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Preserving cultural heritage by supporting landscape planning with quantitative predictions of soil consumption

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ABSTRACT

Landscape preservation in Italy is a major issue in national cultural heritage conservation policies. Urban settlements growth is among the most threatening factors for the correct landscape preservation. Such phenomenon may result in corrupting the correct landscape-system functioning, particularly when the development occurs without precise planning prescriptions. Land-use/cover evolution dynamic is a subject widely and thoroughly investigated, especially concerning consumption of natural and other lands due to anthropogenic activities. This paper focuses on a region in southern Italy, where soil consumption is known to represent a urging matter of concern. However, although the negative impacts of soil consumption are well known, to our knowledge there are no case studies presenting a precise quantitative assessment of the intensity of such phenomenon for the region of interest. Furthermore, this study aims at forecasting the development of urban settlements through the application of the cellular automata model SLEUTH; the case study concerns the Municipality of Altamura (Apulia region, Italy). Results highlight how current landscape preservation instruments alone cannot ensure a reduction in soil consumption phenomenon and how urban areas expansion is incompatible with a correct landscape conservation in the study area.

1. Introduction

Landscape values are among the main foci of the recently revitalised scientific and cultural debate on environmental sustainability. In fact, although for long time the scientific community investigated and tried to warn about the deleterious influence of anthropogenic activities on environmental and climate change, is only recently that this urging problem was echoed extensively. This was also due to the United Nations that brainstormed about the (partially unsuccessful) Millennium Development Goals (MDGs) [1,2] and improved them through the definition of the Sustainable Development Goals (SDGs) by the UN to be achieved by the year 2030 [3]. Furthermore, media attention on environmental issues was also due to the intervention of Pope Francis who with his Encyclical Letter "Laudato si" highlighted how the current development model based on the intensive use of fossil fuels is the major responsible for land use change process leading to soil sealing, progressive overconsumption of natural resources threatening Earth's resilience, and depauperation of the values of landscapes as a whole [4]. Nevertheless, also the intense weeks of negotiation that ended with the historic agreement at the Conference of Parties on climate change (COP21) in Paris in December 2015 helped echoing this topic even more.

Therefore, the identification of landscapes as part of the identity of a territory is of great interest. Cultural heritage preservation is a top priority for Italian legislation. Art. 9 of Italian Constitution reads: "Italian Republic promotes culture, scientific and technical research development; it preserves National landscape and historical and artistic heritage". The Ministry of Education with Bottai's laws started the first Italian historical goods preservation act. The current statement is DLgs 42/2004, "Codice dei beni culturali ed ambientali". Art. 1 of the previous DLgs states that "[...] preservation and valorisation of cultural heritage contribute to preserve the memory of the national community and its territory, and to promote culture development". There is a biphasic logic: a will of goods valorisation and use is coupled with a constraint preservation. Then the article continues: "[...] administrations promote cultural heritage fruition and valorisation". Finally, comma 5 imposes a very interesting constraint to property right, since "private owners of such goods must always provide to their conservation [...] private owners must guarantee goods fruition". Article 2 describes the composition of cultural heritage. This "is made up by cultural

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and landscape goods". The law defines landscape as "the territory expressing identities deriving from actions and interrelations of natural and human factors. Landscape is preserved by the State, Regions [. . .]; landscape preservation aims to recognise, preserve and safeguard cultural values which it expresses". Categories of landscape goods are defined according to art. 134. They are:

- goods defined by law;
- goods defined according to a concertation process;
- goods defined by landscape planning instruments.

Goods preserved by the law are coastal territories within 300 m from the shore line, lakes and their 300 m respect zone, rivers and creeks including a respect band of 150 m, glaciers, national and regional parks and reserves, wetlands, mountains for the part exceeding 1200 m a.s.l., volcanoes and archaeological areas. The latter undergo a double preservation, since they are also part of properly said cultural goods.

This paper considers soil resource as part of the landscape, and therefore of the cultural heritage. Soil is not directly protected by Italian legislation, even though the need to protect it is now a belief shared by the scientific community. The European soil Charter (1972) [5], in fact, states that "soil is one of the most precious human goods, because it allows plants, animals and human beings to live on the earth surface". Soil can be compared to a living organism, continuously changing, which is the necessary base for all biosphere biological activities. Agricultural and zoo-technical production – and therefore human food production – strongly depends on soils. The increasing and constant growth of world population was made possible only through the introduction of intensive cultivation technologies, which aimed at maximising the exploitation of soil potential. Monoculture, i.e. growing of a single plant species, on one hand ensures more food production, but on the other hand it implies high environmental costs, e.g. a large use of petroleum derivatives for machinery moving, fertilization and crop defence from parasites. However, still nowadays, the main threaten for the agri-food sector is urban areas expansion, which mainly occurs on agricultural areas. Thus agricultural areas are pushed further away often replacing soils of poorer quality; this is a major concern, since having less fertile land may means weakening the production potential.

Urban areas growth processes are a top threaten for the correct safeguard of landscape goods. Despite the presence of landscape preservation instruments, the more or less regulated growth of settlements tends to affect landscape and ecosystems configuration, even when it does not directly occur in areas under preservation. Soil preservation is therefore an important issue [6]. Soil is a non-renewable resource and, like water and air, it has to be considered a common good. Soil degradation can be caused by many factors (e.g. erosion, organic matter decline, compacting, landslides, floods, and desertification). Only in recent times, the attention has been focused on the main threat of soil: soil sealing. Consequently, the construction of new residential areas, industrial zones, trade and services centres, roads and other infrastructures, is a major problem because it causes soil sealing [7–11]. A sealed soil loses its biological value, becoming unable to absorb and filter rainwater [12]. Excessive urbanization, especially when it is due to ineffective urban planning, generates a strong fragmentation of natural and agricultural landscape [13–18]. These issues are typically included within the definition of soil consumption, a term which describes the land cover transition from natural to artificial. The European research LUCAS allows to compare general characteristics of land cover in 27 European countries (Fig. 1). In Italy, the portion of territory with artificial cover accounts about 7.8% of the total, while EU average reaches roughly 4.6%. Italy is ranked at the fifth place among the countries with the highest proportion of artificial cover, after Malta (32.9%), Belgium (13.4%), the Netherlands (12.2), Luxembourg (11.9%), and slightly before Germany, Denmark and the UK [19] although it is one of the biggest. Analysing in detail artificial cover, distinguishing between residential areas, services and other artificial areas such as infrastructures and annexed areas, it is clear that in the 27 EU countries the value of residential areas and services is about 1.5% of total area, approximately one third of the artificial surface, while other artificial areas represent the 3.0% of the territory. In Italy, there are 7.8% of artificial areas, with 2.7% residential areas and services and 5.1% other artificial areas.

