i.e. summer drought and vulnerability to soil erosion. Adverse pedoclimatic conditions increase the negative effects of global warming. García-Ruiz and Lana-Renault (2011), Terres et al. (2015) and Lasanta and al (2017) provide an analysis of the drivers of land abandonment in Europe and of the distribution in space of abandonment phenomena. Lasanta et al. (2017), on the base of the analysis of relevant literature, state that there have been two surges of land abandonment. The first surge affected mountain areas, in particular the ones located in the Mediterranean areas, as a consequence of their bio-physical limitations, low agricultural population and limited competitiveness of their products. The second surge was caused by CAP, that deeply affected the arid and semi-arid areas of Southern Europe, and, in minor degree, the regions with small-scale agriculture and fragmented land ownership. Renwick and al. (2013) analyzed the effects of policy reform on agricultural land abandonment in the EU confirming the relevance of CAP for this phenomenon. Queiroz et al. (2014) argue that scientists are still discussing whether farmland abandonment should be considered as a threat or an opportunity for biodiversity conservation. From a review of relevant literature, they conclude that researchers from Eurasian countries usually stress the negative effects while researchers from New World countries stress the positive effects. Agnoletti (2014) highlights the risk of policies promoting renaturalization in Mediterranean areas, that cause reforestation and the loss of valuable cultural landscape. In summary, the abandonment of large agricultural areas is usually seen as bringing about a loss of ESs (Huang et al., 2015, Lasanta et al., 2017) and a decrease of the custodianship role of farmers (Rovai and Andreoli, 2016).

At present, the survival of a continuous and careful management of a territory is mainly ensured by processes and productive activities that are not competitive from an economic point of view and are, consequently, unable to survive without public aid (Ahnström et al., 2009). In order to enhance agricultural positive roles, the institutional policy context represents a critical factor. Policies are not only one of the main drivers of agriculture and land use change, but they may also be used as a response for contrasting negative effects, e.g. those caused by market trends (Van Zanten et al., 2014; Rovai et al., 2016). Common Agricultural Policy (CAP) is increasingly stressing the role of agriculture in conserving and protecting natural capital, and in producing ESs for urban areas. However, since financial resources are scarce, it is important that CAP aid is distributed in an effective and efficient way. This asks for considering not only territorial and farm characteristics, but also farmers' attitudes (Mills et al., 2016). Farm size and degree of fragmentation[2] are important when setting policy instruments promoting the production of ESs related to landscape, biodiversity conservation, etc., since they are directly related to landscape heterogeneity and ecological quality (Farina, 2006). The degree of family involvement and type of management significantly influence farm strategies about land use, ES provision and farm's chances to be viable in the long run (Wilson, 2008). A good knowledge and understanding of all these characteristics is highly significant both for CAP and for spatial planning at different territorial scales.
In the EU Mediterranean Countries, the institutional context shows complexities and criticalities that hinder the effectiveness and efficiency of policy instruments. These criticalities are mainly related to: a) a governance structure organized in regionalized unitary states; b) shared competences between national and sub-national levels; c) spatial planning traditions mainly related to urbanism; and d) a weak vertical and horizontal co-ordination (Silva and Ransford, 2015). In a recent paper about governance changes in peri-urban farmland protection, Perrin et al. (2018) highlight the practical issues of effectiveness and social acceptability that arise from power devolution and the increased complexity of procedures. Procedures complexity derives from multiple decision-making authorities that, in their turn, are a result of the decentralization process. Howlett (2009) highlights the need for consistency of policy aims and objectives and the importance of assessing the adequacy of policy means and instruments, as a consequence of the "nested" multi-scalar and multilevel nature of institutions.
The situation is particularly difficult in Italy where there were three administrative levels (region, province[3] and municipality) below the national level and where there are problems in ensuring a proper horizontal (e.g. among the territorial governance plan and the rural development programme at regional level) and vertical coordination (e.g. planning at regional and sub regional level). Indeed, according to Vettoretto (2009) and Cotella and Rivolin (2011), planning levels do not always have clear objectives and clearly identified and separate tasks; therefore, there are often multiple overlays among instruments adopted at different administrative levels, and sometimes also among instruments adopted at the same administrative level.
The sectorialization of policy-making processes and the weakness of horizontal and vertical coordination hinder the processes of socio-economic and physical space

[2] Fragmentation is defined as the situation in which a single farm consists of numerous spatially separated parcels (Demetriou, 2013)
[3] Provinces have been recently abolished

regeneration within a framework of sustainable development. In order to overcome these issues, it is paramount to understand the interactions among the above-mentioned policy tools and to base them on a territorial multisectoral and multidisciplinary knowledge (Conrad et al. 2011), able to integrate different aspects and sources.

In this framework a proper tool for promoting the ES provision and the custodianship role of agriculture should allow integrating competences and skills of: a) agricultural economists, who are mainly interested in the state end evolution of farms, but not in the bio-physical feature of the space where farms are located; b) planners, who are mainly interested in the past, present and future land use, but are not interested in the drivers influencing land use evolution; c) ecologists, e.g. landscape ecologists, who are interested in agricultural spaces in terms of their ability to provide functions and ESs. These categories of scientists and professionals have different visions about the role of agriculture in spatial planning. These specific visions often determine conflicts while they should be integrated and reconciled through a tool able to manage and put in relation information and knowledge proper of each discipline. Consequently, a proper knowledge tool should be able to: 1) highlight the transformation that territorial and landscape equilibria are undergoing and will likely undergo in the mid-long term, 2) evaluate their quality, and 3) understand the socio-economic dynamics that have brought about the change or still influence its evolution in time.

The issue of improving ES provision and the custodianship role of agriculture is very complex insofar as it has to be framed within a theoretical framework where: a) farmers compete or interact with other land managers about land use, b) agriculture, as an economic activity, is deeply influenced not only by structural and socio-economic features of farm households, but also by market trends and climate change, and c) sectoral and physical planning policy instruments are drivers influencing farm strategies and development paths (van Zanten, 2013, Rovai et al. 2016).

