sustainability

MDPI

Article

Sprinkling: An Approach to Describe Urbanization Dynamics in Italy

Bernardino Romano *, Francesco Zullo, Lorena Fiorini, Serena Ciabò and Alessandro Marucci

University of L'Aquila, DICEAA, Via G. Gronchi, 18-67100 L'Aquila, Italy; francesco.zullo@univaq.it (F.Z.); lorena.fiorini@graduate.univaq.it (L.F.); serenaciabo@gmail.com (S.C.); alessandro.marucci@univaq.it (A.M.)
* Correspondence: bernardino.romano@univaq.it

Academic Editors: Federico Martellozzo and Beniamino Murgante
Received: 19 November 2016; Accepted: 5 January 2017; Published: 12 January 2017

Abstract: This paper presents research which has defined a new typology of urban patterns (sprinkling), different from the internationally recognized standard urban sprawl, as well as various indicators that have been implemented to measure sprinkling. It is important to highlight that the damage caused to the environment and communities by urban sprinkling is much more serious and irreversible than that notoriously caused by urban sprawl. The paper introduces the difficult methodological and planning aspects of retrofitting (de-sprinkling), a true challenge for land management. We argue that even partial inversion of many negative effects is impossible in the short term. Only medium- to long-term, organized, and politically coordinated programs can tackle the various issues associated with sprinkling.

Keywords: land take; urban–rural pattern; urban sprinkling

1. Introduction

This research defines a new typology of land take that is different from the internationally recognized standard urban sprawl, which scientific literature has consolidated in terms of its characteristics and the related consequences on environmental, economic, social and territorial balances [1–6]. Great interest has also been manifested in rural areas, especially in countries such as China, which is in rapid expansion [7–11].

Taking into consideration a geographical sample of the Italian Peninsula, fundamental differences were identified between the globally diffused sprawl model and the national modalities of land take with reference to vast tracts of rural and hill areas. Therefore, in Italy's case, a different definition is suggested, namely "sprinkling", as it is a better fit to represent the configuration of the peninsula's urbanized areas. Sprinkling is also present in other southern European countries and, although in different ways, also in other continental areas. According to Merriam-Webster's definition, sprawl is "the spreading of urban developments (as houses and shopping centers) on undeveloped land near a city", whereas the word "sprinkling" means "a small quantity falling in scattered drops or particles". This land take modality has already been classified experimentally through ad hoc indicators [12,13]. The study sample is an emblematical configuration of the urbanized areas in Italy's chief plains, but nearly the whole national territory is characterized by this form of land take, without significant meridian differences.

The issues caused by ordinary urban management are massive:

a) Land take has extremely high energy costs for both the public and private sectors [14];
b) The supply of technical/economic/organizational utilities is particularly onerous, due to the distance among urbanized areas and their extremely low demographic density [15];

c) Landscapes and ecosystems are subject to drastic quality degradation due to partial alteration, disturbance, fragmentation, and loss, even when those changes are remote [16,17].

This study begins by providing an analytical outline of the technical characteristics of sprinkling. Next, it introduces the difficult methodological and planning aspects of its retrofit, "de-sprinkling", a true challenge for land management. It is important to highlight that the damage caused to the environment and communities by urban sprinkling is much more serious and irreversible than that notoriously caused by urban sprawl. For this reason, even partial inversion of many negative effects is basically impossible in the short term. Only medium- to long-term, organized, and politically coordinated programs can tackle the various issues involved in de-sprinkling.

It is currently acknowledged that, in Italy, there is a need to reorganize the distribution of buildings and the related functional areas, so as to contain expansion and make development more sustainable both in environmental and social/economic terms. The conclusions reached by this research provide fundamental insights capable of helping tailor future rules aimed at regulating land take behavior in many regional communities.

2. Material and Methods

Despite its various configurations, urban sprawl is characterized by several aspects that are standard even across international comparisons. It is a model associated with strong land transformation and remarkable land consumption, and in recent years there has been an increase in the scientific literature on urban sprawl [18]. When researching the term "sprawl" on Google's research engine, about seven million links are extracted, which in almost all cases refer to the urban phenomenon; few exceptions refer to a different meaning of the noun. One of its distinctive traits is low density housing, which finds one of its most striking examples worldwide in the city of Atlanta, Georgia [19] with an extension of more than 5000 km^2 (a little smaller than the Italian region of Liguria) and fewer than 3.5 million inhabitants. In other words, the population density of Atlanta is less than 700 people/km^2, equal to an urban density slightly more than three times higher than the Italian national (territorial) density and 1.5 times that of the density of the regions of Campania or Lombardy.

Generally speaking, urbanized area characterized by sprawl is delimited and compact, with a homogeneous use pattern planned through apportionment, with mainly (but not necessarily) detached/semi-detached houses. The Asian example in particular suggests much more intensive typologies with multi-floor closely ranged buildings [20–22]. In this case, collective spaces and services are realized through coordinated interventions, often with reference to the architecture of the buildings. Internationally, sprawl develops according to models that, although differing in parts, nonetheless follow various standards related to the distributive layouts of buildings and streets and town planning parameters. To investigate this aspect, several samples of urban patterns were selected from metropolitan hinterlands in different continents. The aim was to understand their similarities and differences with reference to both spatial organization and technical indicators. The purpose of this analysis is to highlight the clear differences between the international standard of sprawl and the model prevailing in Italy, which we call "sprinkling". In our study we found that sprinkling has been widely used in the territory of the Umbria region, where about 10 years of research allows considerably detailed understanding of the settlement characteristics and its evolutionary metrics.

To this end Table 1 shows a series of sprawl models providing the distinctive land indicators that form the urban agglomeration mosaic. The territory values must keep into consideration the incidence of the public road system (on average assessable in the order of 10%) and the variable quantity of collective services. As evident, the housing density is not much spread out, and all the examples are characterized by the actual town planning and the rational distribution of the buildings, also in the presence of strong differences as to typology and economic quality. These characteristics are evident also in cases of higher density sprawl, as shown in Table 1 referring to the Australian, Japanese and Chinese examples. Urban sprawl is typically distinguished by a growth aggregated to pre-existent parts of the city, thus maintaining fabric continuity while increasing its spatial development. In other

words, the urbanized area always maintains a net perimeter as to the rural or forest surrounding context, even when the growth phenomenon is very intense.

Table 1. International examples of sprawl with the assessment of distinctive urban parameters.

Urban Pattern	Location	Building Area (mq)	Floor Area (mq)	Useful Floor Area (mq)	Coverage Ratio (%)	Building Density (build./ha)	Population Density (inhab./ha)
	Los Angeles	800	200	400	0.25	12.5	30–50
	Atlanta	600	150	300	0.25	16	30–50
	London	500	70	140	0.14	20	30–40
	Paris	800	120	240	0.15	12.5	20–30
	Berlin (rural)	600	60	60	0.1	16	20–30
	Sydney	600	250	500	0.4	16	30–40
TYPES OF "DENSE" SPRAWL							
	Sidney	500	300	600	0.6	20	80–100
	Tokyo	100	90	180	0.9	100	200–300
TYPES OF "INTENSIVE" SPRAWL							
	Shangai	1000	400	2000	0.4	10	500–800

Italian sprawl can be identified in the early 20th century cities: the difficulties in moving around obliged people to build houses as close as possible to the consolidated historic centers, which continued to remain the places where fundamental public services were provided. Starting from the second half of the 20th century, these schemes entered into crisis due to vast use of private mobility and a progressive reduction of town planning rules aimed at collective interests. Cities lost cohesion, spreading into the countryside on the basis of individual initiatives and on the land available. In some cases, this sprawl was supported by planning; in others, it was the result of abusive initiatives encouraged by amnesties for the infringement of building regulations, which had already been implemented three times and then relaunched continuously in the parliamentary chambers. The second half of the 20th century is still characterized by examples of sprawl, for instance along the Adriatic coast [23], which in 50 years averaged 10 km a year of urbanized waterfront development [24]. In this case, the apportionments, although rather coarse, were planned. Generally speaking, the buildings were of poor quality, almost always made of blocks of flats and built without an analogous and concurrent planning of utilities.