The "Roadmap to a Resource Efficient Europe" delineated by the European Commission (2011) in Paragraph 4.6 defined the target for 2050 as stopping the use of new areas for location of new neighbourhoods. This phenomenon has been widely discussed in Italy without achieving considerable results. Italian national legislation in the field of soil consumption, and more generally in territory governance, is unfortunately obsolete and unable to tackle the problems of modern urban/rural landscapes. However, several legislative drafts, concerning territorial government, are currently deposited at the Chamber of Deputies, and they deal, in a more or less pronounced way, with soil consumption. Expressing a judgment about the quality of such legislative drafts is not the purpose

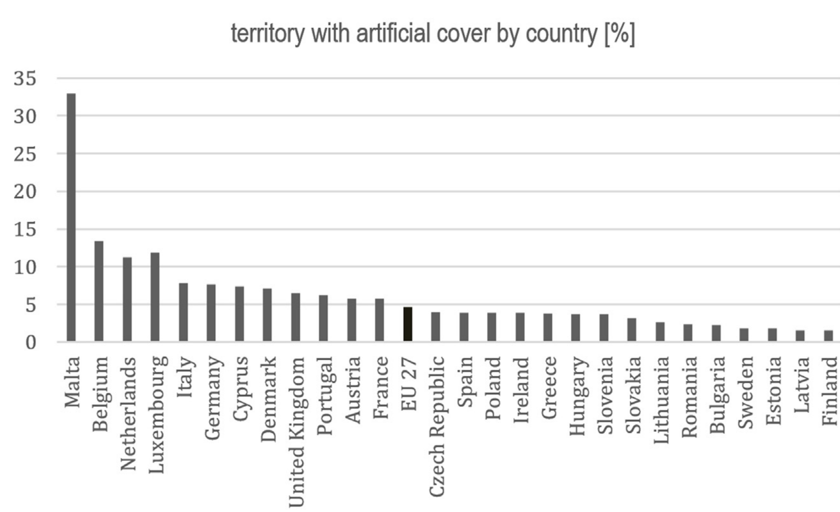

Fig. 1. Territory with artificial cover by country, LUCAS survey, 2012 (percentage incidence on total area).
ISTAT elaboration on Eurostat data.

of this paper, nor is the discussion of their potential effectiveness; however it is relevant to underline that almost all legislative propositions identify systematic land-use change monitoring as a key step towards soil consumption reduction ecosystem protection and sustainability goals achievement. Is in this context, that the application of the SLEUTH model may result in a proficient support for land-use planning and policies; this methodology, based on cellular automata, has been already successfully employed and tested worldwide.

This paper focuses on an application of a predictive model of urban areas expansion; the goal is to quantify and spatially locate the probability of soil loss due to the land use dynamics fuelled by built up areas expansion in order to support policies aiming at fostering landscape preservation. The section "Materials and Methods" describes in details the rationale behind SLEUTH and how the predictive process works. Furthermore the operational steps, needed to build a robust SLEUTHing application and to assess the accuracy of its projections, are also described. With the section "Result and Discussion", we aim at presenting the application of the model to a case study in Southern Italy, highlighting the complex relationship between urban growth, and habitats and landscape fragmentation, and why it represent such an interesting case study. Nevertheless, in the same section a panorama of advantages, limitations and potential implementations of the application are also discussed. Finally, the section "Conclusions" highlights and summarizes the elements that make useful forecast of land use change as a tool to support planning choices.

2. Materials and methods

Many issues in the context of spatial planning are studied through mathematical models. The literature recognizes several groups of geo-computational methods applied to modelling of urban phenomena [20]. Spatially explicit models developed to the purpose of analyzing land use and land cover change (LUCC) generally consider landuse dynamics as the propagation through space and time of specific phenomena. The main families of models are the agent-based model (ABM) and cellular automata (CA) models [21]. LUCC models found over the years large application in the field of urban and territorial planning. Simulation models allow to improve the cognitive framework to support planning choices and to assess in advance the impact in terms of transitions between land use classes of regulation recommended by planners.

In this paper, we aim at presenting an application of on predictive model based on CA. CA models guarantee a high resilience to external shocks, and are therefore particularly suitable for applications aimed at monitoring the evolution of spatial phenomena in a dynamic fashion.

Jhon von Neumann and Stanislaw Ulam firstly developed CA rationale in 1940 [22]. A CA is a mathematical model able to reproduce the system evolution in time and space through a set of rules, expressed in graphs or tables that describe behavioural aspects. These are very useful tools in the analysis of complex systems characterized by behaviour with strong non-linearity.

There are also other types of models usually used to simulate similar phenomena; in particular, similar features can be partially found in the so-called agent-based models. Both the CA and the agent-based model in fact represent the space as an ordered set of cells. However, while CA models are characterized by a bottom-up approach in which the user defines the criteria regulating the dynamics of the system and its space, the agent-based models generally establish a top-down approach, in which space is identified only as a viable network, while the phenomenon analyzed is simulated by rules attributed to agents that can moves within the space. This distinction makes the CA more appropriate for applications in the field of LUCC, because land parcels do not move but do change state; while agent-based model found broad applications in other areas, such as simulations of traffic or fluxes.

In the last 30 years, many researchers have focused their studies on the implementation of CA models to investigate problems in the field of spatial planning. The basic theoretical notions are mainly attributable to Couclelis [23] and Batty [24]. Applications related to simulation of the development of urban infrastructure are attributed to Semboloni [25], while models aimed at the analysis of urban growth have been developed by Clarke et. al. (1997), [26], Batty and Xie [27] and Xia and Yeh [28]. Among the LUCC and urban growth analysis models based on CA, SLEUTH is one of the most widely used and discussed in literature. One of the advantages of SLEUTH is that it can simulate proficiently urban growth, but it can be also used to model multiple land-uses transitions at the same time. Moreover, it is simple and intuitive too because all inputs are needed in a thematic map form and all outputs are spatially explicit and fits the same lattice of inputs [29].

