Suburbs and Fragmentation Patterns: The Case of Rome

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Suburbs and Fragmentation Patterns: The Case of Rome

Summary

This paper illustrates the fragmentation patterns in the suburban area of Rome, by comparing two different points of view: the first related to the urban quality and inhabitants' social conditions, the second related to the survival of agricultural practices and natural habitats. The in-depth study of the fragmentation process and its patterns, as caused by the urban growth of the last twenty years, is combined with a detailed analysis of the demographic trends and characteristics, and of the socio-economic indicators, so as to describe levels of pressure and inequities in spatial terms. A further focus is also given to recent development plans and town-planning policies implemented by the municipal administration, as well as to its relationships with landowners and private developers.

Keywords: Urban Growth Patterns, Remote Sensing, GIS, Spatial Indicators

JEL Classification: Q01, R14, R58, Z19

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Suburbs and fragmentation patterns: the case of Rome

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Key Words: urban growth patterns, Remote sensing, GIS, spatial indicators

1. Introduction

According to the latest census data, more than 80% of the Italian population lives in municipalities having more than 5000 inhabitants. This "living in a city" condition tends to assume new characteristics, often delineating hybrid situations of "urban countryside". Dispersive urbanization processes determine progressively extending urban boundaries to encompass excessively low density habitats. These conditions involve large metropolitan regions of the Central Europe since many years. The quality of the urban space deriving from the low density advancement of the urbanization process depends on many factors. One interesting - but not sufficiently studied - factor regards the fragmentation process related to the physical growth disorder of the recently constituted urban areas on one side, and on the other side how this phenomenon influences social groups and their relationships.

This research aims to quantitatively and qualitatively analyse the characteristics and the conditions of the urbanization process taking place in the municipality of Rome and its immediately adjacent areas over the last twenty years. It will be focus on the fragmentation process characteristics and on the quality of spaces measured in terms of spatial urban and social indicators. The research is part of an on going PhD programme having as a main topic the analysis of very high resolution satellite images for urban fragmentation studies, carried out at the University of Rome "La Sapienza", Faculty of Civil Engineering, Department of Infrastructures.

Where does the city end? Is it still possible to pursue the idea of a sharp distinction between "urban landscape" and open areas? Which are the most efficient urbanization models in terms of environmental sustainability? How is it realistically possible to keep together objectives of quality of urban spaces, quality of natural landscape and efficient relationships between functions and economic activities within the fringe areas?

The hypothesis assumed in this research project is that excessive physical fragmentation caused by uncontrolled urban sprawl, negatively influences the quality of both urban space and natural habitat, and accentuates social inequities.

In this context, the principal objective is to spatially describe levels of urban-environmental quality and social (in)equity, by means of:

- analysing the extension and density patterns of the urban growth over the last twenty years;
- (re)defining and describing the fringe urban regions;
- defining and describing physical and social borders;
- measuring levels of quality and pressure with the use of physical and socio-economic indicators.

The first research trace focuses on the different perceptions of the relationship between urban and open space. It pays particular attention towards different phases of the urbanization process in the fringe areas and in particular enclaves internal to the consolidated urban tissues by evidencing conflictual relationships between land uses (urban and rural) and functions. The second research trace aims to make an in-depth analysis of the dynamics of the fragmentation caused by the progressive erosion of open spaces in the last twenty years. This on going phase of the project focuses on defining appropriate methodologies to analyse fragmentation patterns using high and very high resolution satellite images. The final aim of this operation is to reach a classification of the spatially homogeneous urban and open space units within the suburban fringe, which will be at the basis for the third research trace. This last one will focus on the definition of possible indicators to describe the identity and quality of spaces and the quality of life and the relationships between diverse urban parts.

A confrontation of the results obtained with the prescriptions of the new "Urban Centralities Strategy", proposed by the recent Regulatory Plan of Rome, perhaps will be useful in order to draw conclusions on the concrete impact of possible measures taken to improve the spatial permeability between different - isolated - parts of the city.

This paper is organized as follows: first of all, the urban fragmentation processes and related problems are discussed and a methodological approach is proposed to spatially quantify and analyse the phenomenon; then, problems and characteristics of the study area are illustrated; some preliminary results are shown and, finally, conclusions and recommendations for further work are drawn.