Other Italian development can be comprehended by a different category, which can be called "sprinkling". This distributive scheme is typical of Italian urban development, though it is possible to identify it also in other countries. Figure 1 shows various cases of Italian plain sectors, and Figure 2 highlights similar situations in Asia and in the Balkan area. This model is very different from the international standard sprawl: in this case, land take follows a partially spontaneous development subject to low controls, and is added onto a historical structure. The built-up areas are not homogeneous in size and use and have linear or spread out features with a mixture of rural, residential, industrial and tertiary functions. Land parameters are largely indefinable since the surfaces of pertinence of single buildings are extremely different and public spaces referring to specific levels of use are not recognizable. The main differences between the two models can be summarized by the following definitions:

Sprawl: Urban structure planned through apportionment, with a prevalence of detached/semi-detached houses. Interventions for realizing collective spaces and utilities are coordinated, often with reference to the architecture of the buildings. The urban fabric is homogeneous as to its use. Building density: 10–20 build./ha. Population density: 20–50 inhab./ha, Coverage ratio: 10%–30%.

Sprinkling: Land take with a partially spontaneous development, or subject to low controls, adding on to a historical structure. The built-up areas are not homogeneous in size and use, with a mixture of rural, residential, industrial, and tertiary functions. Building density: 0.1 build./ha, Population density: 0.2–0.5 inhab./ha, Coverage ratio: 0.5%–1%.

Figure 1. Examples of sprinkling in Italy's flat and hill areas (from left: Lombardy, Veneto and Campania). Source: Google Earth 2016.

The current Italian urban landscape is the result of a transformation process started back in the years after WWII. From the 1980s on, this process became increasingly widespread and weakened due to regional, provincial and municipal planning [25].

Local land take models are conditioned by the distribution of mountain ranges, but also by limited regulatory power in implementing plans. In fact, it is worth recalling that regulatory power is managed

in Italy by more than 8000 individual municipalities; that is, at a very low decisional administrative level, considering that the national average size of a municipality is 36 km^2 (6 × 6 km).

(**a**) (**b**)

Figure 2. (**a**) Example of urban-rural fabric highly linearized in the northern area of Shanghai in the Jiangsu region between the eastern section of the river Chang Jiang (Blue River) and the southwest coast of the Yellow Sea; (**b**) Urban "sprinkling-like" pattern in a flat area in Albania. Source: Google Earth 2016.

This situation has led to a systematic change of important rural and cultural landscapes. It has also introduced vast areas to flood risk, with dramatic consequences for the safety of housing and productive areas, which every year increase their extreme vulnerability due to the climate changes taking place [26]. All this has caused a serious decrease in the quality of anthropic life: the widespread land takes have very high energy management costs, low overall resilience [27,28], difficulty in providing services and public transport and therefore a generalized dependence on private mobility [29], all issues that the Italian scientific literature has been highlighting for the last 15 years. Moreover, the rural, mountain and coastal landscapes have undergone deep changes, to the point that some of these landscapes are far from the image historically held by international tourism. A further effect, already highlighted long ago, concerns a decrease in the quality of ecosystems and related services due to serious ecologic erosion and fragmentation caused by urban linearization and the proliferation of streets required by urban sprawl [30–32].

Some of the data mentioned here were drawn from almost 10 years of research (2006–2015) assessing the evolution and dynamics of Italian urbanized areas starting from the years after WWII. We evaluated the data following a non-sampled measured method, using a scale of 1:20,000 for the 1950s (source: Military Geographic Institute—IGM), and of 1:10,000–1:5000 for the following period up to the year 2000 (source: Land Use Regional Maps). Qualitative and quantitative phenomena connected to urban growth were analyzed through various indicators which then allowed us to identify the prevailing models in various areas of the country [33,34].

Taking into consideration several threshold values, this study identified new trajectories of regional convergence towards said values within a timeframe of remarkable statistical validity. The indicators used allowed us to classify land take behaviors throughout a peninsula that, as is known, has always presented deep economic, social and cultural differences between north and south, differences which governmental policies have never been able to balance.

3. Results

On the basis of data extracted from land use regional maps updated after the year 2000, the Italian urbanized surface is currently assessable at two million hectares (7% of the country), excluding streets, outside of densely urban areas. The last 50 years have been characterized by extremely quick acceleration, considering that in the years immediately after WWII the density of urbanization did not reach 2%. Therefore, the mean speed of transformation is equal to more than 80 ha/day (Figures 3 and 4).

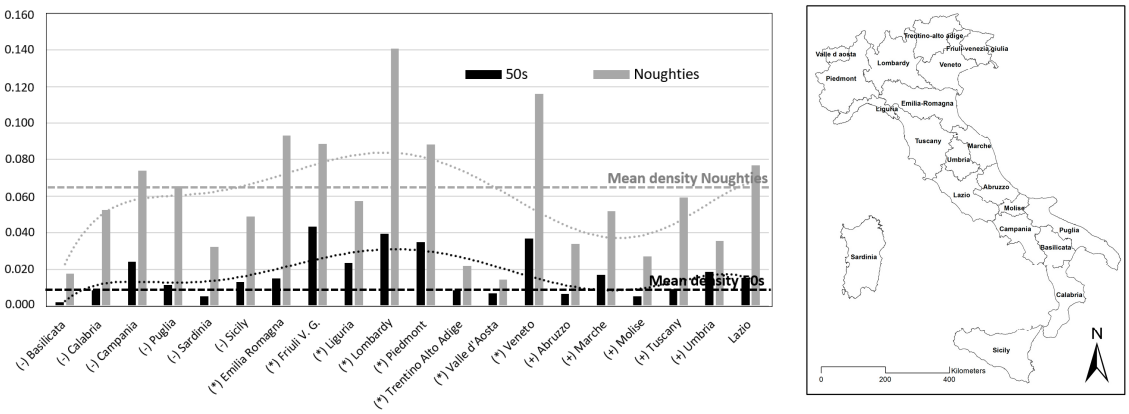


Figure 3. Regional variations of the density of urbanization from the years after WWII to the period after the year 2000. (*) Northern regions, (+) central regions, (-) southern regions.