From this point of view, GIS tools are very suitable for managing spatial information related to different decision levels and for integrating them into a holistic approach. In literature there are many contributions using GIS analysis for different purposes. Malczewski (2004) provided a review of methods and techniques for GIS-based land-use suitability analysis. Piorr et al. (2009); Lobianco and Esposti (2010); Brady et al. (2012) used GIS analysis for an ex-ante estimate of the potential impact of agricultural policies or measures on farm structures and on ESs provided by the territory. Matthews et al. (2013) used GIS to evaluate ex-post CAP effects, since an ex-post approach seems to reduce policymakers' costs and increase the effectiveness of policy results. Yang et al. (2014), after analyzing the implementation of agro-environmental measures in Scotland, argue that spatial models are more suitable to promote an effective policy, if compared to non-spatial regression models.

In this framework SIDECAR (Spatial Integrated Database for the Enhancement of the Agricultural Custodianship Role) represents a tool for integrating information regarding agriculture that is relevant both for physical planning and sectoral programming. This by allowing an analysis of farm and agricultural activity typologies, their location and their relations with other activities and phenomena. SIDECAR has been developed with the aim to provide a tool that is both flexible and user friendly, to increase its chances to be accepted and used as a scientific robust basis for decision making. Indeed, Beunen and Opdam (2011), in a paper on the role of science in governance processes related to landscape, affirm that landscape scientists must develop much more insight into how their knowledge and knowledge tools affect societal processes. Furthermore, they affirm

that an effective use of scientific knowledge depends on its functionality as well as on the manifold influences of social and political factors.
SIDECAR has been tested in Tuscany Region, Italy, a typical Mediterranean region characterized by a great variety of territorial and landscape contexts, some of which are currently under threat because of the high risk of farmland abandonment (Agnoletti et al., 2011; Agnoletti, 2014).
Tuscany has a good international reputation due to its rural landscape (see, e.g. Gaggio, 2011) and the high quality of its agricultural products (see, e.g., Miele and Murdoch, 2002). These resources need to be protected by maintaining and enhancing the rural territory, through adequate policy instruments and tools.
Since the 14th Century, Tuscany was characterized by the presence of several cities surrounded by a network of small settlements. The multipolar nature of Tuscan urban landscape has characterized the following centuries, despite the economic and demographic prevalence of Florence. In recent times, the polycentric nature of settlements has been in some case altered by processes of "incomplete metropolization", including the spread of settlements, often in the form of urban sprawl (Paba et al, 2017).The interpenetration among agricultural land and urbanized areas is often quite strong.
After this Introduction (Section 1) the paper is organized as follows: Section 2 - Methodology, where data sources and GIS approach in building SIDECAR are given, followed by a brief description of the case-study area; Section 3 - Case-study application, where hypotheses and results of the use of SIDECAR in programming, planning and design are presented and discussed, Section 4 Conclusion.

2. *Methodology*

There is a great variety of GIS tools, able to provide a wide range of useful applications. By using spatialized information, physical systems can be described from various points of view. As a result, several interdisciplinary aspects may be included into a model, even if they are characterized by a technical and substantial diversity of reasoning. These aspects may be related to each other through a unitary representation based on the spatially distributed nature of their features.
The innovativity and potential usefulness of the proposed methodology rest on its two main aims. The first one is to provide a tool able to spatially represent in a scientifically robust, even if simplified, way the state of agriculture, the main drivers of change of the agricultural situation and its impacts at territorial level, e.g. in terms of landscape quality and potential provision of ESs. Territorial and landscape governance models need multidisciplinary and transdisciplinary approaches and, consequently, they need to be able to include knowledge from practitioners and local community preferences (Sevenant and Antrop, 2010, Conrad et al 2011). The second one is to provide a flexible and useful tool for supporting the process of decision-making at different scales, administrative levels, and times. From this point of view SIDECAR:

a) provides useful information for assessing policy decisions,
b) consents the integration of local knowledge (e.g. gathered through on purpose surveys) and facilitates a participative approach (e.g. thanks to the high explicative meaning of maps), and

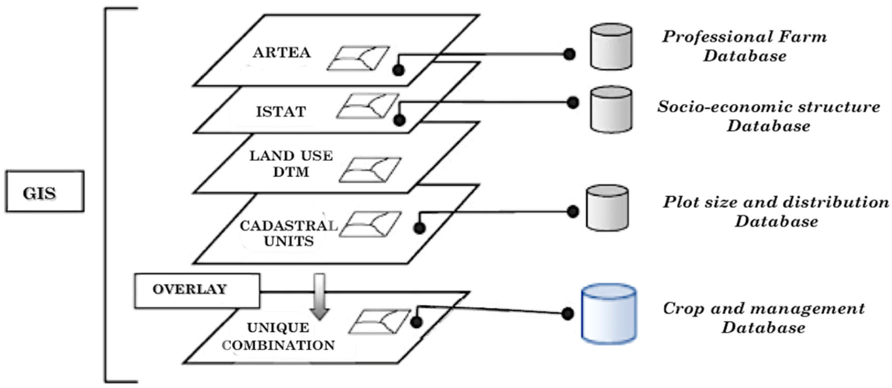
c) can be used for simple purposes by Regional Officers, since SIDECAR mainly uses public databases and the same open source GIS that the Tuscany Region's administration uses to archive and process data.

In this way the growing criticism and distrust towards scientific knowledge highlighted by some authors (e.g. Schermer, 2010 in Beunen and Opdam, 2011) might be reduced and thus also the risk that, within decision-making practices, scientific knowledge is contested or ignored (Beunen and Opdam, 2011).

The proposed methodology is based on an integrated use of different instruments with the aim to build a comprehensive database developed through QGIS (QGIS Development Team, 2012).

SIDECAR has been built (Figure 1) by merging and integrating the information from several pre-existing databases: a) the data warehouse of the 6th Agricultural Census (ISTAT, 2010); b) the Tuscany database of the pillar I and pillar II payments to farmers (ARTEA); c) the Land inventory of cadastral parcels[4] and their utilization type[5]; and d) data on altitude, exposure and slope from Digital Terrain Model (DTM).