2. Methodological approach

The urban structures and their living communities in the developed countries are experiencing a sort of limbo: an intermediate position between a definitively-lost and a not-yet-defined condition. The cities where we live are facing a transition period where affirmed urban models undergo deep and radical quantitative modifications and the

existing relationships between shape and function are no more sufficient to interpret urban dynamics. The scientific literature clearly reflects these difficulties (Byrne, 2001). The frequent use of neologisms such as *post-industrial*, *post-fordist*, *post-modern*, indicates through the reiteration of the same prefix, the incapacity to attain a positive description of the new urbanization paradigms. "Fluxes" are progressively substituting "places", baring not only the physical discontinuity, but also the alteration of wealth and power distribution, both in the "macro" and in the "micro" levels.

Sprawl is the most evident physical effect illustrating the new urbanization trends. A fast-evolving-high-impact terminology is nowadays used to describe forms of low density soil occupation. *Greenfield*, *boomburb* or *zoomburb*, *sitcom suburb*, *streetcar buildout*, are only some examples for describing detached houses in residential neighbourhoods built in raw land, usually agricultural land. *Category killer*, *edge node*, *power center*, *strip*, are used to describe infrastructures and functions typically representing sprawl (Hayden, 2004). Yet, a positive connotation of any of these expressions is hard. Sprawl causes the fragmentation of open/agricultural spaces and the increment of impervious surface. Large rooftops and parking lots transform the natural world into asphalt deserts, causing heavy runoff that erodes the adjacent soil. Networks further enhance isolation, causing efficiently connected urban fragments to hide against noise walls.

From the beginning of the 20th century, Emile Durkheim and other sociologists describe social solidarity and cohesion as collective processes supported by proximity and concentration (Friedmann, 1973). These spatial characters have the effect of mixing social and cultural hierarchies; that is the same effect created by the modernization process (Martinetti, 1993). The globalization process has deeply changed the social equilibriums. The re-emerging of inequities within the urban space rises numerous problems in terms of empirical description and interpretation (Andersen and Van Kempen, 2001), theoretical implications and trends individuation (Moulaert, 2000), and policy efficiency (Savitch and Kantor, 2002).

The most relevant aspects of inequities are those related to social geographies and the creation of new non-univocal urban structures. Their complexity and ambiguity can be efficiently described only by integrating different information levels. In this context, the traditional classification criteria (dimensional limits, density, spatial continuity, concentration, functional specialization, …) must be integrated with data on fluxes intensity, communication, real estate, and with data describing the socio-economic conditions of the inhabitants. The interactions established between different indicators and components of the urban and territorial space, must be taken into account to evaluate conditions in which an urban aggregation can be transformed into a democratic space, where the participation of citizens into the social life and decision making processes is ensured.

2.1. The spatial dimension of the research

The physical transformations and spatial distribution of these phenomena can be studied from a "geographical-thematic" perspective using modern information techniques. Since the spatial approach is fundamental for understanding the fragmentation effects of sprawl, Remote sensing (RS) and Geographical Information Systems (GIS) techniques can truly help to efficiently perform comparative studies and spatially homogeneous analysis of different urban contexts. The geographic key gives the opportunity to analyse qualitatively and quantitatively different characteristics of the city: transformation of the urban space, distribution of the functions, physical and social stratification, property distribution, administrative and public welfare services, cultural institutions, public spaces, etc. This spatial "container" is able to support increasing levels of complexity and great variety of information coming from different sources.

The availability of high resolution commercial satellite images, such as Landsat TM (30m/pixel), SPOT 5 (10-2.5m/pixel), IKONOS (1m/pixel) or QuickBird (2.4-0.60m/pixel), offers great opportunities and interesting research perspectives related to the large and middle scale study of urban contexts. The use of satellite images has conspicuous advantages with respect to other surveys, in terms of analytical procedures automatization, scene extension and the availability of historical time series. Costs might be elevated, especially for very high resolution (VHR) products, although different collaboration projects between universities and image distribution centres, offer the possibility of low cost (or free) utilization for research purposes.

While working with satellite images, the goal is to build up a standardized and functional methodology that can be used to process multitemporal data for producing information on urban growth and spatial fragmentation patterns. This operation implies planning and execution of a complex data acquisition exercise, where satellite images are required to cover the entire study area with different resolutions. At the state of the art, Landsat MSS/TM images covering the entire study area for the years 1983, 1992 and 2002 are available and fully elaborated. Some experimental studies are carried out on Quickbird and Ikonos images for the years 2005 and 2004 respectively, covering only portions of the study area. Spot 5 images are not yet delivered. Thus, the results presented in this paper are still partial, and intended to be used in terms of generic methodological multiscale approach for the study of the fragmentation patterns and trends.

