Agriculture and Development Processes: Critical Aspects, Potential and Multilevel Analysis of Periurban Landscapes. Part II

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ABSTRACT

This work is part of a broader study on periurban territories and the urbanocentric development patterns that have, in many cases, compromised landscape quality and led to a widespread loss in identity of these "border" settings, whose evolution is essential to the overall balance of the sustainable development of the whole area.

In particular, this paper considers the analytical aspects useful for characterising some of the significant processes undergone in these places. These contents are closely connected to a vaster exploration of the critical aspects and the potential of periurban landscapes, which was in turn conducted as part of a greater research project of which this treatise constitutes a product and whose handling is presented in a separate treatise (see part 1 of the work).

The study was based on the specific quantitative analysis of the development systems characterising suitable sample areas of Italy, defined using a multi-level approach. Data on land use, demography, the built-up system and town planning zoning is used. The data is analysed using parameters whose consolidated use emerged from the state of the art formulated as part of the aforesaid treatise belonging to the same overall study as this paper, and through an integrated evaluation of the same performed in a GIS environment. The processing performed demonstrated that the integrated analysis of developed land and population density variables offers a highly accurate description of development arrangements and their evolution, contributing to providing both qualitative and quantitative indications useful for measuring the level of efficiency of development arrangements and the degree of alteration of the landscape matrix.

Keywords: Land consumption, urban sprawl, built-up areas evolution, building density, population density, periurban context identification, Italy.

1. FOREWORD AND AIMS OF THE STUDY

This report is part of a broader study that focuses on the critical aspects, potential and evolution at the urban fringe, constituting that specific declination that the landscape assumes on the border between the urban and rural environments.

The critical analysis of the state of the art regarding the definition of these settings, the analysis of the relationships between the main territorial resources and human processes and the consequential environmental and landscape repercussions and the investigation of the current prospects and the potential of the farming sector useful for the definition of potential strategic agricultural guidelines that were conducted as part of the above study, are dealt with

in another specific publication (Tassinari et al., 2007b). As part of the same study, which focuses on the critical aspects connected to development matrix processes and their integration with the local agricultural structure and with its primary natural and cultural resources, this treatise presents the results of some of the processing conducted to date to describe the above territorial processes.

In particular, the general objective of the work is to analyse the qualitative and quantitative evolution of the development system and land use in general, using the structural exemplification of certain significant case studies in Italy.

The specific objectives of the paper are therefore to provide elements supporting the interpretation of evolution at the urban fringe through basic processing useful for illustrating a number of key phenomena belonging to the aforesaid critical aspects, and mainly concerning land use changes, and the evolution of rural settlements and built system in general, and to make suggestions that may contribute to devising criteria and methodologies for identifying territorial patterns for the same geographical definition of these periurban contexts.

This theme, and the wider one to which it can be referred about the analysis of the productive, landscape, cultural and environmental particularities and values of rural areas, as well as of its interference and interactions with settlement and non-agricultural production systems, are extremely topical in the most recent European spatial and economic planning policies. Further studies aimed at defining tools capable of operating such a qualitative and functional characterization of rural areas, useful to the targeted application of appropriate government policies, prove thus to be of great interest.

The work's specific objectives also integrate with the abovementioned intention of formulating general, concise considerations on development phenomena and the role of agriculture, for which the analyses dealt with in this treatise provide valid support.

2. MATERIALS AND METHODS

As mentioned previously, these analyses refer to a number of territorial case studies, identified within Italy using the multi-level approach that considers increasing scales of detail (figure 1). The first level analysed is the regional situation and the study area examined is the Emilia-Romagna region, one of the first in Italy to have shown full awareness of the importance of a rational use and management of territorial resources and to have translated this sensitivity into pioneering territorial protection and usage laws starting from the 1970s. The regional territory as a whole has been recognised as including many interesting cases of aggregation and urban sprawl by numerous authors, including Ingersoll (2001, 2002) and Indovina et. al. (2005) and it was therefore decided to investigate such phenomena by using basic data and indicators in this study. Given the shortage of comparable data on the Italian situation on a national scale, the outcomes of regional level analysis are also compared with the land consumption data from other European states available in literature.

Analysis then focused on the Province of Bologna, which has provided the focus for several studies on the same subject (see, for example, Cavalcoli, 2006 and Guerzoni and Savino, 2004) and is characterised by significant geomorphologic and landscape diversification, which makes it possible to observe structured dynamics for all the main land use systems.

For the subsequent increase in the scale of the investigation, the super-municipal territory of the New District of Imola[1] was chosen as the study area for the evaluation the descriptive effectiveness of types of data with greater detail and spatial definition. This area (figure 2), which covers approximately 787 km^2 in the eastern part of the province of Bologna, has been taken as a reference in numerous regional and nationwide scientific research projects (Tassinari, 2007), on account of its representativeness of the phenomena studied.

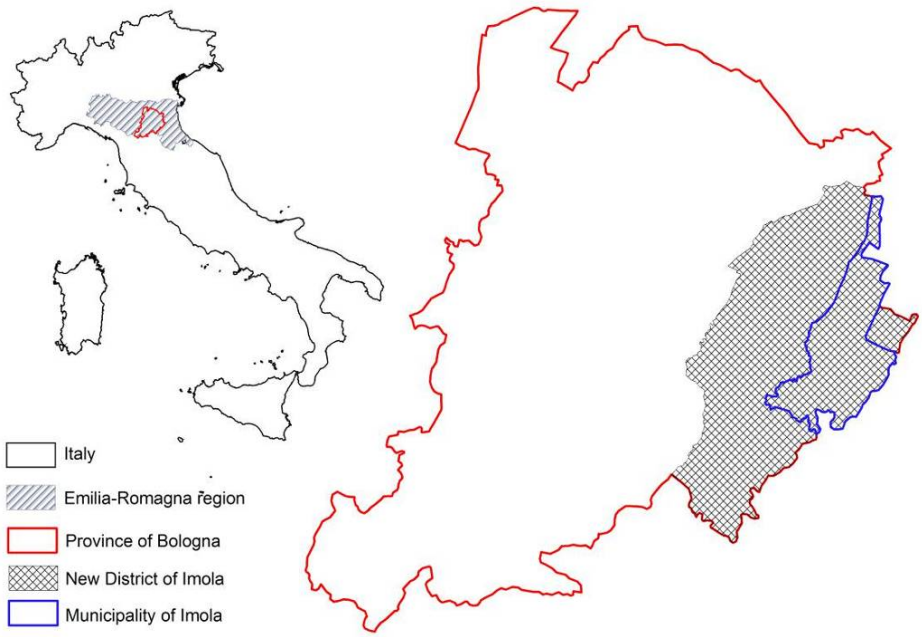

Figure 1. Location of the study areas within Italy.