Figure 1. The different steps in building SIDECAR



ARTEA 2013 dataset provides information on all farms that have applied for CAP aid. In this paper they are called professional farms, even if they do not comply with requirements for being qualified as "professional farmers" according to the Community and Italian legislation. In this case the aim was to single out business units which were still responding to economic stimuli provided by CAP aid and to assess their relative contribution to the provision of ESs. When the share accounted by professional farms does not ensure an adequate level of ES provision or custodianship, policy makers need to find different ways to influence farmer's behavior. Besides, ARTEA dataset made it possible to link every cadastral parcel to the business unit (i.e. the farm) managing it. In this way it was possible to know the territorial base of each farm and to represent in space the results of farmer strategies. Agricultural Census (ISTAT, 2010) provides information on farmland utilization, farm structure, farmer's age and education, etc. Census is the main source of information utilized for describing the agricultural situation of an area, but usually its information is not spatialized. Corine Land Use

[4] The Italian cadaster is an inventory of real estate property. In the case of rural cadaster, the elementary unit is the cadastral parcel, which is characterized by belonging to the same municipality and holder and by having the same cultivation typology and degree of soil fertility.

[5] Agenzia delle Entrate, Catasto terreni; extracting 03/12/2013

database updated by LaMMA[6] provides information on land use and bio-physical features of terrain (slope, altitude and exposure) that might represent powerful natural constraints for agricultural activities (Van Orshoven et al., 2014).
The final output of the process of merging and integrating data sources was a thematic database, named SIDECAR, including spatialized information for each parcel conducted by professional farmers. SIDECAR provides information on a wide range of fields, such as socio-economic and management types of farms and terrain characteristics. For specific purposes, the database may be integrated with further information, e.g. coming from on-field survey, to promote a more participative approach.
Technical aspect on how SIDECAR has been built can be found on Fastelli et al. (2017).
SIDECAR includes the georeferenced cadastral parcels belonging to 67,293 Tuscany farms, i.e. about 92.6% of the 72,686 farms that have been surveyed by the last Agricultural Census (ISTAT, 2010) and that are responsible for the management of 1,048,575 cadastral parcels and of 754,345 ha of Utilized Agricultural Area.

As stated in the introduction, SIDECAR has been tested in Tuscany (figure 2), one of the 20 administrative regions of Italy, which is located in the Central-Western part of the country. However, in the Authors' opinion, SIDECAR approach could be extended to most of Italian Regions and developed countries, since it uses data that are generally available.

Figure 2: Tuscany location in Italy

Tuscany has a territory of about 23,000 km^2, which is mainly hilly (66.5%) and mountainous, due to the Tuscan Apennine chain located along the borders with Liguria and Emilia Romagna (25.1%). The valley of the Arno River and the Versilia, to the North, and the Maremma, to the South, are the main plains, which account for 8.4% of the whole territory. Tuscany was organized in 10 provinces (recently abolished as administrative units) and 279 municipalities and has a population of ca. 3.7 million inhabitants, with a population density of 463,6 inhabitants/km^2. According to Ciampi et al. (2015), in 2013 land cover in Tuscany was distributed in the following way:

[6] Databank of Tuscany Region, Lamma Consortium, 2013

artificialized surfaces accounted for about 8.6%, agricultural areas for 38.1%, natural and semi natural areas for 52.3% while water bodies and wetlands only for 0.9%. These average figures hid a high variability among areas; artificialized areas, e.g., account only for 5.3% in the Apennine, for 7.5 in hilly areas, but raise up to 33.9% in the alluvial lowlands. Agricultural landuse is most important in hills (68.0%) and lowlands (57.4%), , while in the Apennine natural and seminatural surfaces make up to 75.3%. In the period 2007-2013 artificialized surfaces increased for about 5,200 hectares, while agricultural areas decreased for 5,800 hectares, mainly due to artificialization processes and in some areas, to an increase of woodlands (Ciampi et al., 2015). Settlements are very often characterized by low density, with a high consumption of soil for each inhabitant.

As regards the institutional context of Tuscany, according to Scattoni and Falco (2011) Tuscany legislation about territorial governance has been characterized from its beginning (1995) by a high importance given to environmental sustainability, community participation, and transparency and collaboration among the administrative levels, rather than hierarchical relations. However, as in the case of other Italian Regions, plans implemented at different administrative levels often lack consistency and suffer for a low level of coordination. Sometimes there are problems of inconsistency even within planning tools (Scattoni and Falco, 2011). Difficulties arise also from a situation where municipalities are no longer capable of managing territories that are becoming increasingly complex and the Region is too much estranged from the immediate local issues relating to efficiency in the use of soil.

The potential utility of SIDECAR has been tested through several applications relating, from the one hand, to ex-post and ex-ante assessments, and, on the other hand, to programming, planning, and design. This last choice allowed analyzing a great variety of situations spanning from spatial planning to sectoral programming, from a strategic level to an operational level, and from analyses at regional level, to analyses at local level.

In the following sections some practical applications of SIDECAR are described, highlighting innovative and applicative aspects, while more details about the methodology can be found in references.

Section 3.1 deals with a case-study about programming. In this case the test consists in an ex-ante assessment of greening measures, highlighting spatial aspects and farm characteristics issues. SIDECAR was used also in an ex-post analysis of the efficiency in the distribution of aid to Less Favored Areas, where also farm strategies and attitudes were taken into account. The results of this analysis are described in Fastelli et al. (2017) and will be partly commented in the discussion of SIDECAR performances. Section 3.2 presents the second case-study, which aroused from a specific need expressed by the Tuscany Region. This latter, when drawing the new regional landscape plan, considered important to know which landscapes were at risk as a result of a high presence of non-professional farms. The third case-study, presented in section 3.3, deals with peri-urban areas and focuses on the demand and supply of ES provided by green spaces.