The fragmentation study is only a part of the process that will spatially describe quality and pressure levels. The definition of homogeneous spatial units is necessary in order to quantitatively measure, represent and compare fragmentation with other urban, environmental and socio-economic indexes. This is done in a GIS environment, by assuming the official Census Units (*microzone censuarie*) as the minimum unit to perform statistical analysis. The produced spatial-thematic information can be

retrieved and analyzed synchronically and diachronically, and the results can be compared with municipal previsions and other planning policies, for efficiency evaluation.

2.2. Describing low density growth and fragmentation patterns

Low density urbanization process in Italy is largely studied in terms of physical and functional characteristics (Indovina, 1990; Boeri and Lanzani, 1992; Pavia, 1995; Clementi and De Matteis, 1996; Secchi, 1997; Camagni et al., 2002). The effort made in this research is to apply consolidated theoretical descriptions of low density urbanization patterns, to a process-flow based on the semiautomatic extraction of urban land cover from satellite images, and the successive retrieval and mapping of the density classes (see Figure 1). As far as fragmentation is concerned, it can be described inside the urban fragments by measuring land cover ratios, or in terms of relationships between urban and non urban areas, by marking the progressive "insularization" of the open space caused by the advancement of urbanization (see "Some preliminary results", further on this paper).

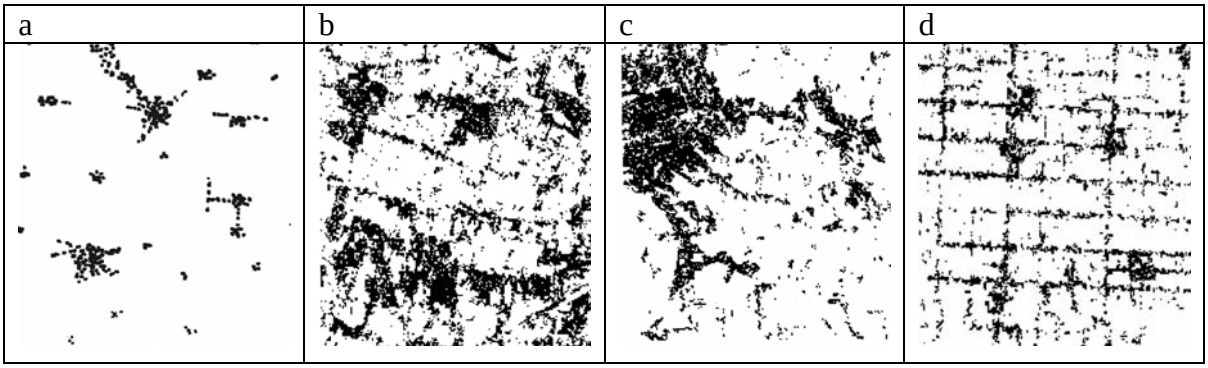


Figure 1. Examples of low density patterns: a) urbanized campaign; b) diffused city; c) ribbon development and fragments along axes; d) grids

The elaboration of satellite images implies, at a first stage, the rigorous orthorectification procedure, enabling for correct diachronic comparative analysis (Baiocchi et al. 2004). Different image classification methods are afterwards explored and applied, in relation to the scale and the objective(s) of the work. The pixel-based approach allows to accurately classify land cover from Landsat TM satellite images for the years 1983, 1992 and 2002, and the successive description of the progressive occupation (and fragmentation) of open spaces. The utility of this approach relies on the fact that it is possible to obtain, in short time and at reduced costs, a comprehensive description of the relationships between built up areas and the rest of the territory during the last twenty years, over a vast territory (in this case, the provincial limits). The Landsat scenes are classified by obtaining training sets for each land cover, and by running a maximun likehood classification, which assigns each pixel to a land cover class (Lillesand and Kiefer, 1994). The obtained land cover classes are: urban; cultivated land; dense vegetation; sparse vegetation; grass-land; bare soil; water.

Object-oriented classification methods are often used to extract information when dealing with very high resolution (VHR) satellite images. This classification method represents a conceptual evolution with respect to the traditional pixel oriented method, implying a preventive subdivision of the image in homogeneous objects through a procedure called segmentation. Some of the greatest advantages of the object-oriented approach rely on the high accuracy of classification results, the capacity to generate objects whose dimensions are adequate with respect to the scale of work, and the fast and easy integration within GIS environments, thanks to the generation of homogeneous spatial units (Baatz and Shape, 2000).