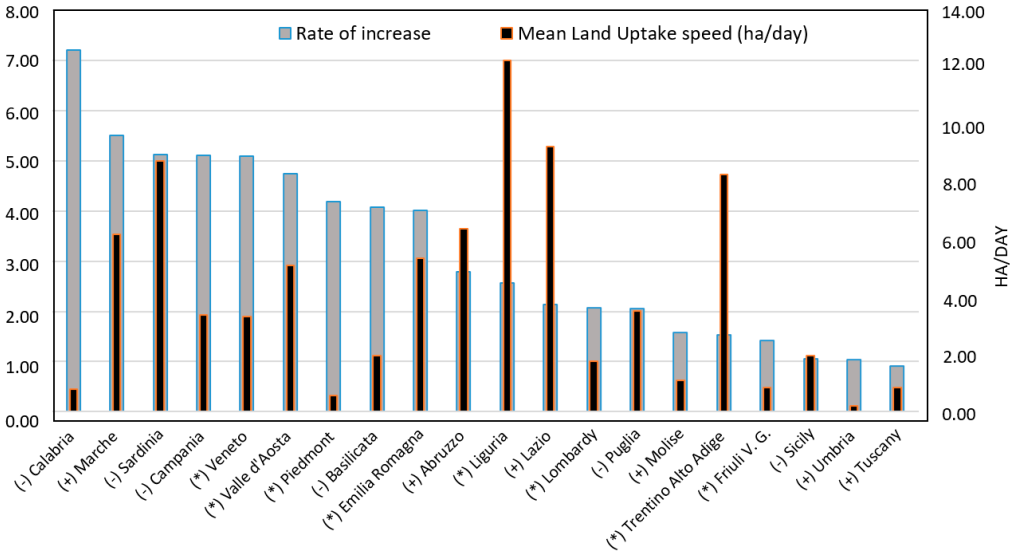


Figure 4. Urbanization variation rates and mean land take speed in Italian regions from the years after WWII to the period after the year 2000.

The changes occurring in urban structures have affected Italian municipalities in different ways, depending on the amount of population and the geographic relationships with the country's main metropolitan areas. Based on the classification of the Italian National Institute of Statistics (ISTAT) of the municipalities' demographic size, Figure 5 shows an analogous polynomial distribution for both the demographic (ΔDem) and urban (ΔUrb) variations (R^2 higher than 0.85 up to 0.92). Small cities (up to 3000 inhabitants) have experienced a considerable decrease in population, despite having doubled their urbanized areas. The cities showing the most important dynamics are those ranging from 5000 to 60,000 inhabitants (an average Italian city), in which a 50% increase of population corresponds to an increase of urbanized areas higher than 300% (a six-fold increase). Big municipalities with more than 250,000 inhabitants show almost stable demographic dynamics and a 1.5-fold urbanization increase.

However, the major variations across half a century were not found in the large cities, but in the surrounding municipalities, within a range of 10 km. In fact, if the large municipalities had, on average, a ΔUrb = 136% and a ΔDem = 14%, the values in their hinterlands amounted to 200% and 38%, respectively, confirming the understood pattern of peripheral land take. Although this is a common phenomenon in many countries, in Italy it takes on much more problematic features, as mentioned and as will be discussed in more detail hereafter.

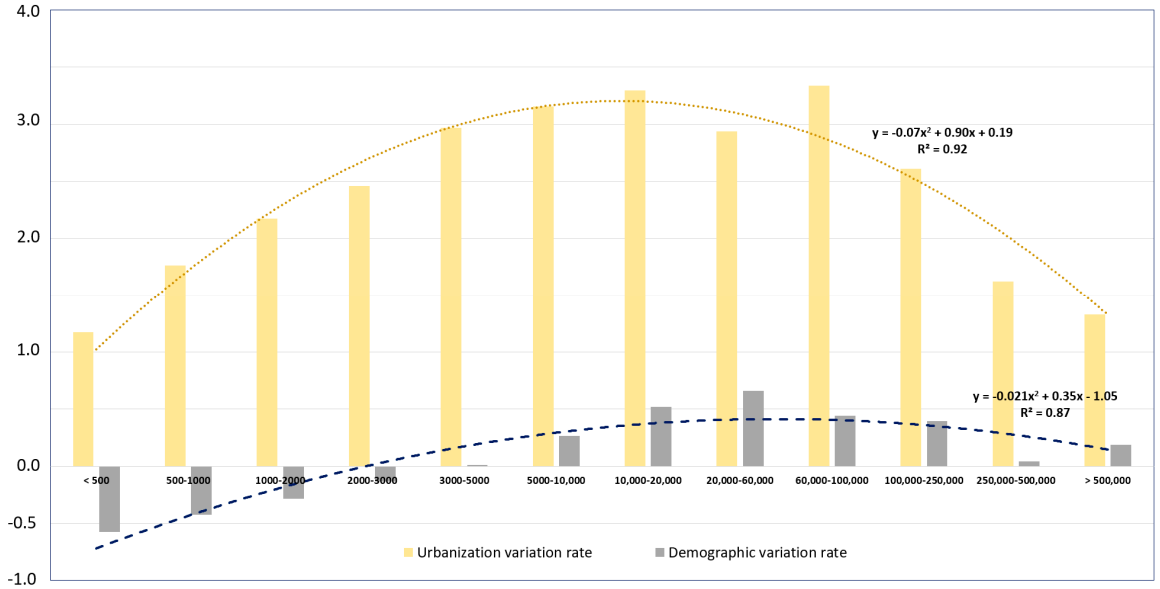


Figure 5. Population and urbanization variations on the basis of ISTAT's demographic categories of municipalities.

One very important indicator of land take behaviors is per capita urbanization. The values referring to the years after WWII differ between regions with an economy based more on agriculture (less than 100 m^2/inh) and regions already industrialized (more than 200 m^2/inh). Currently, most regions have an average of 360 m^2/inh (with a standard deviation that has halved, passing from 60% to 30%), which is also western Europe's average.

Sprinkling prevails in the main northern plains (Piedmont, Lombardy, Veneto and Emilia Romagna), but it is also found in the Mediterranean hill and coastal areas and in the smaller internal or coastal plains of central southern Italy. Dispersion modalities have changed in the mountainous areas where land take is concentrated on the valley floor with linearization extended even for dozens of kilometers and with variable densities (Figure 6). The dispersion of buildings and related functional areas is impossible to intercept and therefore measure through cartographic surveys, if not extremely detailed. Therefore, it is basically impossible to register, take a census, calculate and thus control the urban conversion of lands with methods and metrics homologated in their definitions and processes. National or regional structures for monitoring urbanized land are few and still not coordinated; there are no shared protocols and the data available are rather approximate. Even this problem is due to land take models [35,36]. Other countries, with more compact urbanized areas, can make use of European-managed remote sensing products, such as Corine Land Cover (CLC). However, Table 2 shows that this is not possible for Italy due to the extremely reduced size of various urbanized areas, which cannot be caught by satellite readings with a minimum cartographic unit of 25 ha and a minimum width of 100 m detectable polygons. Considering all 20 regions, the satellite survey averages 26% less detail than the photographic one. In some cases, there is a detail loss of more than 50% when the land take areas are very small: that is, at the level of a single building drowned in an agricultural area.

Therefore, more than one-fourth of Italy's urbanized areas escape CLC's survey. The curves in Figure 7 show the clear relationship between the average size of the built-up area (broken line) and CLC's ability to intercept its presence. This attests to a relative validity of the European satellite datum only for the six Italian regions for which error rates are lower than 10% (Figure 7). At the same time, though, it highlights the inefficacy of the satellite dataset throughout the rest of the national territory, at least with reference to urbanized surfaces.