3. Case-study application: hypotheses, results and discussion

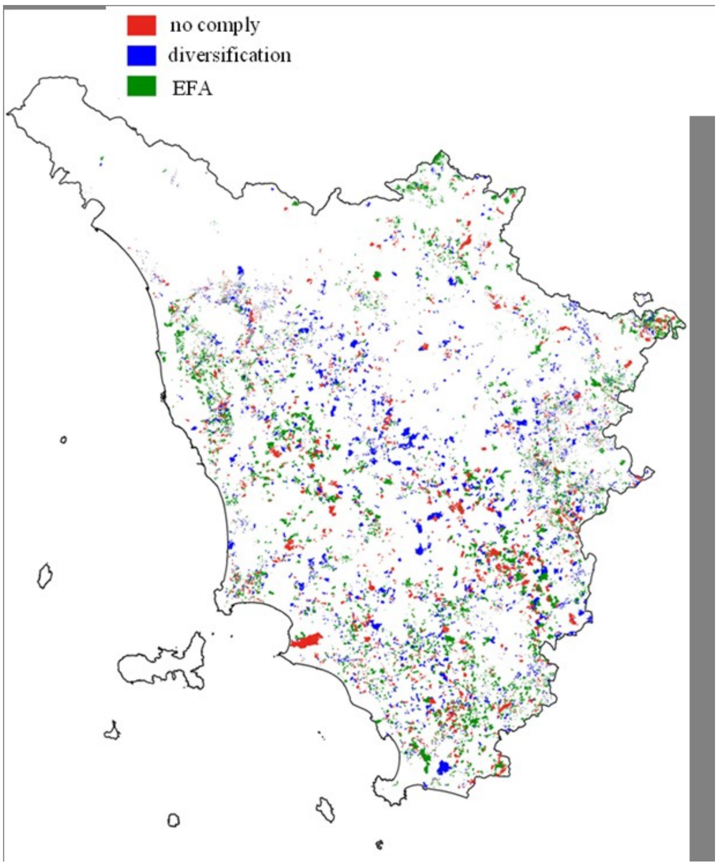
In the present section, the use of SIDECAR as a decision support system (DSS) for programming, planning and design issues, is presented and discussed on the basis of some case-study analyses.

3.1. Testing SIDECAR as a DSS for programming: the case of greening

Greening has been introduced with 2013 CAP reform and consists of a package of compulsory measures for farms. The main purpose of these measures was to boost crop diversification and to maintain natural and semi-natural crop systems in Europe's rural landscapes (Zeijts et al. 2011), consequently increasing the provision of ESs. Pillar II measures, which are regulated at State or Region level, had often resulted in a great variety of requests in terms of environmental standard, sometime set at a very low level (see, e.g. Hart and Baldock, 2011). As a result, the EU decided that common basic prescriptions among all Member States were needed about environmental standards. The introduction of greening created confusion and worries among farmers. Indeed, farmers perceived greening as a further constraint hindering their competitiveness on the market.

The present study tested SIDECAR's ability to assess ex-ante the share of farms that would have to comply with greening requirements, their localization and level of land fragmentation, since this latter may influence greening effects. A geo-referenced sample of the farms that were not meeting crop diversification and minimum share of Ecological Focus Areas (EFA)[7] was created. The third greening requirement, namely permanent grassland maintenance, was not considered since it was asking for a diachronic analysis at farm level.

Figure 3: Tuscany. Farm parcels that do not comply with both (no comply) or one of greening requirements (crop diversification, minimum share of Ecological Focus Areas)



[7] For a short description of greening rules, see, e.g. Gava et al., 2015.

Figure 3 shows the localization of parcels which need to comply with greening requirements and, consequently, the territories more affected by its enforcement.

Table 1 shows data at regional level. Based on table 1, the low importance of farmland where at least one of the first two requirements was not met is apparent. It includes 148,040 cadastral parcels belonging to 4,842 farms, that account only for 6.7% of the universe of Tuscany farms. Inside this sample, 1,143 farms, accounting for 8.9% of the regional UAA did not meet both requirements, while a further 26.5% did not meet one. This means that 93.3% of Tuscany farms, accounting for 64.6% of the regional UAA, were exonerated or already complying with both the analyzed requirements and, as a result, were not influenced by greening enforcement.

			Diversification requirement	
			Exonerated or meeting	**Not meeting**
EFA requirement	**Exonerated or meeting**	Farms (N; %)	67,844 (93.3%)	1,710 (2.4%)
		UAA (ha; %)	481,135 (64.6%)	87,058 (11.7%)
	Not meeting	Farms (N; %)	1,989 (2.7%)	1,143 (1.6%)
		UAA (ha; %)	110,234 (14.8%)	65,916 (8.9%)

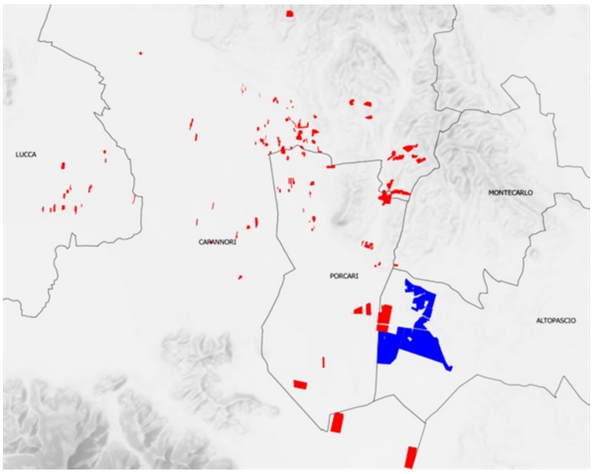
Table 1: Farms and relative UAA exonerated by EFA and crop diversification requirements or meeting them

The above results confirm those presented by Westhoeck et al (2012), who stated that the great majority of EU's arable land already complied with the crop diversification prescription.

Our ex-ante analysis at Tuscany level is confirmed by the first ex-post data on the implementation of greening requirements at Member State level, gathered by the EU (Ecologic Institute, 2017). Many Mediterranean Member States are characterized by a low impact of greening obligations. Indeed Malta, Portugal, Italy and Greece are the countries with the lowest share of agricultural areas that have to comply with at least one of the three greening requirements. This share spans from less than 5% for Malta to less than 50% for Greece, while in Italy it accounts for about 40%. While most of the analyses are at Member States or at Regional level, SIDECAR, by locating farm parcels on the territory, consents to reach a finer scale, that could be very useful when designing actions at local level.

Figure 4 shows that farm fragmentation can highly vary, as is the case of the two farms given as an example, one represented in red, and the other in blue. The degree of fragmentation is relevant insofar as it influences the effects of the greening requirement implementation.