Detailed technical aspects of image classification, which constitutes a relevant part of the ongoing PhD research program, will not be discussed in this paper. What is important to stress out, is the possibility of integrating within a GIS system, the relationships between diverse urban and non-urban parts of the territory, derived from the elaboration of satellite images, with spatial indicators describing the urban-environmental quality and socio-economic characteristics.

2.3. Defining urban-environmental quality and socio-economic in(equities)

This research phase is still at the beginning. Working with spatial indicators requires the definition of a pertinent minimum spatial unit. An initial investigation on official territorial units showed different problems. The following definitions actually exist:

- Urbanistic Zone (*zona urbanistica*). Homogeneous urban areas, defined as such by the official Planning instrument, based on the specifications of the *Decreto Interministeriale* n. 1444, 1968, which distinguishes: "A" fully built-up residential areas; "B" partially built-up residential areas; "C" residential expansion areas; "D" industrial areas; "E" agricultural land; "F" infrastructures. These units faithfully represent the distinction between built-up and non built-up areas, but have no correspondence with the spatial aggregation of the data coming from census sources.
- Cadastral Census Zone (*Zona censuaria catastale*). Portion of the municipal territory, considered homogeneous in terms of environmental and socio-economic characteristics, and of real estate values. These units are very large: in the case of Rome, a municipal territory of 128.000 Ha approx., is divided in 7 Census Zones only. Part of the census data are found aggregated at this level.
- Census Units (*microzone censuarie*). This subdivisions, much smaller if compared to the census zones (the municipality of Rome is divided into 238 units), are established in 1998, by D.P.R. n. 138, having as an objective to furnish the cadastral and municipal administrations with a reference system for the correct revision of the real estate evaluation system. The effective

subdivision is rather recent and the criteria adopted are not very clear, but it seems that the new system takes into account qualitative and quantitative parameters to define homogeneous areas, introducing also information coming from the Regulatory Plan (Salvemini and Pasquino, 2000). The aggregation of existing census data within these units is to be evaluated.

The use of Census Units as the minimum spatial unit seems to be the best solution, although for the moment there are consistent difficulties on representing the spatial indicators and considering also the fact that part of the indicators are retrieved from punctual data, or from sources different than the census.

This research has specified operational definitions (whose complete descriptions are not included here) in order to construct the indicators. These definitions reflect the issues outlined in the previous sections, and follow the guidelines of the UN-HABITAT for the Urban Indicators Programme (UNCHS, 2000a; UNCHS, 2000b). This institution has specific experience in the development and application of urban indicators (Hall and Pfeiffer, 2000).

A proposed set of indicators is given below:

Domain	Indicator	Areal unit	Data source
Urban Quality Axis			
Physical environment	urbanization class (spatial continuity)	census unit	elab. of satellite images
	urban land cover index	census unit	elab. of satellite images
	edification index (m^3/m^2)	census unit	elab. of satellite images + ancillary data
	vegetation index	census unit	elab. of satellite images
	agricultural cover index	census unit	elab. of satellite images
Functional specialization	primary sector	point data	administrative data
	secondary sector	point data	administrative data
	tertiary sector	point data	administrative data
	cultural offer	point data	administrative data
	commercial offer	census unit	administrative data
Socio-economic environment	overcrowding	census unit	census
	educational level	census unit	census
	unemployment	census unit	census
	socio-economic status (income)	census unit	census
	immigration	census unit	census
	crime	municipio	administrative data

Accessibility Axis			
Social infrastructure	education (primary schools accessibility)	point data	administrative data
	Health (primary health facilities accessibility)	point data	administrative data
	day-care centres	point data	administrative data
ICT infrastructure	% households with internet PC	census unit	census

3. Characteristics of the study area

The Municipality of Rome is the largest in Italy, counting 128.530 hectares. According to the census data, during the years 1990-2000, this territory has lost 31,24% of the Utilized Agricultural Land and 8,23% of the residential population. These features may appear contradictory, but they become comprehensive while observing the phenomenon of sprawl: a centrifugal, negatively balanced demographic explosion, bringing the population to settle in traditionally agricultural land, transforming large portions of territory in “diffused city” or “urbanized campaign”. The phenomenon is further accentuated by the tendency towards dispersion of the productive and tertiary activities, more often settled in the hinterland, in nodal positions with respect to the principal metropolitan axes. As a consequence, a complex urban structure is extended over the alluvial plain of Tiber River, covering a 60x60 km area, including the municipal territory and its adjacent regions (Lelo, 2006).