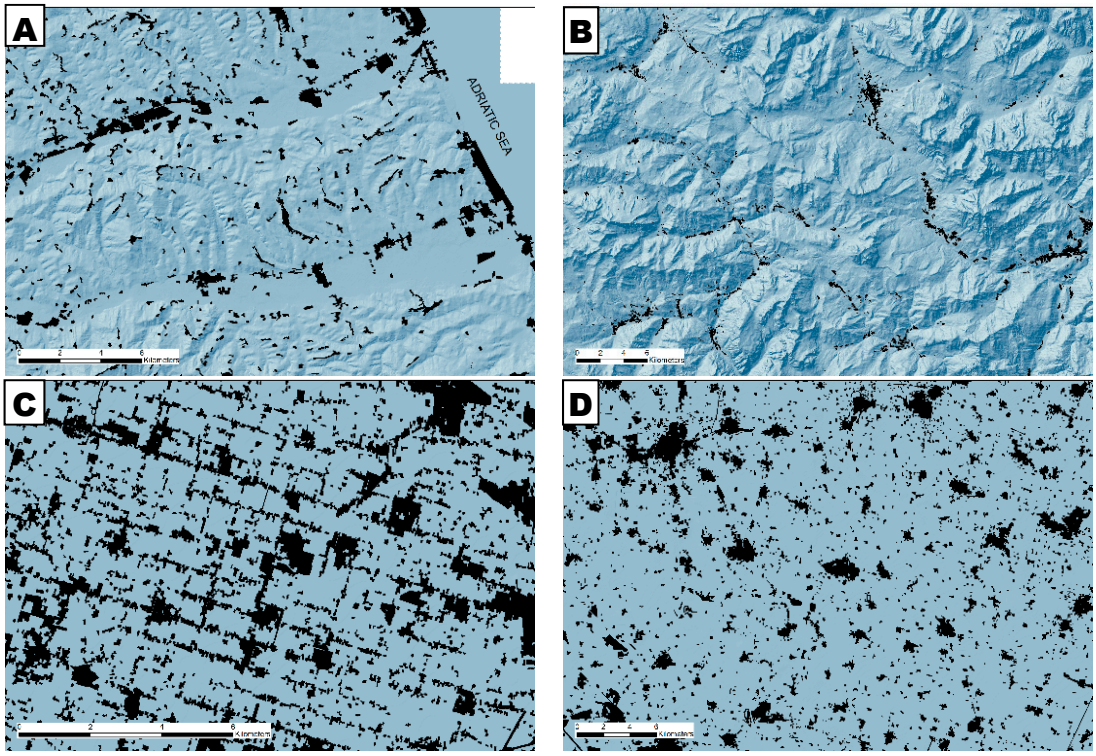


Figure 6. Models of morphological linearization in the valley and hill areas of the Adriatic coast (**A**) and of the Alpine valleys (**B**). Models of infrastructural linearization and of extreme dispersion (sprinkling) in the flat agricultural areas (**C**,**D**).

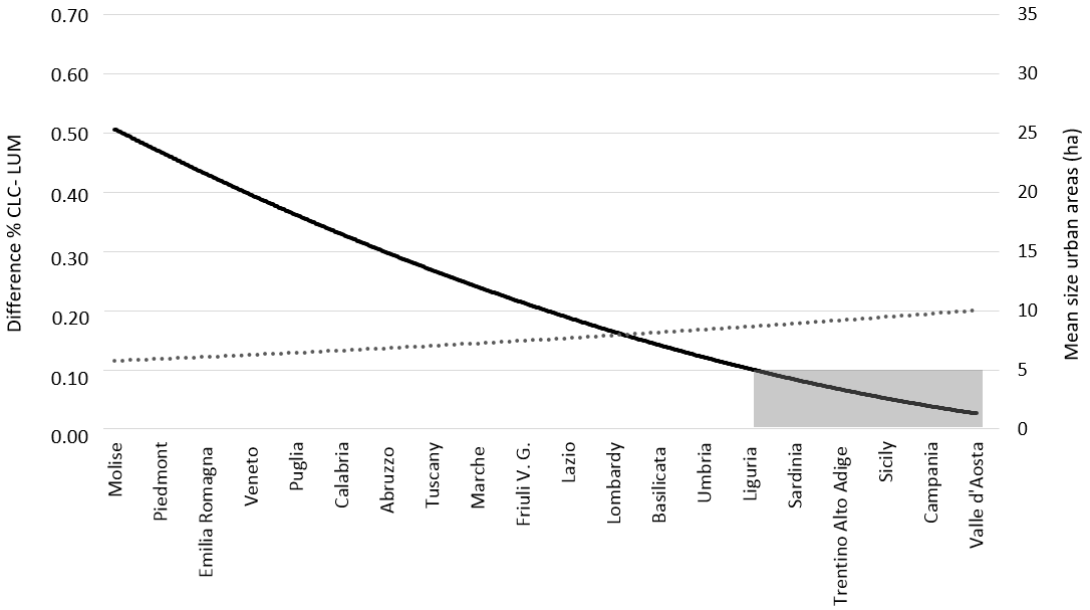
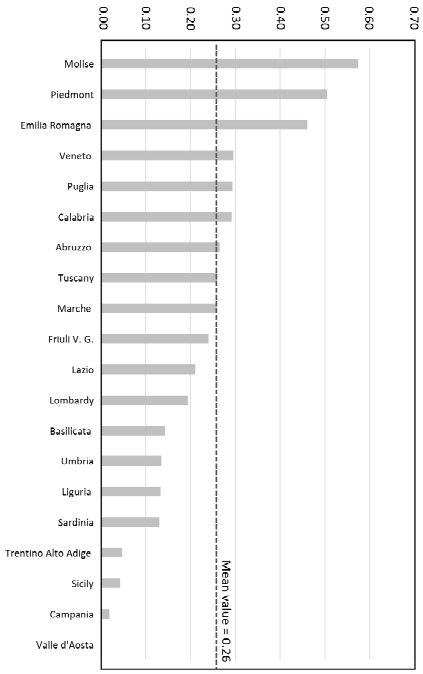


Figure 7. Relationship between the mean size of the built-up areas, indicated by the broken line, and CLC-CUS % gap in measuring the urbanized areas only with reference to the six Italian regions with an error contained within 10%.

Table 2. The gap between CLC and regional cartography in measuring urbanized areas. The comparison was carried out taking into consideration CLC's time-section closest to the date on which the regional datasets were updated.

REGIONS	Urbanized Area (ha)		Difference %	Regional Data	
	CLC	Regional Data		Type and Scale	Updating
Molise	5123.42	12,028.05	**0.57**	LUM 10k	2002
Piedmont	111,100.05	224,410.99	**0.50**	RTM 5k	2006
Emilia Romagna	111,252.73	206,369.06	**0.46**	LUM 10k	2008
Veneto	150,319.42	213,532.15	**0.30**	LUM 10k	2006
Puglia	90,478.03	128,190.03	**0.29**	LUM 10k	2006
Calabria	56,506.33	79,779.47	**0.29**	ISTAT 2011	2011
Abruzzo	26,989.85	36,740.00	**0.27**	LUM 10k	1997
Tuscany	100,897.87	136,357.68	**0.26**	LUM 10k	2007
Marche	37,529.1	50,580.37	**0.26**	LUM 10k	1990
Friuli V. G.	52,992.43	69,719.61	**0.24**	LUM 10k	2000
Lazio	104,254.81	132,078.31	**0.21**	LUM 10k	2004
Lombardy	270,739.26	335,882.1	**0.19**	LUM 10k	2009
Basilicata	15,212.4	17,764.66	**0.14**	RTM 5k	2010
Umbria	26,064.95	30,124.74	**0.13**	GBM 10k	2002
Liguria	26,921.58	31,047.42	**0.13**	LUM 10k	2000
Sardinia	67,880.54	78,061.88	**0.13**	LUM 25k	2008
Trentino Alto Adige	28,203.8	29,604.11	**0.05**	LUM 10k	2005
Sicily	121,229.63	126,690.16	**0.04**	LUM 10k	2007
Campania	99,245.75	101,163.93	**0.02**	AM 50k	2009
Valle d'Aosta	4715.1	4709.36	**0.00**	NM 50k	2000
Total	1,507,657.1	2,044,834.08	**0.26**		



GBM = geobotanical map, LUM = land use map, NM = nature map, RTM = regional technical map, AM = agricultural map.