Figure 4: Spatial representation of farmland belonging to two farms (individuated by the colors red and blue) characterized by the same acreage, but with a very different degree of fragmentation and distance among plots.



SIDECAR confirms that compliance requirements based on a-spatial criteria do not allow an adequate fulfillment of the aims pursued by them (Yang et al., 2014). From Figure 4 it is apparent that compliance with greening requirements by farms characterized by various levels of fragmentation may result in a different contribution to the aims pursued by the Policy-Maker, or even in a total failure. This as a result of the impossibility to disconnect the ecological value of requirements from the localization where requirements have to be met. Moreover, the need to comply with greening requirement may furtherly worsen the economic situation of farms characterized by high land fragmentation, by increasing their costs. In their turn, higher management costs caused by fragmentation may well hinder the slow process through which larger and economic viable farms are recovering land parcels that are at risk of abandonment. On the other hand, land fragmentation is usually able to result in crop diversification at territorial level and, consequently, the effects in term of ES provision risk to be negligible.

3.2 Testing SIDECAR as a DSS to support planning: the case of landscape planning in rural areas

The Landscape Plan of Tuscany[8] has classified rural landscapes according to the Abacus of Rural Landscape Morphotypes (Brunori et al. 2014). Rural morphotypes (or morph typologies) have been identified through the overlapping of several informative layers, i.e. anthropic characters such as settlements, size and characteristics of cultivated plots, soil typologies and landuse, hydro morphologic characters (Brunori et al. 2014). The maintenance of an adequate farm income in changing markets and technological scenarios requires changes in farm structures and cultivation and in mechanization techniques. Tuscany Landscape Plan gave a central importance both to agricultural enterprises and to non-professional entities to ensure the maintenance and reproduction of a landscape identity which is commonly shared. This, by avoiding both unjustified restrictions on the exercise of business activities and the indirect promotion of an

[8] Regione Toscana, 2015. Piano di Indirizzo Territoriale con valenza di Piano Paesaggistico.

inefficient use of resources. As a result, to highlight the degree of "viability" of rural morphotypes, not only a structural analysis, but also functional and management analyses were performed. Indeed, rural landscape viability depends also on farm typologies and their attitude towards landscape invariants and environmental protection (Mills et al. 2016, Rovai et al, 2016, van Zanten et al. 2013, Wilson, 2008). Thus, regional bodies in charge of Landscape Plan deemed important to know, for each morphotype, the share of UAA managed by non-professional farms, that do not respond to public aid. This implied the integration of information on landuse and land cover with information about farm typologies (professional or non-professional farms).
Farm strategies can be influenced both by sectoral and planning instruments. Sectoral policies are usually characterized by a voluntary adoption as a response to public aid, and consequently influence only "professional" farms. Vice versa, planning is usually related to the compliance with compulsory standards, that in some case could be opposed (Tempesta, 2014).
SIDECAR was used to single out rural morphotypes whose permanence could be at risk due to the lack of viable farms. Table 2 presents the results obtained by crossing the areals where morphotypes were located and farmland belonging to professional farms.

ID	Morphotypes Denomination	A (ha)	B (ha)	C (%)	D (%)	E (%)
1	Prairies and pastures of high mountain and ridges	24427.36	4857.79	19.89	1.47	0.52
2	Prairies and pastures of uplands	51581.92	18277.73	35.43	3.09	1.94
3	Arable land at risk of re-naturalization in marginal areas	6392.40	3298.94	51.61	0.38	0.35
4	Simplified arable land in areas with low housing pressure	68293.96	43623.67	63.88	4.10	4.64
5	Simple and traditional arable land with plots of medium-large size	136433.36	106331.16	77.94	8.19	11.31
6	Simplified arable land on lowlands or valley bottom	184152.22	108704.66	59.03	11.05	11.57
7	Arable land on lowlands or valley bottom with small size	33273.78	20846.42	62.65	2.00	2.22
8	Arable land in reclamation areas	79876.65	54621.53	68.38	4.79	5.81
9	Enclosed fields of arable land or meadows in hills and mountains	169591.34	89283.92	52.65	10.18	9.50
10	Enclosed fields of arable land or meadows in lowland or at the hills foot	34951.56	21893.44	62.64	2.10	2.33
11	Viticulture	33029.17	25339.45	76.72	1.98	2.70
12	Olive groves	124869.60	55104.49	44.13	7.49	5.86
13	Specialized tree crops associated to arable land	6083.74	2661.19	43.74	0.37	0.28
14	Arable land with tree at the field borders	3437.58	2578.98	75.02	0.21	0.27
15	Vineyards associated with arable lands	83602.71	57883.19	69.24	5.02	6.16
16	Areas with prevalence of arable land and olive groves in hilly areas	126066.21	74808.74	59.34	7.56	7.96
17	Arable land and specialized vineyards and olive groves in lowland or hills foot	47968.62	35008.19	72.98	2.88	3.72

18	Mosaic with prevalence of olive groves and vineyards in hilly areas	148130.61	90678.82	61.22	8.89	9.65
19	Mosaic with crops and woodlands	94459.31	55687.05	58.95	5.67	5.92
20	Complex crops mix mosaic, with small fields in the lowlands or hills foot	91972.40	33899.09	36.86	5.52	3.61
21	Complex and traditional mosaic of crops and parcels in hills and mountains	91746.78	28123.46	30.65	5.50	2.99
22	Horticulture, floriculture and plant nurseries	11523.86	4846.30	42.05	0.69	0.52
23	Small agricultural landlocked areas	14820.10	1553.48	10.48	0.89	0.17
	TOTAL	**1,666,685.22**	**939,911.69**	**56.39**	**100.00**	**100.00**

Legend: ***ID***: numerical code with which each morphotype is designed in the Landscape Plan of Tuscany; ***A***: morphotypes surface; ***B***: surface of parcels managed by professional farms; share (%) of morphotype accounted by parcels managed by professional farms; ***C***: share (%) of each morphotype on the morphotypes total surface; share (%) of the parcels associated to the morphotype on the total surface of parcels managed by professional farms.