The typological models of recent residential expansion are mainly represented by detached or semidetached houses with garden and garage. The image of private property is in contrast with the traditional public housing models: huge multi-storey residential complexes spread all around the Roman suburbs. Typologies hosting tertiary activities are repetitive, often squalid, and limited to the activity container and the parking area.

The actual decentralization phase was preceded by a long phase of suburbanization, bringing about the growth of “historical” peripheries (first half of the 20th century), the construction of new suburban neighborhoods, and the welding of the most advanced urbanizations with urban areas beyond the municipal limits. The result is a very large and highly fragmented periphery (see Figure 2a). In fact, Rome’s relationship with the surrounding territory is characterized by the physical discontinuity since the first post-Unitarian years (the physical growth of the city started after its proclamation as the Capital of the Italian Kingdom, in 1871). Informal dwellings used to grow beyond the perimeter of the Regulatory Plan, to avoid the plus valence gained by territories included within the Plan limits. As soon as the “official” perimeter shifts towards the city edges, new informal dwellings are built up outside the limits, while old nucleus are surrounded by heterogeneous, legal, urban expansion (Clementi, Perego, 1983).

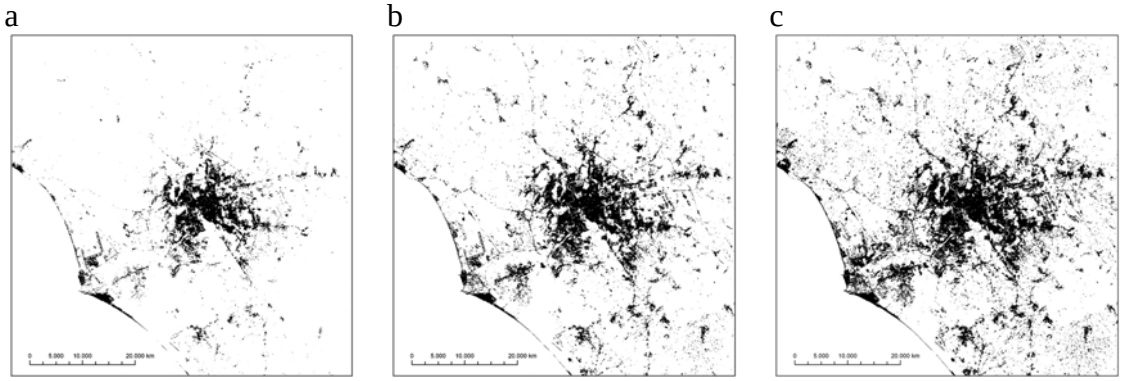
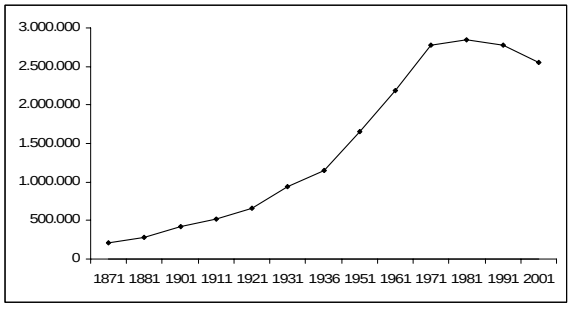


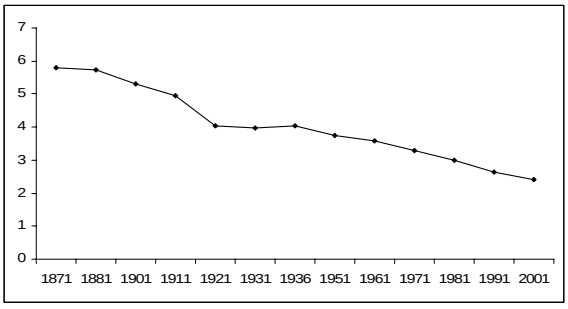
Figure 2. Urbanization process: a) 1983; b) 1992; c) 2002. Information obtained from semiautomatic classification of Landsat MSS + TM images (after Lelo, 2006).

Figure 2 illustrates the urban expansion process during the last twenty years. In the 1970s the municipal population starts diminishing for the first time after the Unification, while the overcrowding is no more an emergency (see also Graphic 1 and 2). Nevertheless, the regressed demand keeps the dwelling production high. What strikes out while observing the growth patterns during the years 1983-2000, is the progressive urban pulverization. The most devastated territories are the Eastern and South-Eastern (Castelli Romani) regions and the coastal area. These areas, characterized by environmental richness and great historical and cultural traditions, are irremediably losing their original characters.