The morphological and historical-economic differences that characterize Italy, especially in the meridian direction, cause a very differentiated distribution of the urban areas in the 20 regions in which the country is divided. Half of the urban surfaces are concentrated in the plains (a morphology that involves less than a fourth of the territory), identifying a 12% urbanization density. This value has more than doubled since the 1950s (when this index was below 5%), with an average speed of transformation near 43 ha/day. The hill areas, which represent less than half of the national territory, are 6% urbanized, which means that 22% of total urbanized areas are concentrated in the hills, with an average speed of transformation that has been a little less than 20 ha/day. Even the mountainous areas have reached 2% urbanization, versus six per thousand in the 1950s, with strong concentrations along the valley floors (Figure 6).

The higher values of urban density in the flat regions are clearly due to the ease with which these areas can be connected with industrial/commercial localizations and services in general. The hill areas attract residential interest due to reasons of climate and landscape, the mountains mainly due to tourism.

The influence of the country's morphology is very evident along the peninsular arch, where the meridian line of the Apennine chain has always limited urban development in internal areas while being very intense along the coasts. Currently, less than 30% of the over-4000-km peninsular coast is free from urbanization in comparison to more than 60% in the 1950s: 26% of the 788 km Ionian coast, 30% of the 1940 km Tyrrhenian coast and 31% of the 1472 km Adriatic coast. The urbanization density of the 500 m coast is five times the national average (34% vs. 7%) with urbanization peaks of 40% and even 50% in some regional sectors, such as Liguria, Emilia Romagna, Friuli and Calabria. Increases in urban density are evident also in the areas leading to the coasts, as they have been affected positively by the economic and transport advantages of the fast infrastructural lines that pass through Italy along the two coastal sides.

This study analyzed the growth models of the urbanized areas in depth, through a dispersion index (Urban Dispersion Index, UDI) formulated as follows and applied to all the Italian regions on a 1×1 km plot (Figure 8) together with the urban density (UD):

$$UDI = \frac{Nuc}{A} \quad (1)$$

where Nuc is the number of the urban nuclei and A is the area of reference (km^2).

The graphs in Figure 8 show that, in almost all regions, the prevailing model of urban growth is the intensified dispersion model (UDI+). The exceptions are Veneto, with an important variation of the UDI model due to phenomena of linearization along the road system of the plains, and Abruzzo and Calabria, where the steep morphology has led to the establishment of linearizations along the valleys. Regions with weak economies or with a difficult morphology also report invariability models (no change) involving more than 50% of the territory (up to more than 80% in Basilicata): this is the case for Aosta Valley, Trentino A.A., Liguria, Abruzzo, Basilicata, Calabria and Sardinia. The opposite model is found in Piedmont, Lombardy, Emilia Romagna, Tuscany, Marche, Umbria and Apulia, where the dispersion phenomenon involves more than half of the regional territory. All regions, on average, have not balanced much (maximum of 30% of the territory) and have substantially avoided aggregated urban growth (UDI0 + DU) which represents a generalized standard for northern European countries.

However, other indicators for measuring sprinkling are being tested, and these are more complex than the UDI-DU combination described above.

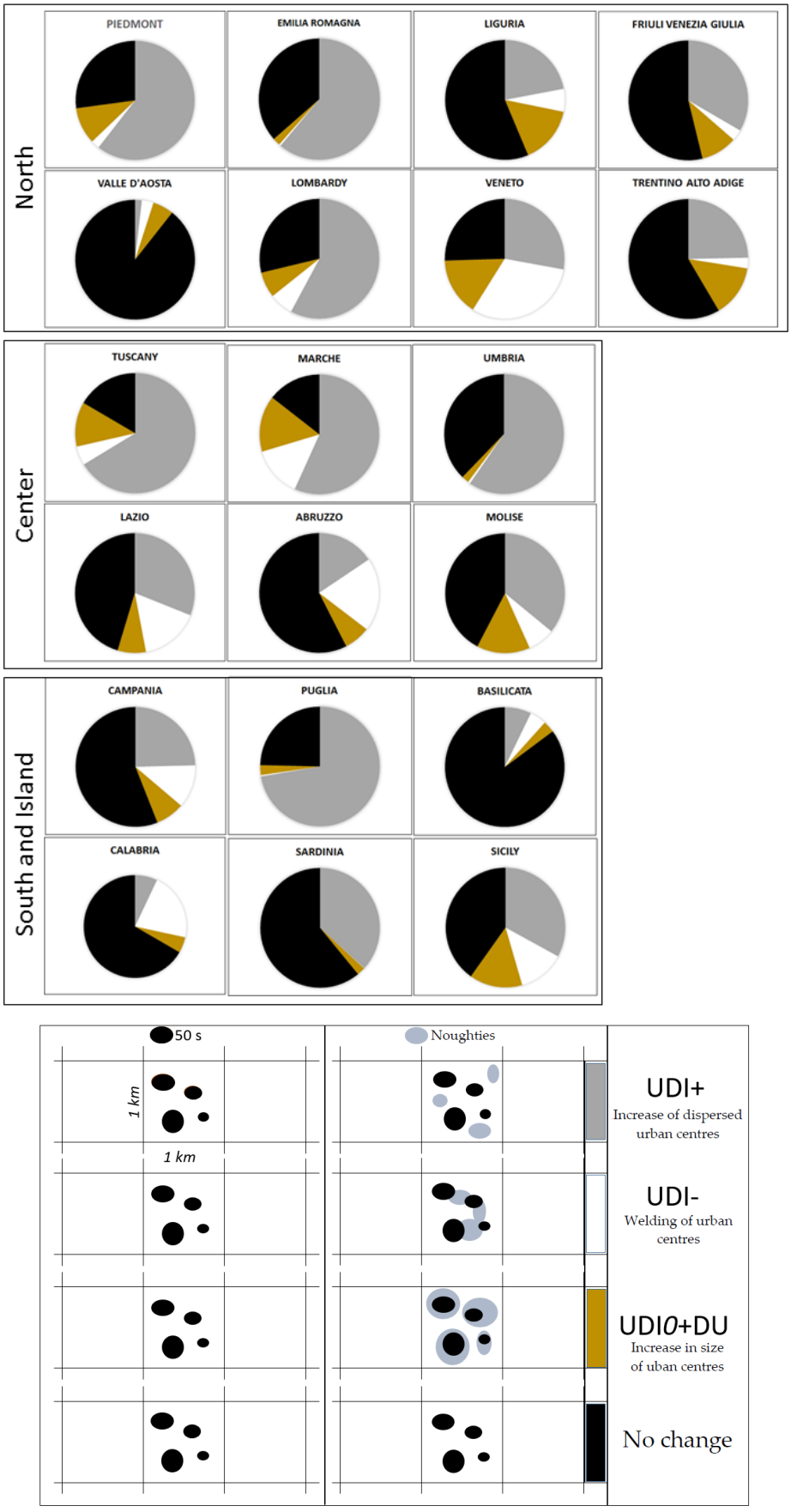


Figure 8. Indicators and models of urban growth in the Italian regions.