[1] "Nuovo Circondario Imolese", intermunicipal association voluntarily established in December 2000 within the province of Bologna, pursuant to Emilia-Romagna Regional Law 3/1999 on administrative decentralisation.

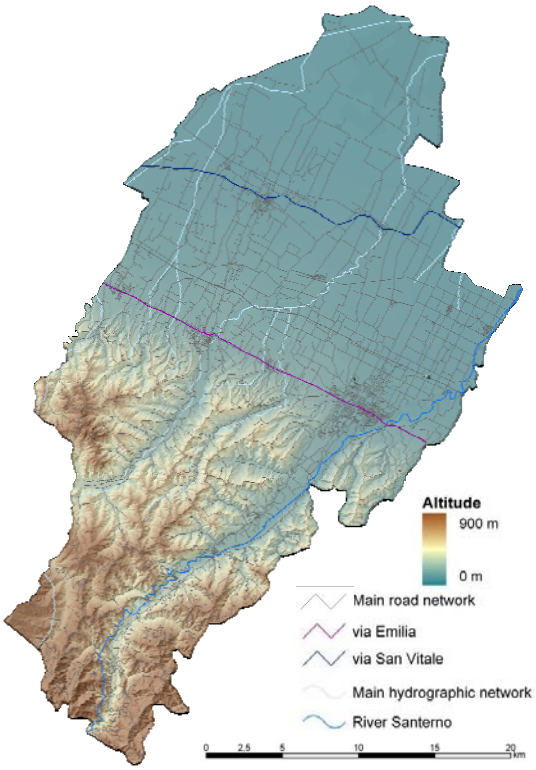

Figure 2. Geomorphological map of the super-municipal study area (New District of Imola, Italy).

Its mean elevation is 130 meters above sea level, its highest mountains reach an elevation of almost 900 meters and it has a population of more than 121 000. Among the main roads, which mostly in the flat part still follow the structure defined by the mesh of Roman centuriation, we can mention the via Emilia, which ideally divides the study area into a northern flat and a southern hill part, and the via San Vitale, which runs almost parallel to the via Emilia in the northern part. The Santerno valley lies southwest and northeast between the Apennines and the hill-foot area. The landscape of the southern part of the study area is characterized by hills that sometimes are soft and crossed by wide scenic routes, and sometimes are more hard and rough. From north to south the hilly part of the study area is more and more characterized by marginal agriculture and uncultivated areas, forests, and, mainly in the south-western part, gullies.

Lastly, a municipal level territory was considered to allow a more detailed examination of the evolution of the perimeter of the urban centre through multi-temporal analysis of various information sources. For this purpose, we identified one of the municipalities belonging to the aforesaid super-municipal context of Imola. The municipality in question is not only the largest in the context, but it is representative, in productive and landscape terms, of both the aforesaid territory and the vaster provincial context it belongs to.

The investigations make use of data obtained from various sources.

Firstly, by analysing the scientific literature we found the most recent settlement land consumption data, with reference to various European and North American countries. These data resulted from processing carried out by several authors (Frisch, 2006) based on different

sources. They nevertheless allow the comparison of the above-described Italian areas that have been considered. In particular the “Digital Enumeration Area Centroid Files” database of the Canadian National Statistical Service (Statistics Canada) and the National Resources Inventory represented the data sources for Canada and USA respectively. Data about European states have generally been derived from official government reports.

It is a well-known fact that US and Canadian data deal with very different scales and landscapes from the European and Italian ones in particular; nevertheless we considered interesting to compare the data found in the literature with those resulting from our calculations carried out on the Emilia-Romagna region.

We thus examined a number of digital land use maps compiled at different points in time by the Emilia-Romagna Regional Geographic Information Systems Service. The most recent edition available, which was used in regional level analysis, was drawn up on a scale of 1: 25 000 and was processed using photointerpretation performed by a technician using panchromatic orthoimages taken in 2003 by the Quickbird satellite. The areas classified as homogeneous in terms of land use were recognised according to the consolidated principals of prevalence and greatest probability, as well as using tests on the ground and the simultaneous use of ancillary data in the interpretation process. The cartographic product presents a vector type geographical structure with a minimum mapping unit of 1.56 ha and a key structure referring to the four levels of the Corine Land Cover (European Environmental Agency, 2000), with the exception of a number of slight amendments intended to suit local peculiarities and specificities at the greatest level of detail. The recognition and calculation of the total extent of the urbanised areas was performed through the preliminary consolidation of all the information levels connected to artificially modelled territories, according to a suitable reclassification of the original key items. For the cases examined and the second level key items of the Corine Land Cover project, these consolidations regard residential type built-up areas, industrial, commercial and infrastructural areas, areas used for mineral extraction, construction sites, dumps and waste and abandoned land and lastly the artificial, non-agricultural parkland (urban parks and sports and leisure facilities). Analysis involved the use of two significant indicators, whose interpretative efficacy has been reported in the state of the art analysis (Astengo and Nucci, 1990; Frisch, 2006; Romano and Paolinelli, 2007), performed as part of the broader research this treatise belongs to and which is dealt with in another publication (Tassinari et al., 2007b). Said indicators are the urbanisation ratio, defined as the area covered by built-up areas of a given region out of the total surface area of the same and the per capita consumption of land, i.e. the ratio between the built-up area of a given territory and the number of inhabitants of the same. The latter was derived from the data recorded during a population census contemporary to the geographical data used (Emilia-Romagna Regional Authority, 2003).

The provincial level analyses involved comparisons between the most recent land use database with one of a previous edition, in order to investigate the main variations taking place. Of the maps available for the whole study area considered during the period following the second World War and having the same scale as the 2003 digital maps analysed previously, it was decided to use the 1976 thematic regional land use maps. This map was prepared assuming a minimum mapping unit of about a quarter of that of the aforesaid subsequent edition (0.38 ha) and provides a picture with far sharper definition. This map therefore makes it possible to distinguish the elementary polygonal units homogeneous in terms of land use, determined according to the aforesaid concepts of prevalence and maximum probability, with a greater level of detail than the most recent maps available. This

difference in definition between the two databases inevitably leads to a different degree of precision in the quantification of the built-up areas, as the 1976 map effectively picks out even very small rural developments (provided they are no smaller than 0.38 ha), whereas the most recent one only recognises development fabric with a larger scale.