The *Agro romano*, historical agricultural region surrounding Rome, can still be recognized in a few surviving fragments, thanks to a system of parks and protected areas ensuring the discontinuity of the urban region.



Graphic 1. Population:1872-2001 (census data).



Graphic 2. Components per household:1872-2001 (census data).

Rome is actually a complex urban system growing beyond its administrative boundaries, containing a multitude of micro cities, each one with a proper story. The administrative system is trying to adapt to this condition. The institution of fifteen *Municipi*, in 2001, (substituting previous administrative subdivisions) constitutes an

effort to selectively address persistent heavy problems such as: traffic congestion, lack of services, informal dwellings, and environmental degradation.

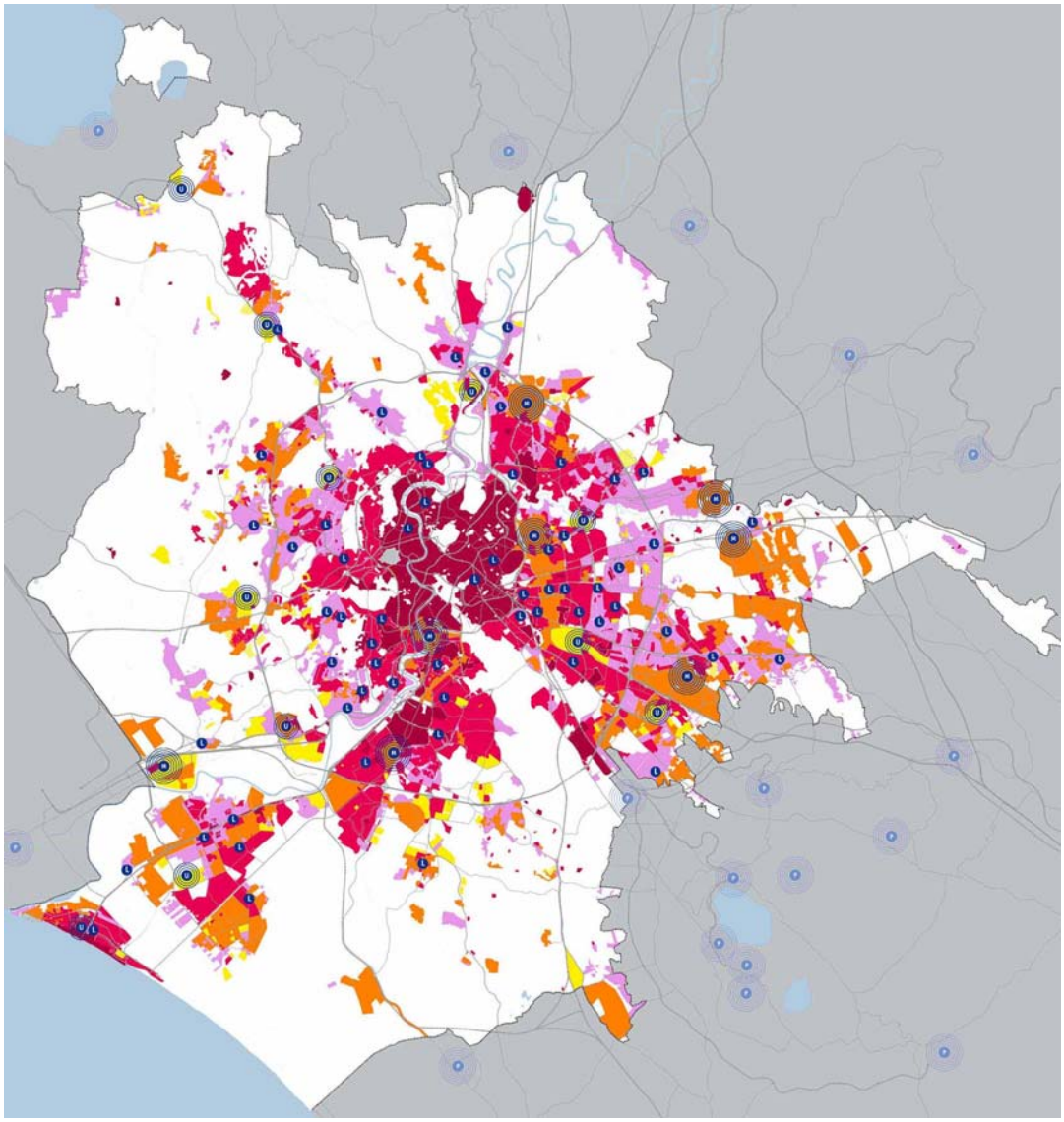


Figure 3. Urban tissues and new (Local, Urban and Metropolitan) centralities. Regulatory Plan (*Piano Regolatore*), Municipality of Rome, 2006.