Table 2: Analysis of the results of the association process between the 23 morphotypes described in the Landscape Plan of Tuscany Region and the cadastral parcels that are managed by professional farms

Table 2 shows the results of the analysis that associate the 23 morphotypes described in the Landscape Plan of Tuscany and the cadastral parcels that are managed by professional farms, highlighting the most important morphotypes in terms of surface. As regards professional farms, on average they managed about 56% of the total surface belonging to morphotypes, and in six morphotypes this share was higher than 70%. The highest values were associated to the morphotypes of *Simple and traditional arable land with plots of medium-large size* (77.94%) and *Viticulture* (76.72%). It is important to note that for *Olive groves* and the *Complex mosaics,* i.e. morphotypes that strongly characterize the Tuscan landscape, the share of professional farms went down to about 35-45%. Among the main causes of this low incidence there were: a) the interpenetration and diffusion of urban utilizations and b) a higher incidence of farmers who did not consider agriculture as an activity aiming to produce income and, as a result, did not respond to aid. Non-professional farms are particularly widespread in areas of urban sprawl, where agricultural land is more often considered as a real estate asset in view of selling it, rather than as a resource for producing an income. This highlights a higher vulnerability of some morphotypes that characterize the identity of the Tuscan landscape and the need for adequate and better designed actions for maintaining them. Since compulsory standards stated by plans are usually opposed by farmers and the local population, while voluntary actions, such as Pillar II measures, are more acceptable (Tempesta, 2014), the challenge is to find new aid able to involve a larger share of farmers.

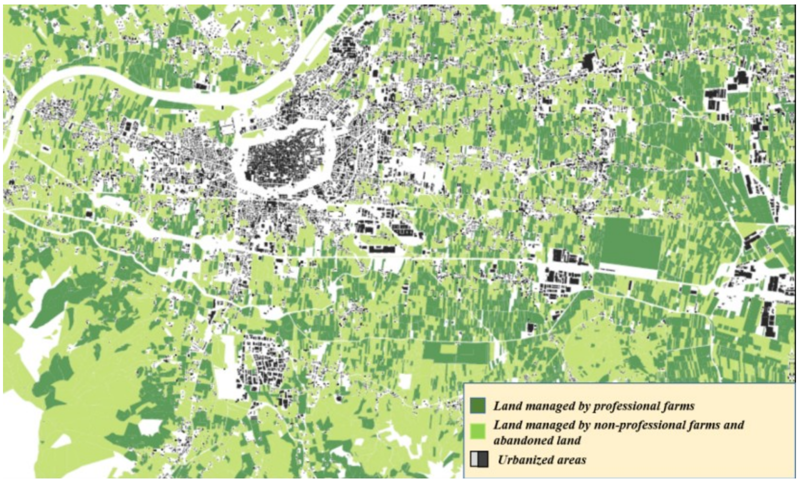
When analyzing 2013 data for the sum of all morphotypes, it emerges that in Tuscany there were about 638,000 ha managed by professional farms vs. about 284,000 ha, managed by non-professional farms. Therefore, farmland abandonment by non-professional farms might well have a very significant impact not only in terms of efficiency of the agricultural sector, but mostly in terms of landscape structure and provision of ESs.

3.3 Testing SIDECAR as a DSS to support design: the case of urban gardening

Open spaces in urban and peri-urban areas are increasingly characterized by phenomena of abandonment and degradation Often these spaces are relics of agricultural land enclosed among artificialized surfaces, because of inefficient low-density urbanization processes. The last case-study explored the relationships between agricultural activities and the resident population in the rural-urban fringe of Lucca, to check for the existence of win-win solutions. SIDECAR allowed to analyze at spatial level the degree of interpenetration between urban and agricultural areas. SIDECAR has been integrated with information about the importance that the local population attributes to ESs provided by open spaces. The opinion of local population was obtained from an "ad hoc" survey focused on the perception of the quality of peri-urban green spaces. 320 people were interviewed either online or "in situ". The aim of the case-study analysis was to study the demand of agricultural spaces by urban population and to study the potential supply by farmers to test if ES provision, through diversification of farm activities, may represent a strategy for ensuring farm survival, while at the same time increasing the well-being of local population.

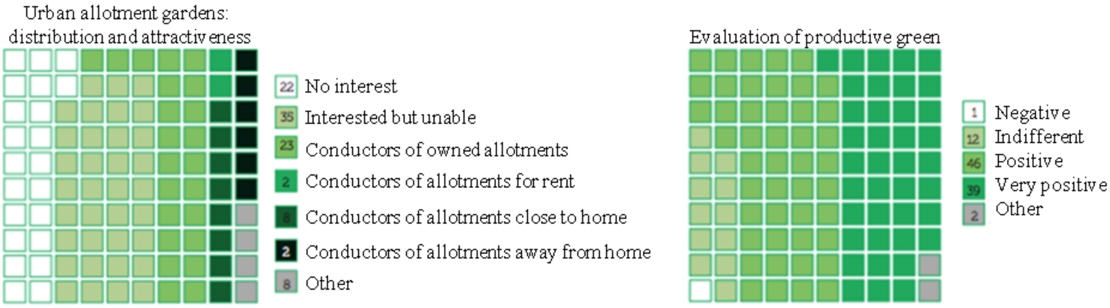
Figure 5 shows the rural-urban fringe around Lucca. In this figure, professional farms are identified by dark green areas, non-professional farms or other agricultural uses are identified by light green areas, while urban areas are in black. Interpenetration among agricultural land and urbanized areas clearly emerges from Figure 5.

Figure 5 – Agricultural and urbanized areas in the rural-urban fringe around Lucca town (Tuscany)



In this case the use of SIDECAR had to be integrated with an "ad hoc" survey that focused on the perception of the quality of peri-urban green spaces (figure 6) and was conducted on eight "case-study areas". Perception was analyzed, among others, by inquiring the degree of appreciation of the several productive functions that could be associated to urban green spaces (social vegetable gardens, community gardens, multifunctional farms, etc.) and the degree of interest in having some space where to practice the hobby of growing vegetables. In the first case, more than 80% of people interviewed showed a significant interest for a higher presence of productive green spaces while, in the second case, 35% of interviewed people said that they would like to have a small plot of land for growing their own vegetables.