The databases relating to the two different eras examined were jointly processed, firstly, to define the necessary consolidation of information levels according to suitable criteria to obtain a restricted number of macro-classes of land use common and transverse to both. The reclassification of the geometrical component of both maps according to the macro-classes and the calculation of the total areas for each one, allowed a concise diachronic interpretation of the main evolution in land use.

Considering the points raised above as regards the difference in size of the minimum mapping unit, the overall increase in the extent of built-up areas that can be observed using the diachronic comparison performed, would appear to be affected by an underestimate. Following more detailed tests, which were performed to calibrate the study methodology and are not described in full for brevity, the entity of the underestimate was found to be acceptable as regards the level of approximation compatible with the study's objectives. These tests were performed by making comparisons on suitable representative areas, between the perimeter of the built-up areas present in the 2003 database and those obtained from the interpretation of contemporary high-definition satellite pictures using the same minimum mapping unit as the 1976 map.

It was decided not to use the 1994 edition of the land use map as it was produced assuming a minimum mapping unit of 2.25 ha. This would have caused errors in extension estimates each time the sources for the other two time thresholds considered had smaller isolated areas. With reference to built-up areas in particular, we were able to quantify the entity of the consequent approximation, thus verifying the size of the areas recognised as built-up in both 1976 and 2003 and conversely classified differently in 1994. These areas were found to be so large that in 1994 the total amount of built-up areas is about half that detected in 2003 and very similar to that of 1976. It was therefore decided that the 1994 database was unsuitable for use for a diachronic comparison with those of 1976 and 2003.

For the aforesaid super-municipal study territory, the information source chosen for development system evolution, was the 2001 census of the population and homes by the Italian National Institute of Statistics (ISTAT, 2001), of which we acquired both the alphanumerical and geometrical data relating to the relevant sections. Specifically, the information relating to the number of inhabitants and homes and the respective era of building were considered and used to calculate the population and development system density parameters, as described in greater detail below.

The information on residential buildings allowed the definition of an evolutional picture of their consistence and density referring to the size of the census sections. The geometrical sub-municipal level base used made it possible to observe evolutional pattern differentiation in urban, periurban and rural territories. The results obtained were combined with those of a digital land model calculated using the vector numerical values of the regional technical map on a scale of 1: 50 000 to allow a distinction between these evolution patterns according to suitable altitude classes. These were defined by assuming ISTAT criteria, following adequate reprocessing and integration to optimise this classification method for the study territory and to grasp the peculiarities of the lowland portion of the same. The altitude thresholds considered were 50, 300, 600 and 900 m above sea level, which respectively relate to a "full

plain" area (46% of the study territory), a "foothill" area (38% of the study territory), an "intermediate hilly" area (15% of the study territory) and lastly, a band that can be classified as "full hill", with altitudes in any case below 900 m (1% of the study territory).

The population database was used for the calculation of a population density map, produced in GIS raster environment by means of aerial interpolation using the summarised data available for the ISTAT census sections following attribution of the relative centroids, calculated using a specific GIS tool. To that end, suitable raster surface pixel dimensions and research range used in the calculation of the same were assumed. A variation in pixel dimension obtains coarser or smother surfaces and similarly the calculation and filing costs also vary significantly. If the cell dimension is too large for the territorial distribution of the phenomenon dealt with in analysis, the finer patterns could be completely obscured. The pixel dimension generally used must be suitable for establishing a relationship between it and the unit of reference for density calculation and in particular, the pixel dimension must be equal to a suitable fraction of said unit (between 1/100 and 1/10, as in Mitchell, 1999). As we intended population density to refer to the square kilometre, a 100 m pixel side length was adopted. Similarly, the interpretational capacity of the calculation result may vary significantly with a variation in the research radius adopted. In general, high radii give more generalised patterns and smaller ones conversely reveal more local variations. In any case, if the radius is excessively small, vaster scale patterns might not be visible (Mitchell, 1999). After various simulations, a research radius equal to 500 m was adopted, since it was able to capture the individual patterns of the single main urban centres, and to highlight the important spatial relations of a super-urban scale between it and metropolitan type conurbations.

The thematic population density map obtained was examined in parallel with a building density map for the same study area. The latter was processed by a constructing a density map similar to that described above apply applying the aforesaid calculation parameter considerations, this time on the basis of a geo-referred database of all the buildings present. This database was obtained using the mosaic mapping and georeferentiation of the most recent vector layers present in the various Land Registry records of the municipalities in the study area.

Unlike the previous case for the population, in which data summarised by defined area was available, for buildings, the density surface calculation considered the simple ratio between the number of buildings present in the research area and the extent of the surface of the same as a mobile medium.

In both cases, an interpolation algorithm was adopted, which envisaged the attribution of a weight that, by varying inversely with distance, assigns a greater importance to objects closer to the centre of the pixel. This made it possible to make the territorial patterns much more legible and easy to interpret.

Lastly, in order to capture the evolutions of inhabited centre perimeters, municipal town planning programmes were used as a source, and both numerical and cartographic data on territorial zoning and sociodemographic information were considered. In this sense, for the reasons described previously, reference is made to the territory of the municipality of Imola. Processing made use of both the current plan, the general variant to the 1999 General Development Plan (Imola Municipal Authority, 1999), for which the values of the cognitive situation were available in a numerical format, and more dated town planning documents, which were therefore only available on paper, such as the first General Development Plan, dating from 1953 (Imola Municipal Authority, 1953). In this last case, a particularly

burdensome preliminary digitalisation and georeferentiation of the data was necessary. The establishment of an integrated territorial system containing all the databases acquired and the pictures obtained using digital aerial photography based on aerial photos with stereoscopic coverage surveyed by the IGMI flight (Italian Aerial Group) in 1954 (5500 m flying height, 1: 35 000 mean scale) allowed GIS environment processing to obtain maps representative of the urban growth phenomena that had taken place.