The new Regulatory Plan, adopted in 2006, is also positioned in a decentralization perspective. For the fist time, to the *Municipi* are assigned the so-called "ordinary" planning and urban transformation tasks. The reorganization of peripheries is one of the principal objectives of this Plan, strategically relying on the idea of Centralities. Local, Urban and Metropolitan Centralities are groups of functions to be implanted inside the degraded areas that would hopefully constitute poles of attraction, guaranteeing the spread of the "city-effect" over the periphery. The Plan identifies two

hundred micro cities to be reorganized with functions and activities, compatible with their respective weight and position within the urban mechanism (Marcelloni, 2003).

As far as the residential dimensioning is concerned, taking into account that Rome's population continues to drop, and that the previsions confirm such a trend in the middle and long period, for the first time the new Plan adopts a policy of reducing the residual previsions of the previous Plan (1962), in order to adapt them to the actual transformation necessities and dimension.

3. Some preliminary results

The spatial-temporal analysis conducted with remote sensing and GIS techniques is based on the comparison between land cover types in different years and at different levels of detail. A first fragmentation pattern is studied by comparing results obtained from the classification process of Landsat MSS/TM images for the years 1983, 1992 and 2002. This investigation reveals spatially and quantitatively the advancement of the urbanization process (see Figure 2). Further comparative analysis conducted with GIS techniques highlights the different types of advancement (merging of existent urban areas, creation of new urban core areas, etc.) as well as the different patterns (compact, dispersive, etc.).

Relationships between urban and non urban areas are analyzed by marking the progressive "insularization" of the open space caused by the advancement of other land covers (urban and/or forest). The different dimensional characteristics of the residual open space fragments oscillate from few hectares to 1.000 hectares, and can be associated in GIS environment, with other quantitative and qualitative sources deriving from census data and other territorial studies, to better describe the characteristics of the places.

In Figure 4, land covers classified as "open space" are compared for the periods 1983-1992 and 1992-2002. The fragmented areas are contiguous open spaces, whose dimensional thresholds appear reduced in the most recent situation. In chronological terms, the analysis shows the fragmentation process involving the hinterland regions closer to the main city (1983-1992 period), moving towards areas located beyond the municipal borders (1992-2002 period): a sort of wave that propagates the phenomenon over progressively larger territories. Differently from the central and southern regions, the fragmentation process in the northern regions is mainly caused by the advancement of forests over agricultural land. This scenery needs further investigation, but is not considered a priority in this stage of the research.

The working scale, based on the elaboration of Landsat TM satellite images, doesn't allow describing fragmentation processes taking place inside small dimensional thresholds of 1 to 10 hectares. The migration from agricultural to urban land use

destinations would presumably be high in this dimensional interval. Agricultural census data give an indirect confirmation to this assumption: during the years 1990-2000, the number of agricultural enterprises is 56% reduced and this feature holds mostly for small family conducted business. It is possible to argue that in most of these cases, when agriculture territory is abandoned, we are dealing with “lost areas”, ready to be swallowed by the urbanization process, and meanwhile sources of degrade and isolation.

