The analysis of the urban form for the characterization of land consumption.

Roberto Gerundo[*], Michele Grimaldi[*]

Abstract

The quantification of urban sprawl is a prerequisite to identify the relationship between urban sprawl and its impacts in terms of land use. This paper aims to strengthen the understanding of the spatial and temporal dynamics of urban form, starting from a frequently available database to the public entities. The developed methodology provides the breakdown of the urban pattern in spatial areas characterized by a different degree of density and the analysis of morphological changes that these areas suffer over time.

Keywords

Land consumption, Kernel density, Landscape metrics, Fractal analysis.

Introduction

The rapid urbanization has become one of the main concerns, on a planetary level, due to its harmful effects on the environment (Jaeger et al., 2010), including the land consumption to the detriment of natural areas and

[*]University of Salerno, Italy

agricultural soil (EEA, 2006). The growing attention to this matter has renewed the attention on urban form (Schwarz, 2010). In fact, the most intense processes of artificialization of soils are tied for the most part to the shapes of the urban sprawl, which are common to many contexts (Ferreira, et.al. 2010), producing different modes of land consumption, i.e. some processes of conversion for soils connoted by a different degree of intensity and of spatial distribution. The analysis of the different modes of land consumption is traced back to the modelling of the fragmenting environmental process that the urbanized area determines through its growth. This modelling provides the definition of an area of influence with different intensity around the elements (buildings) which exercise pressure and its temporal modification. Starting with a database routinely in availability of public agencies, the developed methodology provides the definition of the influence areas through measures of density of the local type, implemented by the *Kernel Density Estimation* (Bailey, Gatrell, 1995), and, in addition, the characterization of the mechanisms of growth of the urbanized areas by the diachronic analysis of a set of indicators relating to *landscape ecology* (McGarigal, 2002), and the *fractal analysis* (Batty, Longley, 1994; Tannier, 2011).

Material and method

The methodology for the characterization of the mode of land consumption, that has been implemented in a GIS environment, consists of two phases:
- identification of areas of settlements;
- analysis of the mechanisms of growth of the urbanized area.

In order to identify the area of influence, the basic hypothesis is that the set of the different configurations, that the urbanized area assumes, can be decomposed into a defined number of spatial areas, that are characterized by different degrees of density of buildings and by a different organization of the building system (Gerundo, Grimaldi, 2009). Each of the above areas, examined time by time, which are considered exhaustive of the entire territory, can be decomposed into sub areas and undergoes, in time, a plurality of modifications, in terms of physical size and spatial configuration.

Table 1 - Selected metrics

Level	Type	Metrics	Formula	Description
Patch	Size	Patch number	n	n= patch number belonging to the j-th area.
		Area	Ai	Ai = surface of the i-th patch.
	Configuration	Coefficient of shape	Cfi=Pc/P	Pc = perimeter of the circle having the area equivalent to the area of the patch. P= perimeter of the i-th patch.

For the characterization of the mechanisms of growth we resorted to a process of *Time History Analysis* (van Eetvelde, Antrop, 2009), based on variation in the time of selected landscape metrics (table 1) and the fractal dimension.
In fact the transition from one area to another thus quantified, weighed as a function of the variation that assumes the fractal dimension, allows us to discriminate the different modes of land consumption that the evolution of the urbanized land determines in the investigated territory.

Case study

The proposed methodology has been tested on the system of the settlements of the municipality of Giugliano in Campania, in the province of Naples. Through the developed algorithm, articulated in selection rules and the subsequent aggregation, we obtained the maps representing the five areas of settlements, to the two historical thresholds.

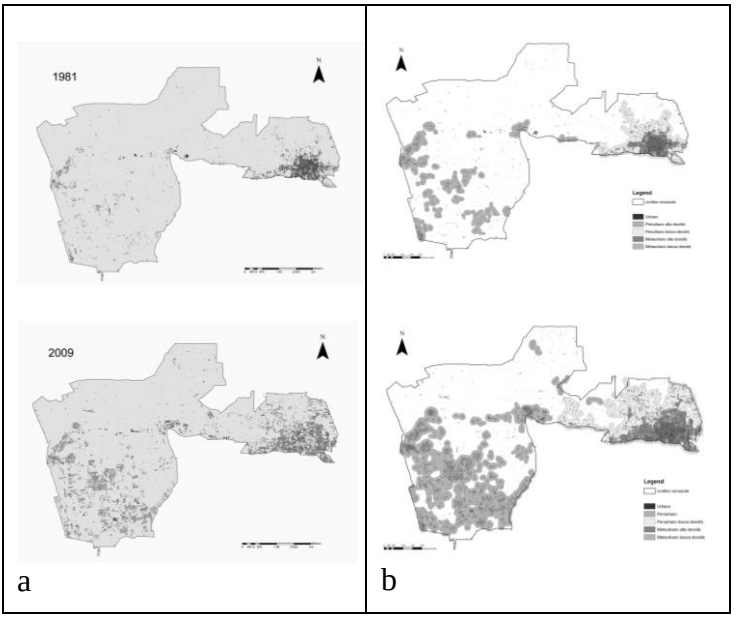

Figure 1 - Buildings maps a); Influence areas maps 1981-2009b).

According to the second phase of the methodology we proceeded to quantitative analysis, first to patch level and then to the class level. After that, we passed to the characterization of the mechanisms of growth with reference to the different areas.