2.1. SLEUTH model

The name is an acronym of the input variables needed to run it: Slope, Land Use (historical series of landuse of the same region), Excluded (i.e. the set of soils to be excluded totally or in part by transformations provided by the model), Urban (i.e. urbanized areas), Transportation and Hill shade. To date the usefulness of this model application is proven not only in the identification of future development trends, but also in understanding the factors that have determined the growth of urban settlements in the past [30,31]. The SLEUTH model is an integration of the Urban Growth Model, developed in 1998 by Keith Clarke, with the Deltatron model. The first one simulates only urban growth, while the second allows the assessment of land use transitions matrices [32,33]. SLEUTH structure reflects the original first model. Particularly, SLEUTH is a self-modifying model, based on Moore neighbourhood and Monte Carlo simulations. The basic time unit adopted by SLEUTH is the cycle of growth, conventionally equal to 1 year. For each time unit, the module "Urban Growth Model" performs four types of analysis of urban transformations: spontaneous growth, new spreading centres growth, edge growth, road-influenced growth. Calibration uses four historical maps of urban extent to define the coefficient that influence the relative influence among the growth rules. Growth rules used by the model are of huge interest, as they allow to analyse some of the main threats generated by the expansion of urban areas on the cultural and environmental heritage, and therefore on soil resource.

Spontaneous Growth describes the possibility that a generic cell of the grid can spontaneously be urbanized. New Spreading Centre Growth is the process that determines for each of the cells spontaneously urbanized, according to the result of the previous step, the probability that it will become an urban centre, able to spread as long as you have at least two cells developable in the neighbourhood of the cell object of analysis. The increase of artificial surfaces as a result of the simulation of the phenomena described by these stages allows assessing the impacts on ecosystems and cultural services due to land fragmentation.

Edge Growth defines growth of suburban areas, considering the expansion of centres on the edge generated by the new spreading centre growth, or already existing in reality or identified from previous application cycles of the model. Environmental costs of this type of growth are mainly due to the abandonment and degradation of agricultural land bordering the city, as well as increased costs and pollution associated with the need to ensure the functioning of basic urban services, such as mobility and energy supply in settlements characterized by high urban sprawl.

Road-Influenced Growth is the most complex phase of simulation. Firstly, some recently urbanized cells are selected and the closest streets are identified. The maximum radius distance within which streets are searched is defined as a function of the parameter defined through the calibration. If within that radius a street is found, the model poses an urban temporary cell next the closest road cell. This temporary urban cell walks randomly along the road structure. A cell nearby the one where the walk on the road ends is then considered as a new urbanized cell, and therefore its surrounding cells are the considered developable units; consequently, one or more of these cells will be randomly selected and urbanized. This analysis highlights the important role played by the transportation network in generating a dispersed settlement patterns. The methodology presented in this paper is profoundly influenced by how SLEUTHing application work; although a brief description of the model rules, rationale, and operative framework is given, the aim of his work is to investigate urbanization impact on surrounding natural ecosystem and cultural heritage, hence for a thorough revision of the most updated state of the art about SLEUTH the reading of the review elaborated in 2013 by Chaudhuri and Clarke is suggested [34].

2.2. Kappa coefficient of agreement

SLEUTH model needs maps of urban area location as input on at least four dates. However, the quality of the calibration model can be tested only if five or more urban maps are available. In this case, the model can be calibrated using the four eldest urban maps as input data to get a simulation of the fifth available map. Thus, the simulation map can be compared to the available reference map. This strategy, rather common in several applications of cellular automata based models [35], allows to test the real model capability of interpreting spatial phenomena concerning settlement evolution within a territory.

Accuracy may be evaluated by means of Kappa Coefficient of Agreement [36]. A contingency table with simulation map values S in rows and soil use map values A in columns must be built to calculate such value. Elements along matrix diagonal indicate the number of cells belonging to the same soil use class, both in actual and simulation maps. Kappa gives a numeric value evaluating correspondence rate between the two maps. Its calculation is based on the real concordance degree, i.e. the observed agreement, and the expected one, i.e. the expected agreement [37]. Once defined the possible soil use classes, $i = 1,2,..,c$, the generic element of A, a, and the generic element of S, s, it is:

$$P_o = observed\,fraction\,of\,agreement = \sum_{i=1}^{c} \left[p(a=i)^s = i\right]$$

$$P_e = expected\,fraction\,of\,agreement = \sum_{i=1}^{c} \left[p\,(a=i)\cdot(s=1)\right]$$

$$P_{\max} = maximum \quad fraction\,of\,agreement = \sum_{i=1}^{c} \left[\min\left(p\,(a=i)\,,\,\right]\,p\,(s=i)\right)$$

Kappa is therefore evaluated as:

$$Kappa = \frac{P_o - P_e}{1 - P_e}$$

Kappa may also be interpreted as the product of two factors: $K_{Location}$, measuring spatial position agreement of categories between the two maps, and $K_{Histogram}$, measuring the quantitative agreement between the maps (Hagen, 2002). The two values are defined as:

$$K_{Histogram} = \frac{P_{\max} - P_e}{1 - P_e}$$

$$K_{Location} = \frac{P_o - P_e}{P_{\max} - P_e}$$

The analysis of these two values may give further information about the quality of the obtained simulation map. Despite the decomposition of the Kappa some paradoxical situations may also occur. A high level of agreement from the quantitative point of view may not be supported by a high Kappa value, which would conversely seem to not indicate particularly significant agreement values. This distance between the two values is due to the dependence of the Kappa by the amount of observations within each category [38]. This limit is reflected generally in spatial level in low values of $K_{Location}$, especially in situations of binary maps in which from the quantitative point of view a category significantly exceeds the other. In these situations, low values of $K_{Location}$, not necessarily correspond to a general lack of correspondence between the two maps considered.

2.3. Study area and data collection

Despite a growing attention in Europe and in Italy to soil consumption phenomenon, in southern Italy, there is almost a total absence of studies on measuring the phenomenon extent and on analysing its possible future developments. In order to close this gap, an application of the SLEUTH model has been developed for the municipality of Altamura (Apulia, Italy) (Fig. 2). The purpose is to demonstrate the applicability of this methodology also in typical southern Italian urban environments, stimulating the implementation of further studies and researches.