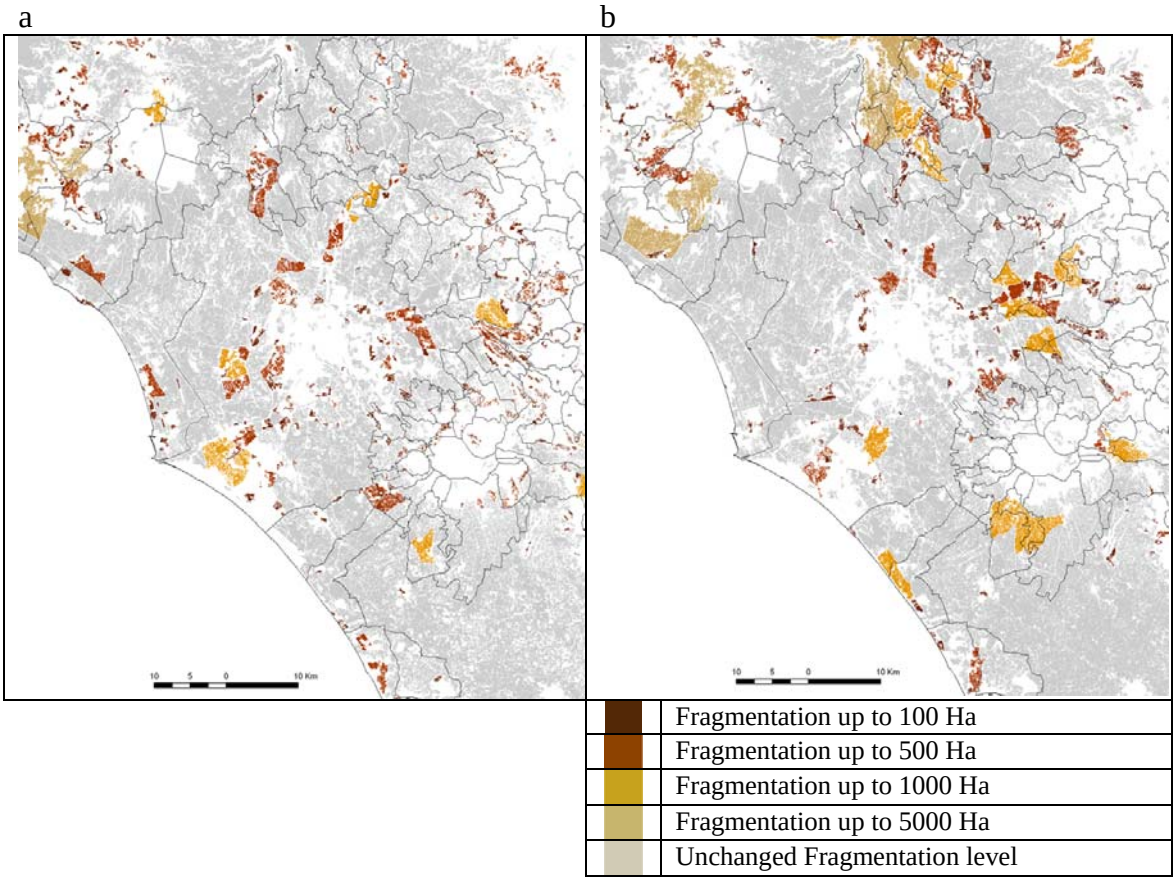


Figure 4. Fragmentation process: a) 1983-1992; b) 1992-2002

The working scale has to be changed in order to be able to go inside these areas for qualitatively and quantitatively description of the transformation processes. The study of urban fragments and their adjacent tiny open spaces requires a very high spatial resolution of the images and different classification techniques. A series of experimental studies have demonstrated the usefulness of object-oriented classification methods for producing meaningful spatial information ready-to-use in GIS systems. Concrete results will hopefully come soon, as a working methodology to extract information from VHR satellite images is being adopted.

4. Conclusions and recommendations

Urban remote sensing remains one of the most under-developed applications of remote sensing, mainly because of the highly variable nature of the urban surfaces.

New methods of classifying urban areas using high and very high remote sensing images represent a valuable attempt to characterise, quantify and classify unsustainable urban growth patterns.

Although offering the possibility of obtaining holistic views of the urban environment, traditional methods of image classification have proved to bare limitations when applied to urban areas. The use of very high resolution images and new classification techniques based on object-oriented approaches is needed to improve the level of detail while describing urban sprawl.

In this project, different definitions of urban sprawl are assessed and distilled into a coherent set of measures that can be quantified from satellite imagery and easily available ancillary data. Being able to efficiently extract quantitative information from imagery is one of the big challenges to be met. Ancillary data such as planning applications and ground surveys may be necessary to refine the urban class distinctions, if spectral and spatial properties prove to be insufficient.

Urban fragmentation data can be represented in form of indexes describing the physical environment, by adopting the Census Units as the minimum spatial unit for performing quantitative analysis within a GIS system. Indicators based on census data, such as population and socio-economic data, can be easily compared then with environmental indicators in order to spatially describe levels of pressure and inequities.

As far as it concerns the definition of minimum spatial units, other comparative techniques will be explored, considering also the possibility of disaggregating census data at the enumeration district level and their successive integration within the classified imagery. This would probably enable data from national census records to be realistically matched to their respective urban districts allowing the calculation of population and development density surfaces.

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