A further clarification of the characteristics of the model under investigation comes from the calculation of the Sprinkling Index (SPX), expressed as follows. An example is provided for the region of Umbria (Figure 9), always with reference to a regular 1 km^2 plot:

$$SPX = \frac{\Sigma \sqrt{(x_i - x^*)^2 + (y_i - y^*)^2}}{R} \quad (2)$$

where x_i and y_i are the coordinates of the centroids of the single polygons of urbanized areas present in the 1 × 1 km plot; x^* and y^* are the coordinates of the mean center of the centroids obtained as an average calculated through the surfaces of the distances among centroids within the 1 × 1 km plot; and R is the radius of the circular area with dimensions analogous to those of the sum of the urbanized areas present in the 1 × 1 km plot.

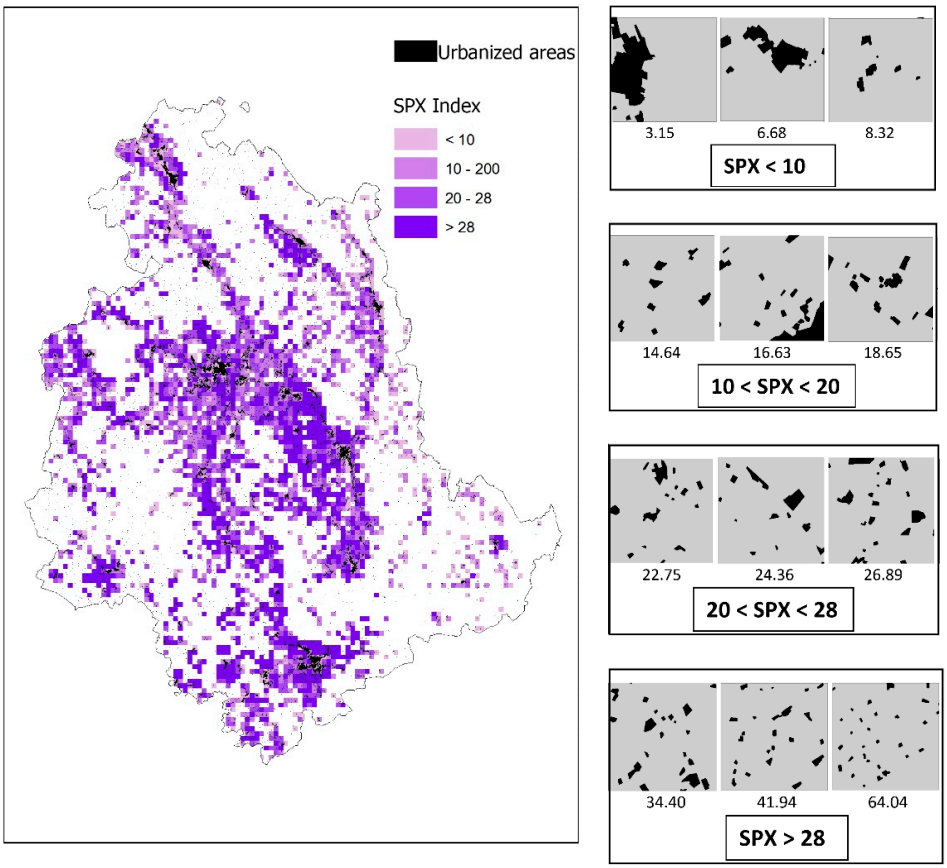


Figure 9. Sampling of the Sprinkling Index (SPX) and the geostatistics map in the region of Umbria.

The SPX is an index capable of providing a more immediate and, theoretically, a more effective description of the dispersion characteristics of urbanized areas compared to the UDI-DU combination. However, it is quite difficult to identify value intervals, such as those processed for Umbria and shown on the right in Figure 9, that are valid also for other Italian territorial and regional scopes. Currently, the SPX method is being tested to verify correspondences between range and dispersive typology.

4. Discussion

The above-mentioned issues are not easy to face, especially because the current situation derives from a series of decade-long political, technical, administrative and economic behaviors. These have contributed to forming a strongly distorted social town-planning culture that is by now almost incapable of accepting forms of more incisive planning compared to the weak methods implemented

up to now. In light of this consideration, a debate has been launched on the actual possibility of containing, mitigating, conforming, and/or inverting the growth dynamics of land take. In order to proceed in this direction it is necessary to be able to record, take a census, calculate, and therefore control the urban conversion of lands using methods and metrical systems homologated in their definitions and processes. To date, though, this is still not technically implementable at the highest administrative levels [37]. The national or regional structures for monitoring urbanized land are still few and not coordinated, there are no shared protocols, and the available data are approximate. These problems are themselves ascribable to the forms of land take. Other countries, with more compact and homogeneous urbanized situations, can efficiently make use of European-managed remote sensing products such as the Corine Land Cover. However, this is not possible in Italy's case as, highlighted above.

Nonetheless, it is important to mention that several efforts are being carried out by institutional bodies, such as ISTAT and ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale), to overcome at least the obstacle of the "census-taking" of urbanized areas [35,36]. This leads us to envisage that a standard database of the Italian artificialized surfaces will be available within a couple of years. As regards the debate on the regulatory framework, which is already animated both at national and regional levels, more resolute conceptual and methodological commitments are necessary so as to overcome simple quantitative limitations. Moreover, it is important to aim for an approach based on "balance" and controls capable of localizing constructions, taking into account obstacles and inevitable "parasite" effects.

It cannot be disregarded that many people and entities oppose housing densification such as infilling [38,39] because such changes are seen as causing detrimental impacts at various levels. Furthermore, possible limitative-aggregative rules would significantly affect current social town-planning issues, so as to require significant action in line with the European directions aimed at zeroing the urban conversion of land [40]:

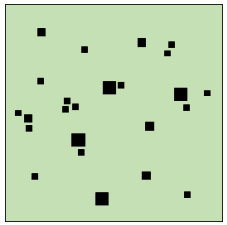
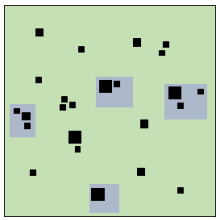
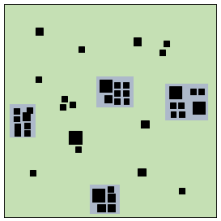
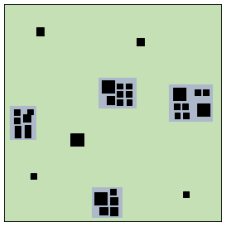
> Land and soil, target: within 2020 the EU's strategies will take into account the direct and indirect repercussions on the use of land in the EU, while at the global level the aim is for the percentage of land take to be zeroed by 2050, land erosion reduced and the content of organic matter increased; at the same time, actions will be undertaken to regenerate contaminated sites.

Table 3 summarizes a possible recovery and reorganization process of the dispersion model described. The proposed process will realistically require a very wide timeframe, amounting to a total of 30 years.

The national local land take models are undoubtedly conditioned by the distribution of mountain ranges, but also by a weak implementation of plans.

Urban sprawl is not caused by weak planning, as it is generally governed by quite uniformed rules and parameters (Table 1), and is therefore connectable to precise assessments of housing needs. Housing assessments could be satisfied through various typologies, but in many countries the prevailing housing request is aimed towards low density. Very often the realization of residential areas is carried out by real estate companies that manage the entire chain of development up to the property's sale. Once this land take model has been chosen, the aggregative land configurations based on surfaces between 500 and 800 m^2 minimize several negative effects of urban sprawl, such as higher energy expenditure, the lack of collective utilities and the lengthening of public and private transport lines. Clearly the most effective answer to these problems lies in residential densification, but this is a different topic to be faced in another context, as it depends on societies' housing habits [41].