Figure 6 – Some results of the survey conducted in the eight case-study areas of Lucca town (Tuscany)



The research has been conducted in accordance to the approach of 'Rurality Standard' (Rovai and Fastelli, 2013), defined in analogy with "Urban Standard", that in town planning represents the minimum level of public space availability to which each inhabitant of a specific urban sub-area should be entitled to in order to make a settlement sustainable.

After the survey phase, the following step was to define the dimension and localization of the operational actions, taking into account the urban fabric.

According to the concept of Rurality Standard, it has been hypothesized a need of space ranging from a minimum of 15 m^2 to a maximum of 30 m^2 per inhabitant to be utilized as urban vegetable garden. The hypothesis of a range stems from the awareness that in designing these spaces it is possible to start from different approaches; projects mainly aiming to satisfy productive needs require minimum space, while projects mainly aiming to create or promote social networks among people utilizing these spaces, require larger areas. Thus, if in the first case, the needed space (15 m^2/inhabitant) has the prevalent functions of production and of complement to production (access ways, storage sheds for tools, etc.), in the second case (30 m^2/inhabitant), besides the area to be used for production, it is necessary to consider also some areas aiming to improve relationships, e.g. areas for recreational and community activities such as meeting areas, kindergartens, etc. On the base of the data resulting from the survey, the amount of population living in the case-study areas and the share of population potentially interested in having a vegetable garden, it has been possible to estimate the demand of spaces to be used as urban vegetable garden for each of the eight case-study areas (see Table 3).

Case-study areas	Interviewees who already have a vegetable garden (%)	Total population	Share of population interested in having a vegetable garden (%)	Spaces needed for vegetal gardens (ha) (hypot. 15 m^2 / inhabitant)	Existing urban green spaces (ha)	Urban green spaces included in planning tools (ha)	Parks (ha)
1. Acquacalda	33.33	2353	36.11	1.27	1.30	0.57	0
2. Alle Macchie	41.46	1586	29.27	0.69	0.07	0	63.15
3. Nottolini	25.71	3232	42.86	2.04	1.99	0.75	7.36
4. Pontetetto	50.00	1721	26.67	0.67	3.92	1.63	3.08
5. Santissimannunziata	48.48	5235	36.36	2.77	4.70	2.36	0
6. Sanvito	27.78	3872	44.44	2.58	1.20	0.32	0
7. Via Einaudi	41.67	4733	36.11	2.56	0.18	0	0
8. Vitricaia	51.85	663	25.93	0.25	0	6.6	3.74

Table 3 – Comparison between surveyed and estimated data as regards the impact of the demand of urban vegetable gardens on the total of green urban areas

As shown by Table 3, the spaces needed to meet the demand of vegetable gardens represent a large share in comparison both to the existing urban green areas and to the green urban spaces included in planning tools, whose amount results to be insufficient in six of the eight case-study areas. The Municipality should verify if in the area there is some abandoned land that could be rehabilitated and might also consider the option of buying private land either included or in proximity to settlements. From the above case-study analysis, it emerges that - to implement these innovative actions - it is necessary not only that farms have a specific localization, but also an adequate support from the part of public administration. This with the aim to start and develop local food networks by helping to bring together the demand by private citizens, schools, etc. and the supply by local farmers. Indeed, there is the need to promote a cultural change among farmers, who have a very traditional vision of agriculture, mainly referring to global markets and economies of scale.
In summary, a good design should start from the knowledge of the socio-demographic structure of the population living in the different districts or areas and make a careful analysis of the different perceptions emerging from public opinion surveys. These surveys are crucial tools in increasing the degree of acceptance of works and, consequently, in increasing the chance of success of the projects.

3.4 Final remarks on SIDECAR and its usefulness

The intrinsic characteristics and the potential interactions of SIDECAR with disciplinary and institutional contexts are summarized below according to the matrix pattern of the SWOT analysis (Table 4).

Strengths	***Weaknesses***
▪ Ability to integrate various thematic databases through shared primary keys ▪ Ability to process aspatial information giving a geo-referenced dimension to aspatial data	▪ Information gaps as regards territorial bio-physical data ▪ Large amount of data to be managed simultaneously
Opportunities	***Threats***
▪ Population increased awareness and sensitivity as regards the issues of reproducibility and management of land resources ▪ Budgetary constraints on public spending due to the prolonged economic crisis; these constraints ask for the efficient use of public financial resources ▪ Continuous developments of GIS technology ▪ Increased availability of Open Data	▪ Difficulty in finding updates for some sources or updates available only ad discrete and distant times (e.g. ARTEA, ISTAT) ▪ Lack of foresight on the part of Policy Makers

Table 4 – SWOT analysis

Some critical remarks on the use of SIDECAR and on policy issues can be elicited from the case-study analyses presented in the previous sections. The first remark relates to the debate opposing common rules, considered as more objective, to tailored instruments, often at risk of subjectivity. The ex-ante analysis of the impact of greening enforcement confirmed that the EU choice to apply the same rules to all Member States resulted in a great variety of “costs” for farmers and “benefits” for the environment. In addition, greening may have even resulted in worsening the situation of farms which are characterized by low economic performance, yet are environmentally relevant in areas with natural constraints and high fragmentation. In this case, the analysis allowed us to determine the areas that, for territorial and farm characteristics, require specific intervention to counteract the negative effects of greening.

SIDECAR has also been used to assess programming instruments ex-post, in the specific Less Favored Areas (LFA) measures within Pillar II (Fastelli et al., 2017). Lately, the scientific debate has focused on the new criteria for the delimitation of areas with natural constraints (van Orshoven et al., 2014). Vice versa, previous studies on Less Favored Areas (Cooper et al., 2006) had also analyzed how financial resources had been distributed according to type of territory or farm typologies. Results of the ex-post analyses performed using SIDECAR (Fastelli et al., 2017) showed that aid distribution in one Tuscany LFA was not consistent either with the degree of natural constraints or with farm typologies. Indeed, farms that were able to intercept the higher share of financial resources were not those more in need of aid or with a higher degree of multifunctionality.