Altamura municipality is interesting within the context of the Apulia region, because with its 70,688 inhabitants is the eighth municipality in the region for population. Moreover, Altamura is the thirteenth municipality in term of territorial extension in Italy. Population dynamics, studied through national census data of Italian Institute of Statistics (ISTAT), show the vitality of the town. The population grew from 57,874 inhabitants in 1991, to 64,167 in 2001, to 69,529 in 2011 and 70,688 in 2014.

Population growth is easily explained by the socio-economic dynamism generated by the proximity with the city of Bari, the regional capital and important urban centre in southern Italy. The City of Altamura, in fact, is part of the metropolitan city of Bari, the new Italian local authority that from 2015 replaces the Province of Bari.

In order to define urban areas at different dates and to use them as input data in SLEUTH model, an analysis was conducted on the historical evolution of built-up areas in the municipality of Altamura. This analysis was developed using the cartography at 1: 25.000 scale realized in 1954 by the Italian Military Geographic Institute (IGM), orthophotos at three dates (1985,1996, 2011) available in Web Map Service (WMS) format on the Italian National Geoportal (www.pcn.ambiente.it), and the cartography at municipality scale (2006) available on Apulia Region Geoportal.

Time series show a constant increase of built-up areas, with an overall increase of 84 hectares from 1954 to 2011 (Table 1).

The increase in built volumes has continued even between 2005 and 2011: in this period 23 new hectares have been urbanized. This tendency is in contrasts with the national trend, where in the period 2005-2006 a significant reduction in building sector has been registered, mainly as a result of the effects of the global economic crisis (Fig. 3).

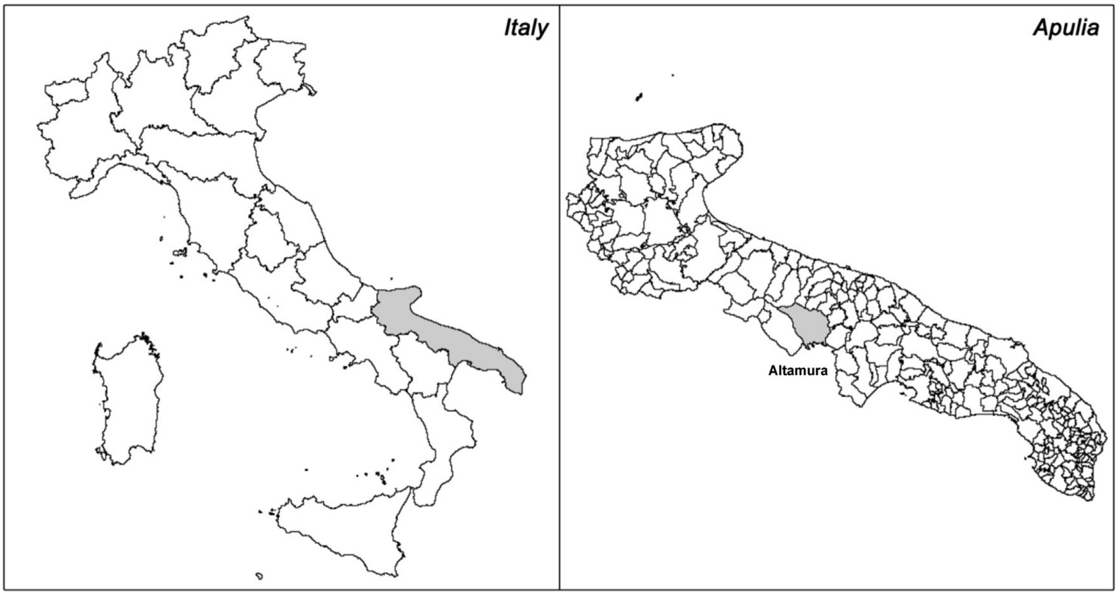

Fig. 2. Left: location of Apulia Region (highlighted in grey); right: location of Altamura municipality (highlighted in grey) within Apulia region.

Table 1
Hectares of built up and unbuilt areas at different dates.

	1954	1985	1996	2005	2011
Unbuilt [ha]	42,466	42,479	42,447	42,405	42,382
Built-up [ha]	261	248	280	322	345

The dynamism of the construction business sector in Altamura municipality well represents the trend of the whole Apulia. This region, although characterized by a high natural and landscape value of soils, is one of the most soil consuming Italian regions (ISPRA, 2015).

Recently, Apulia Region adopted the Regional Territorial Landscape Plan, locating landscape goods, in order to preserve territorial landscape values. Specific prescriptions are defined and viable interventions and incompatible actions with landscape characteristics of an area are described for each landscape goods. Landscape goods are located in Altamura municipality, also. Wooded areas where vegetation transformation and removal interventions are not allowed are located north-east and north-west of the Municipality. The same areas are almost entirely part on National Park of Alta Murgia. Archaeological areas and public interest areas are more scattered within the territory. Furthermore, rivers, creeks and soils within 150 m around are classified among landscape goods. Finally, the Municipality is almost entirely included in Special Protection Zones (ZPS) and in a Site of Community Interest (SIC). Such areas are defined according to Directive 92/43/CEE, called “Habitat”, and are part of Natura 2000 network, i.e. a set of areas which must be preserved to protect ecological habitats and characteristic landscapes of a place. Preservation standards of Natura 2000 network do not prevent land use transformation, but they subordinate every intervention to the release of a specific authorization following the verification of environmental incidence of performing works. The complex environmental features that distinguish the territory of the Municipality of Altamura define a complex scenario. The analysis of the phenomenon of soil consumption in this context becomes of primary importance, because of the sharp contrast that is generated among the marked environmental features of the landscape of the Municipality and the strong pressure from settlements generated by dynamic economic and demographic processes (Fig. 4).

Italian political context shows a growing attention to soil preservation, promoting an interest towards the evaluation of effects of Landscape Plan measures on urban settlement expansion in Apulia.

Input data preparation and calibration are the most sensitive phases of SLEUTH model application. As described in the previous paragraphs, the use of SLEUTH requires the use of several input information (Table 2).

Table 2
Data and data sources adopted in the construction of input.