Table 3. Possible steps in the Italian de-sprinkling process.

	ACTION	TOOLS	TIME HORIZON	METHODOLOGIES/GOALS	PATTERN
1	Stopping urban sprawl/sprinkling	regulatory intervention/tax deduction	short term	Slackening, up to the interruption, of the phenomena of further land take according to traditional dynamics, so as not to further burden the current conditions. It is an action reasonably falling within the Regions' strategic responsibilities. In this sense, the laws pertaining to "land consumption", with which several Regions have already complied, seem to be the main solution for setting regulatory-fiscal regulations aimed at containing the behaviours of Municipalities and private subjects as to further forms of uncontrolled use of territorial surfaces.	
2	Prioritised functional ranking	strategic plan/ operational plan	mid term	Identification and reorganization of "key areas" in which to carry out localization interventions of infrastructures, services and polarizing productive functions, with the intent to reorganize a macro urban fabric with its central areas and its reclassified road system. It is a key step in the de-sprinkling process, as it requires an almost paradigmatic reformulation of the current planning modalities. The aim, in fact, can be achieved by inverting the plan reduction trajectory, giving it a more incisive compulsoriness.	
3	Densification/ infilling	Operational planning/urban project	mid term	Densification intervention of the urban fabric so as to satisfy the future needs of land take increase, but especially to guarantee efficient public utilities, optimizing the users' accessibility and threshold volumes. The key areas host all the functions that in time become indispensible to guarantee the qualitative and supply improvement of the territorial ambit (housing, utilities, industrial, commercial, managerial) systematically using the tools of equal distribution/compensation of land.	
4	Shrinking	regulatory intervention/ tax deduction	long term	Incentives or managerial interventions negotiated in phase of equal distribution/compensation (for example, through the acquisition of public patrimony areas) aimed at the gradual removal of built/urbanized areas, with local projects of re-establishment/restoration of the landscape-environmental-pedological state of the areas and of the original use of the land, with increasing of urban density.	

In areas characterized by sprinkling, being in favor of grass-roots initiatives and derogation, even legal, with reference to planning regulations, is very common; therefore, it is more difficult to manage land take on the basis of calculated needs. The development of sprinkling over the years has often been the result of stochastic behavior processes in communities that have their driving force in the actions of single individuals. Interventions escape any form of control, and are often based on the self-construction of buildings and on the self-assessment of volumetric and distributive needs, with a pathological lack of architectural formal references which produce the chaotic outcomes characterizing the current Italian land take.

Therefore, sprinkling, in both its extended and linear physiognomies (Figure 6), is a non-compactable conformation, only stoppable or perhaps functionally improvable by planning several densified urban sections (Table 3) that can be elements of connection for the main utilities, improving the conditions of "critical mass". These sections, which require accurate planning, should also host possible construction expansion deriving from normal incremental needs. All this must occur, though, within a "planned" fabric which privileges and incentivizes the reoccupation of sections of previously used territory (infilling).

The latter considerations have only been mentioned in the national debate while analyzing the actual possibility to invert the land take dynamics manifested in Italy. Moreover, the issue, placed in these terms, was substantially neglected in the text approved by the Chamber on 12 May 2016 with reference to "Containment of land take and reuse of urbanized land". This text shows no differences among the various fabric and density models, which, instead, require mapping and customized actions.

The procedures to be implemented and the aims to be achieved need to be gradually inserted in a temporal program envisaging the use of various instruments in sequence, within a line of politically robust and continuous consistency. It will be necessary to coordinate incentive and fiscal actions with planning and project actions at various stages and levels, with awareness that the issues are of extreme difficulty and need sophisticated measures that will, in part, be developed through experimentation ex novo [42]. Public bodies (municipalities, regions, states) will have to intervene in order to set and manage the Transfer Development Right (TDR) tools [43]. The latter, in fact, will be indispensable in order to apply techniques and rules for long-term equalization and compensation. However, consistent and continuous results over time cannot be obtained if desired participation processes are not activated among entrepreneurs, social representatives and non-profit associations, groups already sensitized towards the issue.

On the other hand, Italy is a highly advanced country from the technical and cultural viewpoints, and is therefore capable of facing this issue, despite the enormous difficulties entailed. Owing to its methodological experience, Italy could play an important role in transferring tools to countries which, in the past couple of years, have been following the direction pursued by Italy. For example, as mentioned, the Balkan area is undergoing analogous processes; therefore, if it immediately applied the measurement methods suggested in this work, together with containment and regulatory methods based on proper territorial planning, in a 10-year period it could avoid the serious consequences that the Italian territory has already experienced.

In light of these observations, and considering current conditions, a systematic implementation of projects aimed at organizing urban areas and capable of reducing the typological and distributive spontaneity typical of current expansion structures—that is, the medium-term results to be achieved as mentioned up to point 3 of Table 3—would undoubtedly be an appreciable result.

Acknowledgments: The methodology presented was implemented in the RERU3 (Umbria Regional Ecological Network) project (0023769-23.02.2015), and its monitoring was supported by the region of Umbria, which we thank for the resources provided. The indicators used were developed within the SUNLIFE project (LIFE 13/NAT/IT/371—Strategy for the Natura 2000 Network of the Umbria Region).