3. RESULT PROCESSING AND ANALYSIS

3.1. Land Consumption: the Emilia-Romagna Region Compared to Other World Situations

Analysis of per capita land consumption and basic parameters with which it can be quantified, performed on data collected through the survey of the scientific literature, allows us to obtain a global picture of the European situation, highlighting a significant difference compared to other continental situations, such as the North American situation discussed below. In Canada and the United States of America, the per capita consumption of land significantly exceeds the value of 1000 m^2 per inhabitant, whereas the values for Germany and Austria are almost half this figure, one third in Switzerland, and one fifth in England (table 1). This profound difference between the North American and European situations can be understood by considering the urbanisation ratios. In the former case, the overall area of the territory is so great that the urbanisation ratio is very low (lower than 1% in Canada and just over 3% in the USA), despite the high per capita consumption of land. However, in the European countries mentioned, the urbanisation ratio varies from 5.33% in Austria to 12.63% in Germany, with intermediate values for Switzerland and England. Analysing this data gives a clear indication of how urbanisation ratio or per capita land consumption evaluation alone are inadequate for providing an effective measurement of both the general entity and the efficiency of past and current development as both parameters must be considered in an integrated manner.

This very diverse European context, in which the above-reported data illustrates the different outcomes of the territorial land consumption policy, provides the setting for the case of Emilia-Romagna (figure 1), in which specific analysis was performed, whose data is compared, in table 1, with those cases already examined.

The results deriving from land use data indicate an urbanisation ratio lower than those of England and Germany only, and an intermediate per capita land consumption in relation to the range of the other European countries considered.

As regards the vast central-eastern portion of the region, the artificially coloured satellite imagery in figure 3 provides an effective representation of the distribution of its development system and the numerous well-known and previously described fragmentation and sprawl (Tassinari et al., 2007a).

Table 1. Land consumption in some North American and European countries and in Emilia-Romagna.

	Land Area	Built-up Areas	Population	Urbanisation Ratio	Per capita Land Consumption
	10^3 km^2	km^2	10^6 inhabitants	%	m^2/inhabitant
Canada[1]	9984.7	37 000 (2001)	30.0 (2001)	0.37	1233

USA[1]	9631.4	307 500 (1997)	281.4 (2000)	3.19	1093
Germany[1]	357.1	45 090 (2004)	82.5 (2001)	12.63	547
Austria[1]	83.9	4467 (2004)	8.2 (2005)	5.33	545
Switzerland[1]	41.3	2789 (2003)	7.4 (2003)	6.76	377
England[1]	130.4	11 170 (2001)	49.1 (2001)	8.57	227
Emilia-Romagna[2]	22.1	1877 (2003)	4.1 (2003)	8.49	463

[1] Frisch, 2006

[2] Our processing on basic data provided by the Emilia-Romagna Regional Territorial Information System Service

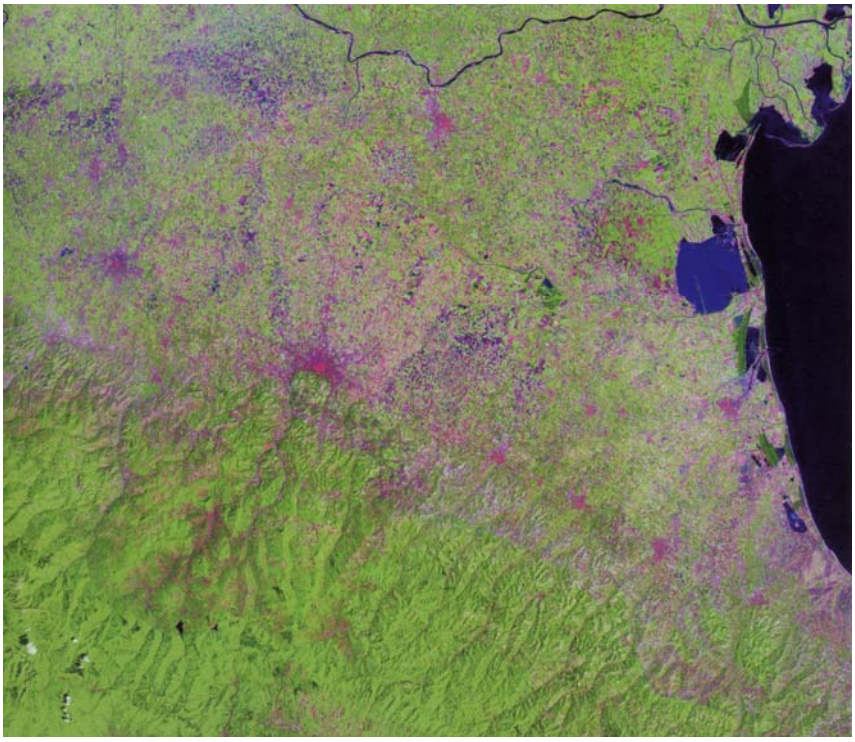

Figure 3. Artificially coloured satellite imagery of part of the regional territory of Emilia-Romagna, Italy (from Indovina et al., 2005).

3.2. The Evolution of Land Consumption: the Province of Bologna Case Study

As mentioned previously, more detailed analysis of urban expansion and sprawl was performed with regard to the province of Bologna alone (figure 1), assuming two significant temporal thresholds for which it was possible to obtain highly detailed geographical land use data. The first, 1976, represents the period in which, following the completion of the industrial transformation and urban concentration phase, an initial “metropolitan form” (or first generation metropolis) of the Bolognese fabric was established, with the localisation of industrial activities in the outer urban ring and the concentration of office buildings in the provincial capital (Cavalcoli, 2006). The second threshold considered was 2003 and relates to a territorial set up in which the development patterns being investigated are legible in a mature manner. The results of the processing performed allow detailed mapping and quantification of the expansion of the provincial capital and surrounding towns. The maps shown in figure 4

illustrate that the increase in artificialised territory took place following a number of key processes.

Firstly, there was an evident significant expansion of the inhabited centres in terms of compact urban areas. Secondly, it is possible to observe the formation and intensification of urban fringes starting from the city of Bologna and extending along the main roads. These stretch from the capital city in various directions, of which the most important is the foothill line represented by the via Emilia, along which building has been more than lively both in the province of Bologna (figure 4) and in the vaster regional context (figure 3). Important urban sprawl can be observed along the main roads of the flatlands north of Bologna and in the vicinity of those which, by following the valleys of the Rivers Reno and Savena, one reaches and crosses to the Apennine ridge to the south. Lastly, it is possible to observe a fusion between Bologna's urban territory and that of the municipalities in the immediate suburbs, with the consequent formation of a compact urban area that is significantly larger than the municipal boundaries of the provincial capital and encompasses a multitude of agricultural wedges and fringe areas.