It would, therefore, be desirable that the use of this approach at different scales becomes part of the body of knowledge necessary for the preparation of the Regional Development Programme in order to reduce its distorting effects on the competitive dynamics of farms. This would also lead to an improvement of the “environmental performance” of agro-ecosystems. For instance, SIDECAR could be used for ex-ante analyses of the impacts on aid distributions among different farms and territorial typologies which derive from policy maker choices in aid priority attribution (e.g. minimum acreage, farmer age, etc.).

The analyses performed according to a cadastral parcel and farm approach allow for a significant improvement when compared to an approach based on the description of land use and its evolution. This simplified approach is still currently used inside the knowledge framework of spatial planning tools, although, from certain points of view, it is misleading in explaining the evolution of agriculture and crops in a specific territory. Data gathered through the agricultural Census, if not integrated with other information, are not able to exploit all their potential in terms of communication. Vice versa, when merged with other information as carried out in SIDECAR they lead to an improvement in the knowledge framework.

While sectoral policies are addressed to professional farms, insofar as they respond to policy aid, non-professional farms may be important for territorial custodianship and ES provision. As a result, they deserve a greater attention.

As regards non-professional farms, the analysis of the planning case confirmed their important role in terms of maintenance and protection of landscapes that are highly valued both by the local population and at an international level, as in the case of UNESCO heritage sites (Rovai et al., 2016). SIDECAR allowed us to assess the importance of these farms in terms of the territory they manage. The important role of hobby or style farms is recognized by the Tuscany Region. However, as these farms often do not respond to policy aid, the issue arises on how to ensure their survival and positive role. In some cases, the problem may be caused by a lack of information or of technical competence. These obstacles could be overcome through adequate services or through a more user-friendly attitude on the part of public officers responsible for aid applications and processing. If this approach is not able to solve the problem, it would be important to understand whether new policy instruments are needed or whether it would be better to promote a cultural change among farmers (Mills et al. 2017). The need for a cultural change among farmers emerged also from the third case study, which showed that the provision of innovative services to the urban population may improve farm viability and quality maintenance of relics of intercluded farmland, while contributing to community well-being. The analysis of the case at design level showed that a solution for an adequate supply of ecosystem services could be the conversion of some existing public spaces or private spaces into new forms of public spaces, modeled through the types of urban agriculture. Farms located in peri-urban areas are often characterized by greater difficulties due to the constraints in conducting traditional agricultural activities and therefore, in continuing their business. Consequently, they need to have the ability to identify new business activities, such as the conversion of part of their land into urban gardens, the management of abandoned land, etc. These activities may represent a significant income integration.

In present times, the definition of the choices for sustainable planning need to consider the relationship of co-production which exists between nature and the use of resources. This relationship should be developed through a process which actively involves many parties operating in urban and rural areas. In this sense, a good example for the construction of a useful interaction between urban and rural areas is the creation of an adequate supply of rural products and services for citizens (local food, agro-kindergartens, educational farms, etc.).

The analyses that have been carried out have allowed us to present an original territorial framework, where farmers are still the main actors in defining landscape features and in bringing about territorial transformations. This framework may be very useful for drawing projects that have to be based on shared and collective strategies at a local level.

The above case-study analyses indicate how the improvement of the knowledge basis achieved through data spatialization and the introduction of farm characteristics may consent one to draw more effective and efficient policies. This confirms the need for spatially based approaches, where the natural characteristics of a landscape are combined with the socio-economic and cultural drivers that affect its change (Pinto-Correia and Kristensen, 2013).

From this point of view, one of the most important features of SIDECAR consists in its ability to integrate information from different disciplines and to make it more comprehensible for policy-makers and stakeholders. This, in its turn, can facilitate the debate among scientists, professionals, policy-makers and the local population.

4. Conclusion

The relation between Research and Policy is frequently debated in the scientific community. Science provides an irreplaceable basis for policy-drawing; however, collaboration among scientists, policy-makers and local populations is not always fruitful. Indeed, as related by Beunen and Opdam (2011), scientific analyses sometimes are not accepted by policy makers. In this framework, SIDECAR does not provide by itself a solution to the issue of adequately drawing and implementing programming, planning and design instruments, since decisions for policy tools are a matter for policy-makers. Nevertheless, it can provide valuable support for the knowledge and management of the rural and peri-urban areas, especially as regards spatial and management characteristics of farms. This implies the need to continuously renew and improve data availability with the aim of enhancing the knowledge at the basis of rural development and territorial government. Indeed, an improved ability to manage a territory means being able to read its transformations to identify appropriate intervention policies, with the aim to prevent negative impacts and to encourage positive outcomes in development.

When developing effective territorial policies, it is critical for the decision maker to have adequate analyses which allow for an integrated approach among sectoral policies (e.g. urban, social, economic and environmental policies) drawing tools that respond to common principles and objectives in a coherent and synergistic way.

SIDECAR aims to provide a DSS that can be accepted by policy-makers and regional officers in charge of drawing policy instruments, by overcoming the diffidence that sometimes arises when important decisions have to be made on the basis of knowledge which is not properly understood. Despite its scientific approach, SIDECAR can be managed by public officers and consultants for basic applications or scenario simulations, thus allowing for its active use outside of research institutions. In this framework, it is proposed as a useful information and knowledge tool to be used to improve quality both in the drawing up and in the assessment of programming and planning policies as well as in the design phase. Its integrated multidisciplinary approach allows for an improved horizontal coordination between sectoral and planning instruments. Vertical coordination is improved by the use of the same knowledge basis for analyses at different administrative levels since for most informative levels local territories can be framed in larger contexts in order to maintain a vertical coherence.

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Reviewer 1

In my opinion, the paper can now be accepted for publication.
Please consider the following few remarks:

Page 8, 3rd paragraph from the top: check the word “aroused”: arose? issued? Resulted?

Page 13, Table 2, Legend ID: columns D and E are not defined

Page 13, last paragraph: check the term “went down”: decreased?

Page 19: 4th line of “conclusions”. Check the word “related”: reported?

EDITOR - please make these corrections when you receive proofs for checking.

Note of Authors:
Further corrections, mainly related to References/Bibliography, have been made when checking proofs