Factor	Input data\source
Slope	Slope/Cartography
Excluded	Rivers, streams and waterways/Law 2004/42 Art.142
	Territories covered by forests and woodlands/Law 2004/42 Art.142
	Civic uses/Law 2004/42 Art.142
	Archaeological Areas/Law 2004/42 Art.142
	Areas with significant public interest/Law 2004/42 Article 136
	Respect area of the network of tratturi, the historic and cultural sites and areas with archaeological interest/Regional landscape plan
	Wetlands/Regional landscape plan
	Grid connection of regional ecological network/Regional landscape plan
	Sinkholes, geological sites, caves/Regional landscape plan
	Shrub formations/Regional landscape plan
	Natural pastures/Regional landscape plan
	Buffer zone of forest areas/Regional landscape plan
	Hydrogeological constraint/Regional landscape plan
Urban	Urban area at 1954/IGM cartography
	Urban area at 1985/Orthophoto national geoportal
	Urban area at 1996/Orthophoto national geoportal
	Urban area at 2005/Regional cartography
	Urban area at 2011/Update regional cartography
Transportation	Transport infrastructures 2005/Regional cartography
Hillshade	Hillshade/Cartography

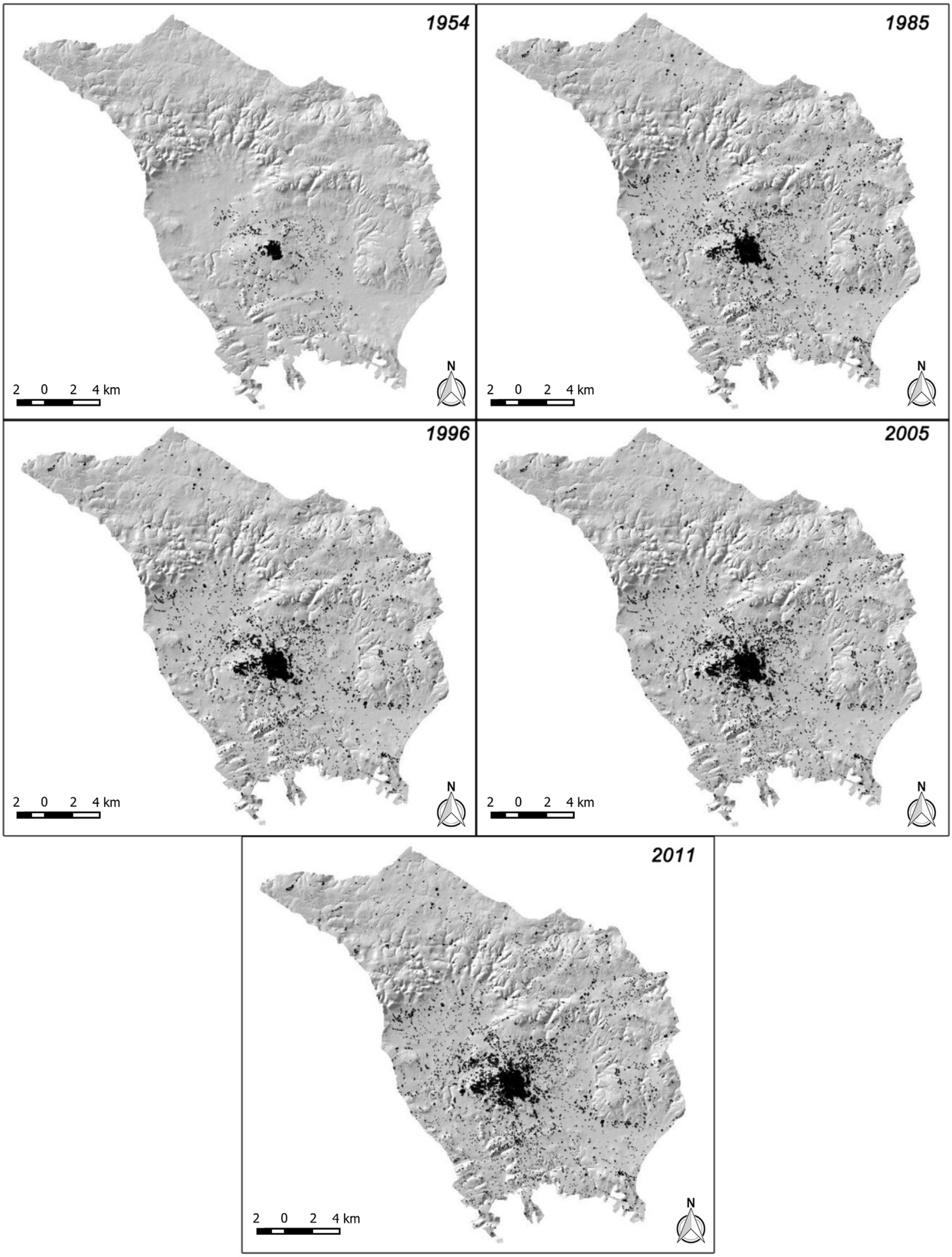

Fig. 3. Evolution of built-up areas at five different dates.

In order to properly apply the model, it was necessary to derive slope and hillshade maps from the regional cartography of Apulia region; a map of transport infrastructure (road and rail) has ben used. Land use maps were not used as input data since simulation of urban areas expansion was performed exclusively by means of Urban Growth Model.

More complex was the construction of maps of excluded areas. In its construction, it was decided to take into account areas