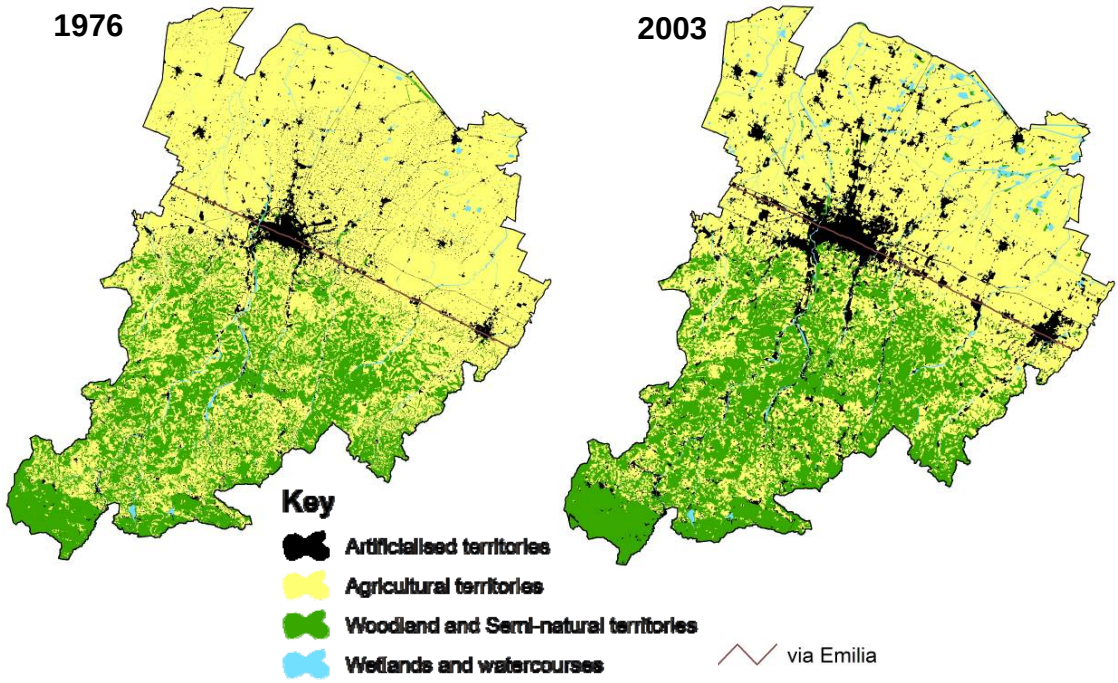

Figure 4. Land use in the Province of Bologna (Italy) in 1976 and 2003.

The significant increase in artificialised territory (table 2) involving the whole of the residential, productive and service fabric does not correspond to similar demographic patterns: in the twenty-year period 1981-2001, ISTAT's population census data shows that the province's population dropped from 930 to 915 thousands inhabitants.

This means that the increased land consumption recorded, which was slightly underestimated as explained in the section on the method adopted in the study, was not due to an increase in the number of residents, but primarily to a different way of 'living' the territory and various non-residential functions that called for high built-up space requirements.

We can also observe that the land destined for farming has been reduced due to both urban expansion and sprawl and, to the abandon phenomena that, in hill and mountain territories, have led to a significant increase in wooded and semi-natural areas (table 2). More modest re-naturalisation and recovery initiatives involving areas of environmental value not shown in figure 4 due to the scale of representation, also took place in the lowland areas, following the assimilation of European Union regulations.

Table 2. Variations in land use in the province of Bologna (Italy) between 1976 and 2003, in absolute and relative terms.

	1976		2003		variation
	km^2	%*	km^2	%*	%
artificialised territory	201	5.4	354	9.6	+76.4
agricultural territory	2515	67.9	2173	58.7	-13.6
wooded territory and semi-natural environments	936	25.3	1081	29.2	+15.5
* in reference to the extent of the whole provincial territory					

3.3. The Evolution of the Development System: the Case Study of a Super-municipal Territory

More detailed analysis was performed on development system evolution, as anticipated in paragraph 2, on the territory of the New District of Imola (figure 2). The processing of the 2001 ISTAT population census made it possible to map the evolution of this system from the period following the Second World War, with ten-year time thresholds.

Figure 5 was produced to approximate the territorial distribution of residential buildings, by processing the data, summarised by census sections, assuming a random distribution of buildings inside each section. Analysis of these representations shows that up to the end of the 1960s, the increase in buildings appears to be primarily concentrated in the expansion of the main inhabited centres.

The growth in towns also continued with the onset of fringe-belt formation, which is particularly evident in the city of Imola. There was also a boom in building density in periurban areas, particularly along the via Emilia, in the foothill band and along the bottom of the Santerno valley (figure 2).