Author Contributions: Bernardino Romano, Francesco Zullo and Lorena Fiorini conceived the model and analyzed the data; Serena Ciabò and Alessandro Marucci processed the data.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. European Commission. Urban Sprawl in Europe: The Ignored Challenge. 2006. Available online: http://www.eea.europa.eu/publications/eea_report_2006_10 (accessed on 4 January 2017).
2. The Worldwatch Institute. State of the World, Our Urban Future. 2007. Available online: http://www.worldwatch.org/taxonomy/term/467 (accessed on 4 January 2017).
3. Frenkel, A.; Ashkenazi, M. The integrated sprawl index: Measuring the urban landscape in Israel. *Ann. Reg. Sci.* **2008**, *42*, 99–121. [CrossRef]
4. Jaeger, J.A.G.; Bertiller, R.; Schwick, C.; Kienast, F. Suitability criteria for measures of urban sprawl. *Ecol. Indic.* **2010**, *10*, 397–406. [CrossRef]
5. Ding, C.; Zhao, X. Assessment of urban spatial-growth patterns in China during rapid urbanization. *Chin. Econ.* **2011**, *44*, 46–71. [CrossRef]
6. Barrington-Leigha, C.; Millard-Ballb, A. A century of sprawl in the United States. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 8244–8249. [CrossRef] [PubMed]
7. Zhang, Z.; Tu, Y.; Li, X. Quantifying the Spatiotemporal Patterns of Urbanization along Urban-Rural Gradient with a Roadscape Transect Approach: A Case Study in Shanghai, China. *Sustainability* **2016**, *8*, 862. [CrossRef]
8. Lin, J.; Cai, J.; Han, F.; Han, Y.; Liu, J. Underperformance of Planning for Peri-Urban Rural Sustainable Development: The Case of Mentougou District in Beijing. *Sustainability* **2016**, *8*, 858. [CrossRef]
9. Jiang, L.; Zhang, Y. Modeling Urban Expansion and Agricultural Land Conversion in Henan Province, China: An Integration of Land Use and Socioeconomic Data. *Sustainability* **2016**, *8*, 920. [CrossRef]
10. Chen, D.; Wang, Y.; Ren, F.; Du, Q. Spatio-Temporal Differentiation of Urban-Rural Equalized Development at the County Level in Chengdu. *Sustainability* **2016**, *8*, 422. [CrossRef]
11. Li, D.; Wang, D.; Li, H.; Zhang, S.; Zhang, X.; Tao, Y. The Effects of Urban Sprawl on the Spatial Evolution of Rural Settlements: A Case Study in Changchun, China. *Sustainability* **2016**, *8*, 736. [CrossRef]
12. Romano, B.; Zullo, F. Half a century of urbanisation in Southern European lowlands a study on the Po Valley (Northern Italy). *J. Urban Res. Pract.* **2015**, *9*, 109–130. [CrossRef]
13. Romano, B.; Zullo, F.; Tamburini, G.; Fiorini, L.; Fiordigigli, V. Il riassetto del suolo urbano italiano: Questione di "sprinkling"? *Territorio* **2015**, *74*, 146–153.
14. Safirova, E.; Houde, S.; Harrington, W. Spatial Development and Energy Consumption. 2007. Available online: http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-07-51.pdf (accessed on 4 January 2017).
15. Peiser, R.B. Density and Urban Sprawl. *Land Econ.* **1989**, *65*, 193–204. [CrossRef]
16. Andren, H. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: A review. *Oikos* **1994**, *71*, 355–366. [CrossRef]
17. Fahrig, L. Effects of Habitat Fragmentation on Biodiversity. *Ann. Rev. Ecol. Evol. Syst.* **2003**, *34*, 487–515. [CrossRef]
18. Ewing, R.H. Characteristics, Causes, and Effects of Sprawl: A Literature Review. In *Urban Ecology*; Marzluff, J.M., Shulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., Simon, U., ZumBrunnen, C., Eds.; Springer: New York, NY, USA, 2008; pp. 519–535.
19. Bullard, R.D.; Johnson, G.S.; Torres, A.O. (Eds.) *Sprawl City: Race, Politics, and Planning in Atlanta*; ISBN: 1559637900. Island Press: Washington, DC, USA, 2000; p. 240.
20. Deng, F.F.; Huang, Y. Uneven land reform and urban sprawl in China: the case of Beijing. *Prog. Plan.* **2004**, *61*, 211–236. [CrossRef]
21. Kew, B.; Lee, B.D. Measuring Sprawl across the Urban Rural Continuum Using an Amalgamated Sprawl Index. *Sustainability* **2013**, *5*, 1806–1828. [CrossRef]
22. Schneider, A.; Mertes, C.M. Expansion and growth in Chinese cities, 1978–2010. *Environ. Res. Lett.* **2014**, *9*. [CrossRef]
23. Sargolini, M. Adriatic urban sprawl and environmental continuity. In *Agricultural Management in Peri-Urban Areas*; Lardon, S., Marraccini, E., Bonari, E., Eds.; Felici Editore srl: Pisa, Italy, 2010; pp. 86–93.
24. Romano, B.; Zullo, F. The urban transformation of Italy's Adriatic coastal strip: Fifty years of unsustainability. *J. Land Use Policy* **2014**, *38*, 26–36. [CrossRef]
25. Cabiddu, M.A. (Ed.) *Diritto del Governo del Territorio*; Giappichelli: Torino, Italy, 2014; p. 494.

26. Medri, S.; Venturini, S.; Castellari, S. Overview of Key Climate Change Impacts, Vulnerabilities and Adaptation Action in Italy. 2013. Available online: http://www.cmcc.it/wp-content/uploads/2013/01/rp0142-serc-07-2012.pdf (accessed on 4 January 2017).
27. Galderisi, A.; Ferrara, F.F. Enhancing urban resilience in face of climate change: A methodological approach. *TeMA* **2012**, *5*, 69–88.
28. Geneletti, D.; Zardo, L. Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. *Land Use Policy* **2016**, *50*, 38–47. [CrossRef]
29. Travisi, C.M.; Camagni, R.; Nijkamp, P. Impacts of urban sprawl and commuting: A modelling study for Italy. *J. Transp. Geogr.* **2010**, *18*, 382–392. [CrossRef]
30. Romano, B. La continuità ambientale nella pianificazione. *Urbanistica* **1999**, *112*, 156–160.
31. Battisti, C. Habitat fragmentation, fauna and ecological network planning: Toward a theoretical conceptual framework. *Ital. J. Zool.* **2003**, *70*, 241–247. [CrossRef]
32. Scolozzi, R.; Geneletti, D. Spatial rule-based assessment of habitat potential to predict impact of land use change on biodiversity at municipal scale. *Environ. Manag.* **2011**, *47*, 368–383. [CrossRef] [PubMed]
33. Romano, B.; Zullo, F. Land urbanization in Central Italy: 50 years of evolution. *J. Land Use Sci.* **2012**, *9*, 143–164. [CrossRef]
34. Romano, B.; Zullo, F. Landscape change in the European Mountain Areas. Settlement of the Alps: Evolution and trajectories. *Ri-Vista* **2016**, *1*, 88–109.
35. Munafò, M.; Salvati, L.; Zitti, M. Estimating soil sealing rate at national level—Italy as a case study. *Ecol. Indic.* **2013**, *26*, 137–140. [CrossRef]
36. ISPRA. Il Consumo di Suolo in Italia. 2014. Available online: http://www.isprambiente.gov.it/files/pubblicazioni/rapporti/Rapporto_Consumo_di_Suolo_in_Italia_2014.pdf (accessed on 4 January 2017).
37. Murgante, B.; Las Casas, G.; Danese, M. The periurban city: Geo-statistical methods for its definition. In *Urban and Regional Data Management*; Taylor & Francis Group: Boca Raton, FL, USA, 2007; pp. 473–485.
38. Freilich, R.H.; Sitkowski, R.J.; Mennillo, S.D. *From Sprawl to Sustainability: Smart Growth, New Urbanism, Green Development, and Renewable Energy*; American Bar Association: Chicago, IL, USA, 2010; p. 269. Available online: http://www.law.du.edu/documents/rmlui/conference/powerpoints/FreilichRSantaFeSLDPSLDC.pdf (accessed on 4 January 2017).
39. Alfirevic, D.; Simonovic Alfirevic, S. Infill Architecture: Design Approaches for In-Between Buildings and 'Bond' as Integrative Element. *Arhitektura i Urbanizam* **2015**, *41*, 24–31. [CrossRef]
40. Commissione Europea, Tabella di Marcia verso un'Europa Efficiente Nell'impiego delle Risorse, Comunicazione della Commissione al Parlamento Europeo, al Consiglio, al Comitato economico e Sociale Europeo e al Comitato delle Regioni. 2011. Available online: http://ec.europa.eu/resource-efficient-europe/pdf/resource-efficient_europe_it.pdf (accessed on 4 January 2017).
41. Duany, A.; Plater-Zyberk, E.; Speck, J. *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream*; North Point Press: New York, NY, USA, 2000.
42. De Santis, E.; Romano, B. LUC, Land Uptake Control: A Gis based Approach. In Proceedings of the 10th International Conference on Informatic in Control (ICINCO 2013), Reykjavik, Iceland, 29–31 July 2013; pp. 450–456.
43. Renard, V. Property Rights and the "Transfer of Development Rights": Questions of Efficiency and Equity. *Town Plan. Rev.* **2007**, *78*, 41–60. [CrossRef]