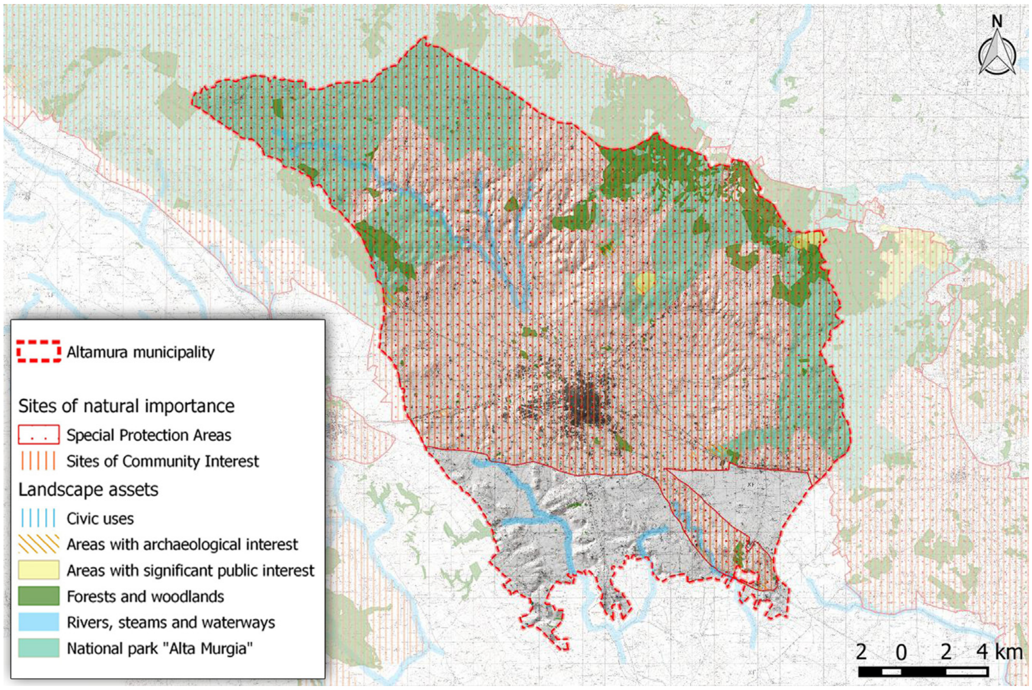

Fig. 4. Main landscape goods in Altamura municipality.

constrained by law 2004/42, which, in articles 136 and 142, identifies landscape heritage to protect. In addition to these areas, more landscape contexts were taken into account, considering Apulia Regional Territorial Landscape Plan, recently approved. In this way, it was possible to verify the impact that the new plan could have on the expansion of urban areas through the application of several constraints. Finally, five maps of built areas at five different dates (1954, 1985, 1996, 2005 and 2011, respectively) have been built through historical maps digitalization and ortophotos. All data were used to build the raster maps needed as input for SLEUTH at 10 m spatial resolution.

3. Results and discussion

SLEUTH model has been applied to the Altamura area to verify the capability of the Landscape Plan in preserving extra-urban territory and in protecting the conservation of landscape integrity. Otherwise contributions from municipal scale planning, still not upgraded, should be intended indispensable.

3.1. Calibration of the model and accuracy testing

The implementation of the model generally is developed in two different stages. The first is the calibration; in this phase the values of coefficients that will be subsequently used throughout the analysis of historical land-use transitions are defined; the second is the prediction, in which historic features of urban growth are used to simulate future developments [39–41].

The purpose of calibration is to identify values of growth parameters that best describe evolution of settlement occurred during the time series used as input, in the specific case between 1954 and 2005. For this purpose, SLEUTH allows the user to define a range of possible values for each parameter. The model repeats the analysis for each possible combination of values within the defined range. For each combination, a simulation of urban growth is performed up to the most recent urban area (2005 in the case of Altamura).

The result of this simulation is compared with the actual built-up areas at the same date through a series of statistical indicators. These detailed analysis and comparison allow identifying the combination that best describes the trend of urban dynamics within the study area. Since each parameter may vary between 0 and 100, the possible combinations are extremely numerous, and test them all in advance would require a significant computational effort. In order to reduce the number of combinations to be studied, SLEUTH calibration is conventionally carried out in three successive steps: coarse calibration, fine calibration and final calibration. In the first stage, the maximum range of values (0-100) is used for each parameter, using, generally, a 25-long step. In this way only four values (1, 25, 50, 100) will be investigated for each parameter. After performing the first calibration, combinations that are closer to a correct description of urban development are used to determine intervals of values to be used in the subsequent calibration phase. In order to identify the best combinations we used the method of Optimum Sleuth Metric (OSM), already widely discussed and described in the literature. OSM is defined by a value ranging between 0 and 1, which calculated for each value combination of the calibration. A value of 1 indicates that the corresponding combination gives a simulation at the last year which is exactly the same of the actual soil use. A value of 0 indicates total inconsistency between the simulation and the map. At the end of each calibration phase, OSM is calculated for all tested combinations. Finally, the five highest OSM values are selected, and the corresponding parameter combinations are used to define ranges of values to be studied in the following calibration phase. This procedure is repeated until a combination is reached, which, among all possible ones, best describes urban areas evolution occurred during the input time series.

Calibration phase followed data preparation, representing the most uncertain phase in the model, despite existing procedure are widely consolidated and validated. In order to eliminate uncertainty, two different simulations were performed for Altamura municipality. The first one used up to 2005 built areas as input data, giving a simulated map of built areas for 2012. Such simulation was compared to the actual 2012 map, and coefficients used for the first simulation were re-utilized for 2050 simulation, only after verifying an acceptable simulation accuracy.

Table 3
Values of coefficients resulting from the calibration phase and used in the simulation.

	Diffusion	Breed	Spread	Slope	Road gravity	OSM
Coarse calibration	45	1	1	1	1	0.835
	60	1	1	50	20	0.828
	60	1	1	50	30	0.828
	60	1	1	50	50	0.825
	55	1	1	50	1	0.774
Fine calibration	45	1	1	31	20	0.949
	45	1	1	31	25	0.949
	45	1	1	31	30	0.949
	45	3	1	31	20	0.889
	45	3	1	31	30	0.889
Final calibration	45	1	1	31	23	0.955

Calibration took three phases, called coarse, fine and final [42], respectively. At the end of each phase, OSM value was calculated for each tested combination. Table 3 shows best combinations and the corresponding OSM values obtained for the three calibration phases (Fig. 5).

Values from final calibration undergo some interesting observations. The value of diffusion coefficient, almost equal to a half of the range of values assumed by the parameter, indicates an average chance of a dispersive growth of the settlement. This trend is further confirmed in the lower value assumed by breed coefficient, which indicates a low probability of developing new settlements separated from existing settlements. The value identified by slope resistance is not very high, which indicates a low dependence of urban development on territory orography. Such a result was already expected, because of the not complex orography of the territory of Altamura: historically, it has been observed that growth of settlements has affected only open territories of the municipality between Murgia hills, leaving substantially undeveloped part of the territory with higher slope.

Finally, the value assumed by road gravity indicates a moderate dependency of urban growth on proximity to infrastructure for mobility, especially main arterial road mobility.