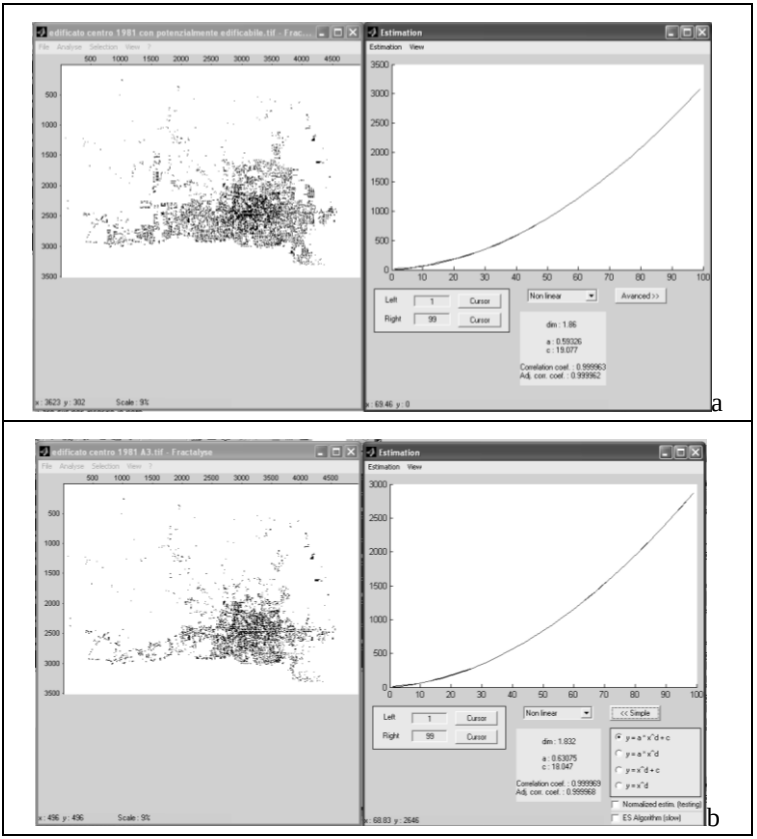

Figure 2 - Screenshots of the correlation analysis for the various areas performed with software Fractalyse 2.44, 2009a), 1981b).

In the interval 1981-2009, the system of settlements undergoes a further considerable modification. As a whole it is growing, although the growth is different in the various fields of settlements (Fig. 1) (Table 2).
The urban areas, that reduce their weight in the considered time span, are affected both by an expansion of margin and by an external expansion. In addition, the expansion is

accompanied by a reduction in the density and by an increase in the dispersion, that is witnessed by the reduction in the value of the fractal dimension (Fig. 2).

Table 2 - Results

Area	n		A[ha]		P[%]		Cfm	
	1981	2009	1981	2009	1981	2009	1981	2009
Urban	1	4	81.4	111.6	4.67	2.53	0.746	0.74
Peri-urban high density	1	1	137.2	360.3	7.86	8.16	0.33	0.301
Peri-urbanlowdensity	1	1	581.8	1189.8	33.3	26.93	0.268	0.187
Meta-urban high density	1	8	2.9	58.7	0.17	1.33	0.94	0.85
Meta-urbanlowdensity	16	11	940.4	2696.6	53.94	61.05	0.58	0.24

Conclusion

The application, tested on the area of study, has allowed to explain different modes of land consumption, induced by urban sprawl. In fact, the examined territory is characterized by different structures of settlements, recognizable in the various configurations in which we assumed to divide the system of the settlements. In the investigated time interval, these configurations have undergone a change, in terms of expansion and densification, whose quantitative interpretation has allowed us to characterize the different modes of land consumption. This interpretation is supported by a system of measures extensively usable, that allows us to compare the spatial configurations of different contexts and monitor the changes over time. This system is based on a set of rules of spatial analysis and an easily implementable set of indicators in a GIS environment. Specifically, the fractal analysis of the buildings relative to the different areas of settlements has allowed us to explain the spatial hierarchy within an agglomerate of settlements, that in the first

analysis does not show any type of rationality in the way it was conceived. In this way it was possible to discriminate the different areas, providing a solid reading modes of the investigated phenomenon. The identified results bring to light a series of questions that open to further developments and issues, that should be corrected by testing the model on different realities. First of all, there is the need to check the range in which the different values of density, characterizing the areas of system of settlements, must vary. To answer this question, we have to test the model on different systems of settlements in order to identify the range of possible values that the density distribution assumes. With regard to the choice of the set of metrics, we have seen that the coefficient of shape cannot characterize the effect of barrier of the areas, but only the indentation, so it becomes necessary to integrate the set of proposed metrics. Moreover it is interesting to study, even for the metrics, a possible range of variation of values in relation to different systems of settlements. However, with regard to the fractal dimension, the local analysis of correlation should be supported by the analysis of expansion, in order to try to reduce the influence of the choice of the window of analysis.Finally, the proposed method provides a layer information that, according to a principle of overlapping effects, is to be considered necessary but not sufficient to give a comprehensive answer to the quantitative characterisation of the phenomenon of the land consumption. However, in the absence of a detailed database on the actual use of the soil, the method proves to be a valid tool for the support of the decision in the choices of government of the territory.

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