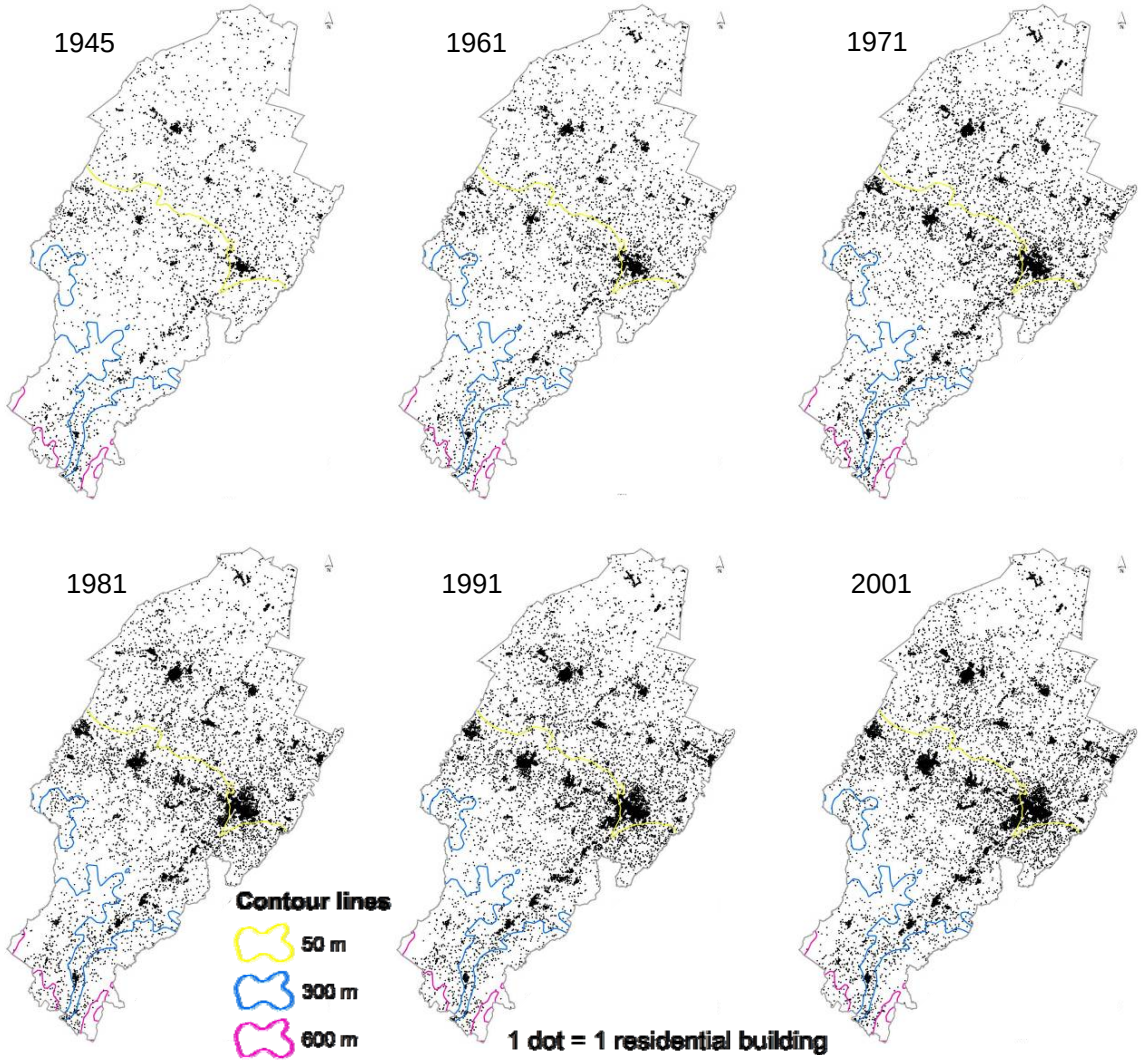

Figure 5. Evolution of the number of residential buildings in the New District of Imola (Italy) from 1945 to 2001 (cumulative values).

These patterns confirm those of a more general nature and scale encountered for the provincial territory. The differing speed and consistency of the increase in residential buildings in the various altitude bands of the study area are shown in figure 6, where there is a sharp increase in building in lowland (with altitudes of 0 to 50 m) and foothill areas (from 50 to 300 m above sea level).

As an initial reference value, the figure shows the density of residential building built before 1919, the first time threshold contemplated in the most recent ISTAT census considered. This very clearly demonstrates the change in pace with which residential building proceeded since the end of the Second World War, compared to the previous period.

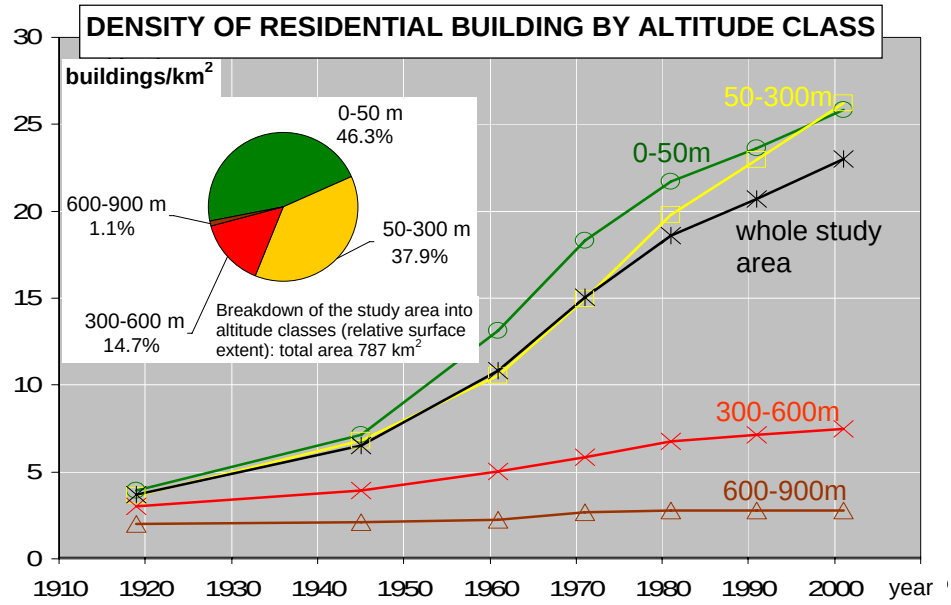

Figure 6. Building density patterns in each of the four altitude bands of the New District of Imola (Italy) and average trend throughout the territory. The insert shows the breakdown of the study territory area into altitude classes.

The same study area was the subject of further specific investigations aimed at a more detailed quantification of the two main urban growth pattern reading variables - building density and population density - and to define their respective distribution over the territory. The reading of the results obtained in the density maps in figure 7, can be directed by considering certain criteria defined by super-national organisations for the discrimination between rural and urban areas.

In particular, we can firstly refer to the European Environment Agency (EEA), an organisation which includes 32 member countries within the European Union members or candidate member States and the European Economic Area, and 6 collaborating countries within the West Balkan countries and the former Yugoslav Republic of Macedonia. The EEA aims to support sustainable development and to help achieve significant and measurable improvement in Europe's environment through the provision of timely, targeted, relevant and reliable information to policy making agents and the public. The EEA defines urban morphological zones as those areas in which built-up areas are positioned at mutual distance of no more than 200 m (European Environment Agency, 2006), the maximum limit that we have thought interesting to translate into a minimum threshold in terms of building density. Such translation proved to be useful in order to interpret the value proposed by the EEA by means of the results of the analysis performed, whose processing method considers a continuous building density surface. We could evaluate this minimum equivalent threshold at a density of 25 buildings/km^2, within approximation limits consistent with the aims of the study.

At the same time, the OECD (1994, 1996) uses a population density of 150 inhabitants/km^2 as the discrimination threshold below which a territory is considered rural.