A simulation of urban areas expansion from 2005 to 2012 was performed through parameters calculated during the calibration. The simulation map was compared to the reference map at the same date, giving the following Kappa values:

$$K_{Histogram} = 0.98; \quad K_{Location} = 0.77; \quad Kappa = 0.76$$

Being higher than 0.75, kappa value was considered enough to assume the parameter combination defined by the calibration correct. Kappa values ranging between 0.6 and 0.8 are in fact conventionally defined as substantial [43]. The high $K_{Histogram}$ value suggests an optimum model capability of defining the correct amount of transformations during the studied time range; whilst the slightly lower $K_{Location}$ value is mainly a consequence of the use of the sole Urban Growth Model. In fact, all non-urbanized cells are considered to belong to the same category, due to the lack of knowledge about land uses different from the urban one. This makes difficult determining the exact location of a change. The situation is in fact exactly as described in paragraph 2.2, since the category "non-urbanized" is significantly more populated then the category "urbanized". This distribution of the population of the categories has a negative effect on the value of Kappa, though as seen the agreement from the quantitative point of view between the simulation map and the reference one results to be of extremely high level.

3.2. SLEUTH simulation

After completing calibration and accuracy evaluation phase, it was possible to create a simulation of the evolution of built-up areas up to the year 2050. The simulation measures in that date 24 new hectares of built-up areas (Fig. 6).

Urban development is expected mainly in the north-west part of Altamura municipality, as well as along the two main roads close to the city centre, S.S. (State Road) 99, which connects Altamura to Matera, and S.S. 96, which connects Altamura to Bari. Moreover, in terms of quantity it is possible to observe how increases in artificial surfaces provided by the simulation will not occur into a linear way (Fig. 7).

In 2012, 345 ha were built areas, corresponding to 0.80% of the total municipal territory. The simulation estimated 369 ha of built areas in 2050, 24 ha more than in 2012, corresponding to 0.86% of total Altamura municipal extension. The largest variation in built areas should occur in the period 2020-2030, consuming soil at a speed rate of 1.2 ha per year. Soil consumption speed rate would

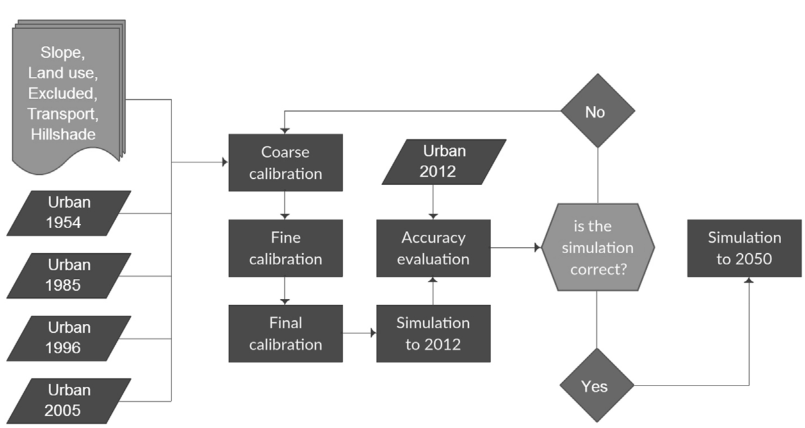

Fig. 5. Development phases of Altamura municipality application.

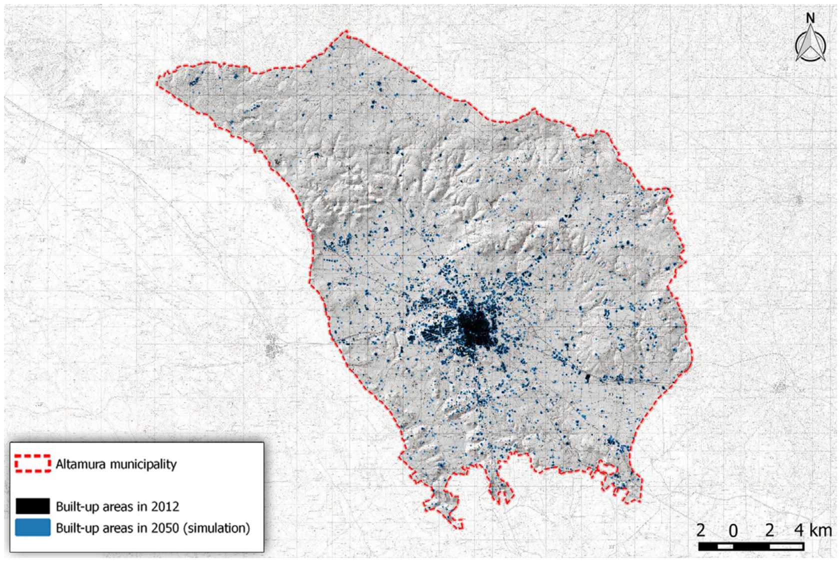

Fig. 6. Built-up areas at 2012 and 2050.

tend to decrease in time, from 0.6 ha/year between 2030-2040 to 0.2 ha/year in the period 2040-2050.

It can be speculated that the increase in built-up areas may be partially due to the demographic dynamics of Apulia. The trends identified at the regional scale follow those defined by national census data, showing that in the decade 2001-2011, the number of legally separated and divorce in Italy has almost doubled, from 1.530.543 to 2.658.943. This fact continues a trend seen for several decades, according to which there is an increase in the number of families equals to 54% compared to 1971. Interesting are also the data concerning foreign population census. Immigration phenomenon is clearly growing. Italian citizens for acquisition increased by 135% compared to 2001, and were up of the 172% the households with at least one foreigner, especially among single-person households and in very numerous families. To 2011 in Italy, there was an increase of 11.5% in the number of occupied housing than in 2001. The percentage of families owning the house in which they live is 72.1%, 18% rents it, and the remaining 9,9% benefits from social housing or have the house borrowed free of charge or else. This demographic portrait is sufficient to justify the presence of a demand for housing, especially in the Italian context, where only in recent periods, the real estate markets suffered the harmful effects of the international economic crisis. Despite this, demographics trends are not enough to justify the continuous growth of urbanized areas observed in Italy since after World War II until today. Real estate market activity is not produced by the real housing demand. Speculative processes, considering the building as a form of safe investment, regulate it. The paradox is that to the continuous increase of real estate investors corresponds a growth of their profit, while new homes continue to be unaffordable for a vast majority of the population. Related to this situation, it should be emphasized the importance of two issues. The first is the excessive simplification in the field of construction, threating the quality and state control. This is more worrying if we compare what is happening in Italy with what is the case in other European countries, where the processes of strategic decision are firmly held by the public and where the principles of transparency, control and sanctions are not only enshrined terms by a law. The second issue refers to the generally widespread connection of the house and urbanism with the municipal planning and choices. In Italy, every municipality has the possibility to determine the amount of land to build on its territory, without any form of control at the regional scale which considers

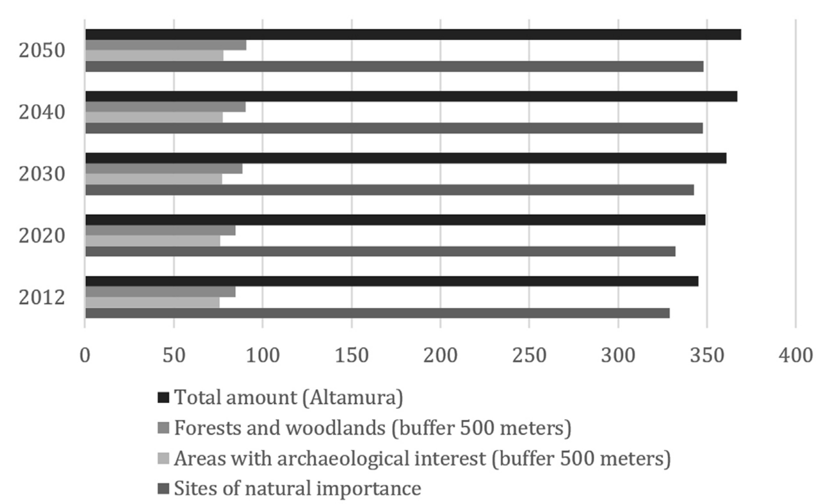

Fig. 7. Built areas evolution (ha), according to whole Municipality simulation, in a 500 m buffer from forests and archaeological interest areas and within natural interest sites.

the real population needs. This administrative fragmentation is intended as a major cause of soil consumption in Italy.

Returning to the results of the simulation performed, it should be analyzed the relationship between urban growth and planned landscape. 19.09 ha out of the new built 24 in 2050 simulation are located in SIC or ZPS areas. Soil transformation is not strictly forbidden in such areas, as previously mentioned. The case of Altamura is very complex: on one hand preservation of soils in Natura 2000 network areas is indispensable to preserve peculiar characteristics of natural habitats. On the other hand, great part of the municipality, including the built centre of Altamura, is located in SIC and ZPS areas. This makes very difficult to totally stop building activity in this large part of territory. Building activity inhibition of bound landscape goods seems stronger. Nevertheless, negative effects of urban areas development on landscape must not be evaluated only measuring the occurrence of detractors within landscape areas, but they must be computed according to the presence of detractors outside the landscape-system. On this purpose, variations in built areas were measured in a 500-m band around forests and archaeological sites. These ones are mainly sites belonging to the historical farm network. As a result, in the period 2012-2050, new built areas are expected to amount to 6.12 ha next to forests and woods, and to 2.12 ha next to archaeological interest elements.

Some considerations must be made. Landscape goods are identified and regulated by regional planning instruments. Nevertheless, the detail scale to analyse landscape does not guarantee a perfect preservation. Accordingly, simulation results are very significant: new building does not occur within landscape goods perimeters, but at a few metres from their boundaries, thus becoming, at a large scale, dangerous in terms of landscape contamination. Solving this issue means applying the inter-scaling principle, i.e. the subsidiarity principle used in territorial management. Therefore, municipal preservation measures should be coupled to general regional planning measures. In the case of Altamura municipality, it could be important to produce a new plan at urban scale, because current planning regulations are obsolete and inadequate to satisfy needs of the area.

However, the impacts of urban growth on landscape are very complex. Settlements, transport infrastructure, production and service sites growth have a strong influence on landscape structure, thus fragmenting it [44]. Habitat fragmentation is produced not solely by the phenomena of urban expansion but also from indirect effects such as deforestation, which restricts the movement of wild populations of animals. Extreme effects of this phenomenon are the local extinction of species or the reduction of their genetic variability resulting in greater proneness to disease and reduced neonatal survival. The use of the SLEUTH model becomes of great interest, since it allows assessing the potential fragmentation of the landscape, i.e. the fragmentation that is generated by the existing procedures and the existing planning instruments. The analysis of the simulation results can support the definition of long-term environmental scenarios, being the urban growth the main factor generating fragmentation of habitats and ecosystems [45].

4. Conclusions

This paper has discussed the need to consider soil as a finite resource and therefore as a common good. According to this meaning, soil becomes part of the landscape and of cultural heritage; consequently, it must be protected from the adverse effects induced by anthropogenic activity, among which urbanization plays a relevant role. To this end, the use of the CA based model SLEUTH has been proposed as a tool for the assessment a priori of the potential effects of informed planning and territorial government tools.

The case study highlights how SLEUTH application provides consistent results with actual housings dynamics trend also in urban areas of southern Italy. The investigation of coefficients obtained during the calibration phase confirms the excellent aptitude of the model to read between the lines of the geography of urban development based on time series data. The model can be useful in defining effects of alternative scenarios suitable in supporting planning choices. However, an essential requirement for its proper implementation is the constant development of technical and thematic maps from local authorities. An essential contribution in data production comes from the interpretations of satellite data [46,47]. Appling the model to a large number of municipalities in the regions of southern Italy can be a crucial step in monitoring soil consumption in Italy.

Only a complete knowledge of the phenomenon may lead to a correct definition of policies, strategies and actions to mitigate soil consumption and its negative effects [35,48,49]. It is important to remember that the soil, often only considered as suitable for future urbanization, plays a key role in biogeochemical cycles of water and its main vocation is agriculture. Threats related to urban growth are numerous and known. Above all, settlement scattering negatively affects the environmental system, implying building of primary infrastructures, such as roads, power lines, sewers, etc., which cannot be easily limited only by prescriptions. Consequently, the use of simulation models in the implementation phase of landscape planning could be vital to improve its effectiveness.

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