The above discrimination criteria were designed and are commonly used for national and super-national contexts and therefore represent rough indicators that are effective when

adopted in relation to elementary areas of a municipal or higher scale. They are, in any case, reference values that may constitute a useful support for the reading of the maps in figure 7, in which the processing, conducted according to the methodologies described in paragraph 2, were performed using sub-municipal dimension calculation areas. These maps provide virtual three-dimensional renderings of the respective density surfaces, where the third dimension indicates the value of this quantity.

The building density chart (figure 7a) shows that the diffuse urban territory, i.e. the extraurban areas with building density higher than 25 buildings/km^2, corresponding - within the above approximation limits - to those that can be identified as urban morphological zones according to the European Environment Agency criterion, has no solution of continuity for an important band of the study area. This stretches from the foothill area south of the via Emilia as far as via San Vitale, including the main towns in the study area (figure 2) and overall, represents some 54% of the whole territory considered.

The population density map (figure 7b) shows that the areas characterised by values lower than 150 inhabitants/km^2 (the equivalent of the OECD threshold mentioned above) overall affect 86% of the study territory. In the remaining areas, which substantially coincide with towns of primary and lesser importance, there are high spatial gradients of the variable examined.

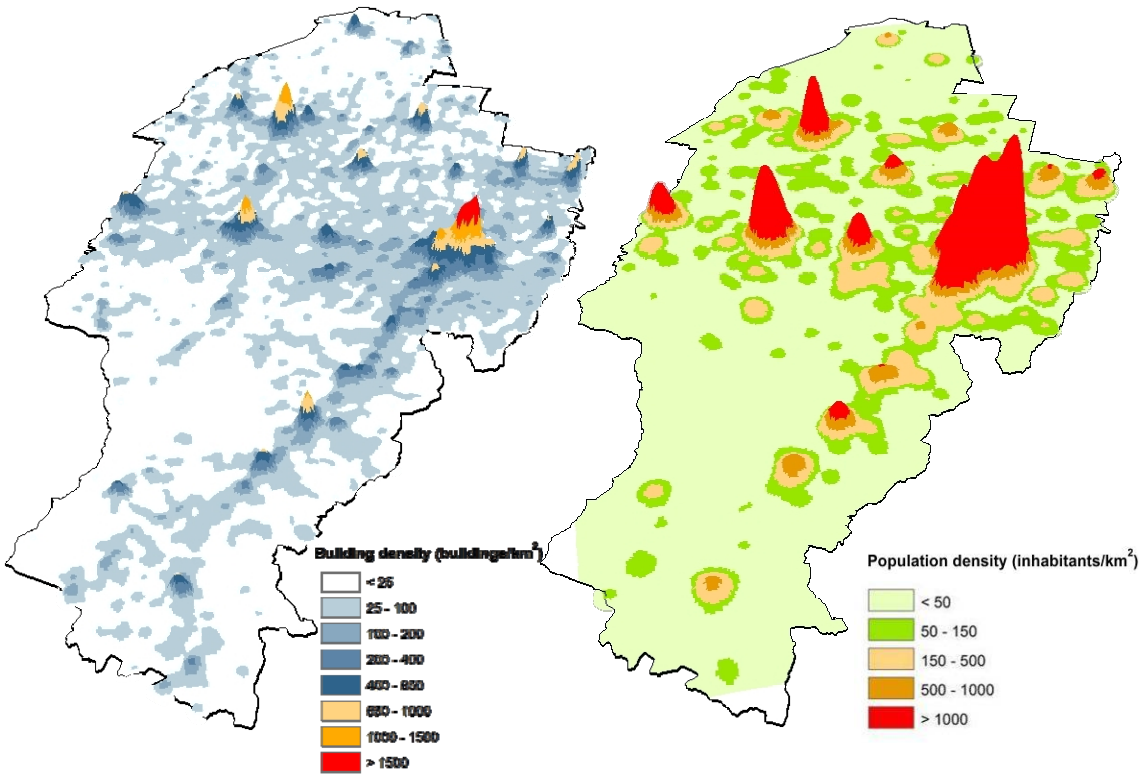

Figure 7a.
Building density map for the study area

Figure 7b.
Population density map for the study area

By comparatively analysing the inhabitant density and building density variables, whose aforesaid threshold values are provided in figure 8, we can see that the areas having

population densities of over 150 inhabitants/km^2 are almost entirely (96%) within the areas characterised by building densities higher than 25 buildings/km^2. Conversely, there are vast areas of the latter (equal to 41% of the entire study territory) with population density values lower than the aforesaid OECD threshold.

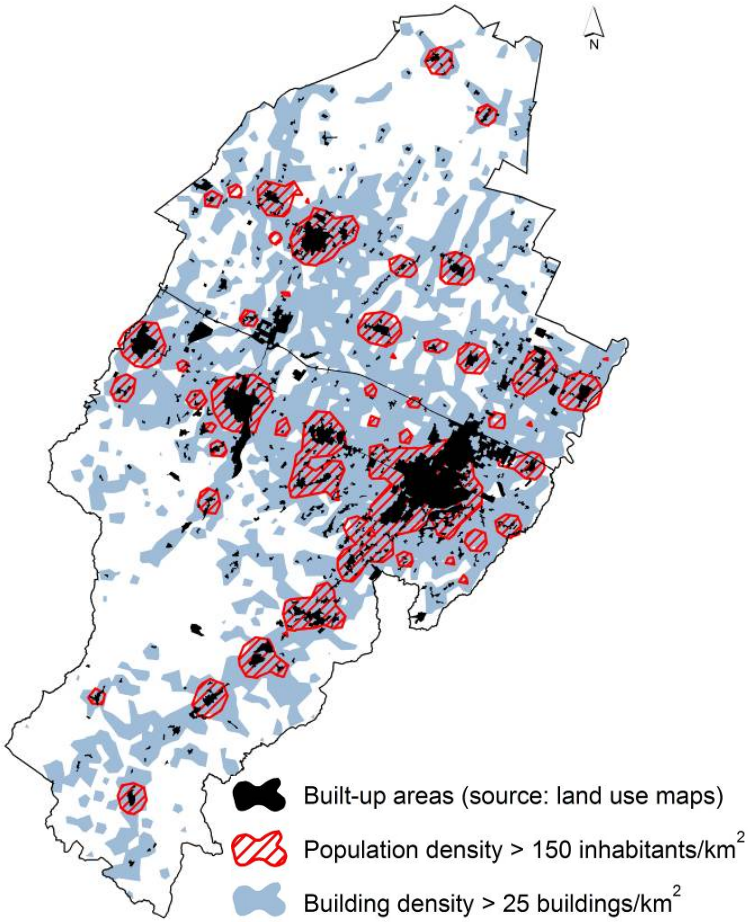

Figure 8. Comparison between the building and population density thresholds.

Urban areas were then considered jointly (figure 8), as shown by the most recent land use maps, in order to evaluate their extent and spatial distribution, also as regards the perimeters deriving from the abovementioned thresholds.

The processing performed demonstrated that:

- these urban areas cover a total of 7% of the study territory;
- 43% of them are characterised by population densities of less than 150 inhabitants/km^2;
- 94% of them have a built-up system density higher than the 25 buildings/km^2 threshold;

In particular, the charts of figure 9 show the distribution of current land uses, computed in accordance with the same classes already considered in the provincial level analyses, in areas having population densities of over 150 inhabitants/km^2 and in those characterised by building densities higher than 25 buildings/km^2 and population density lower than the OECD threshold respectively. The former areas show a great incidence of artificialised territories, which is about half of that of agricultural land; the latter are characterized by a lower, although still

significant, incidence of urban settlements, and vice versa by a wider portion of agricultural and forestry areas, which together take up thirteen times the space of urbanized areas.

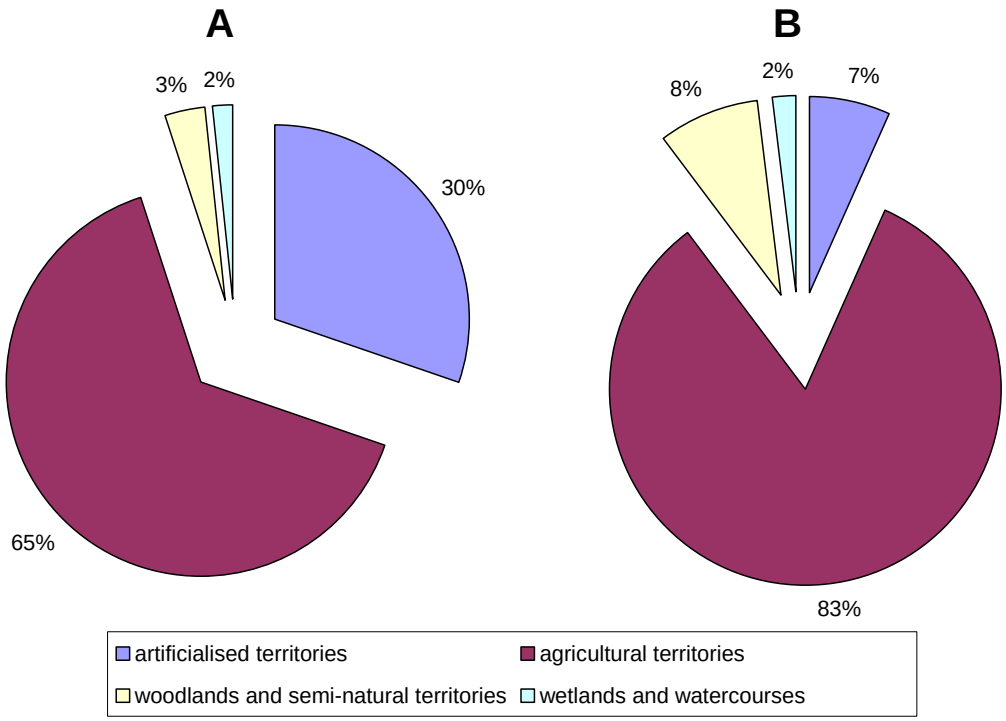

Figure 9. Distribution of current land uses in areas having population densities of over 150 inhabitants/km^2 (A) and in those having building densities higher than 25 buildings/km^2 and population density lower than 150 inhabitants/km^2 (B).

Examples of this type of areas are represented by those that belong to extended conurbation systems (such as those along the Santerno valley and Via Emilia), where we can survey a certain spatial continuity in housing developments (figure 10), together with both residential and agricultural scattered settlements.

We thus observed that large portions of study territory are classified as non-built-up according to the indications provided in land use maps and at the same time, have population density values higher than the OECD threshold (9.5% of the whole study territory), or rather a built-up system density higher than the 25 buildings/km^2 threshold (47.5% of the study territory).

The in-depth study of the characteristics of these areas would call for further specific investigations, for which more detailed data and on site surveys would be needed aimed at checking the real use of the scattered built system.

The processing performed made it possible to observe that the parameters investigated using the integrated analysis of the different sources considered may constitute useful references in contributing to the devising of more complex methodologies aimed at identifying periurban contexts.

In particular, the above-mentioned results showed how the different thresholds considered prove to be distinct and complementary, since they allow different investigation abilities: housing density gives an effective description of spatial patterns of suburban landscapes and

of extra urban settlements; population density gives information about the actual spatial distribution of inhabitants. Their integrated use is thus needed in order to assess the efficiency of settlement systems with reference to land consumption and sprawl issues, as we already mentioned in paragraph 3.1.

Figure 10. A detail of part of the super-municipal study area (along the Santerno valley).

Further in-depth studies should test their joint use and their complementarity to those parameters which consider other socio-economic, agricultural, landscape and environmental aspects, and should aim at calibrating such parameters on the specific study cases. Among the main investigations that are necessary to such objective we may quote the spatial analysis of the qualitative and quantitative farming intensity, of the importance and integrity of landscape characters, of ecological and environmental values, and of interferences and interactions with the settlement and productive systems.

3.4. The Expansion of Urban Centres: the Municipality of Imola Case Study

The analysis of the evolution of the development fabric and its contemporary arrangement in relation to the urban sprawl mentioned previously, can be usefully integrated by a more specific and greater detailed evaluation of development patterns in the main urban centres. To this end, the dilation of the built-up perimeter of the capital city of the municipality of Imola was analysed (figure 1). This analysis, a synthetic processing of which is shown in figure 11, made it possible to highlight certain significant details of the so-called expansion process, a phenomenon that has rapidly become important partly due to the lively industry and service production sectors, in a more general context in which the agricultural sector still maintains a very significant and consolidated presence even in interstitial periurban contexts. With this regard it should also be remembered that, conversely to the result recorded in the general characteristics of the provincial territory, the municipality of Imola has always recorded

positive demographic growth trends, which have led to an increase in population from 45 350 in 1951 to the current population of 66 340 (source: ISTAT).

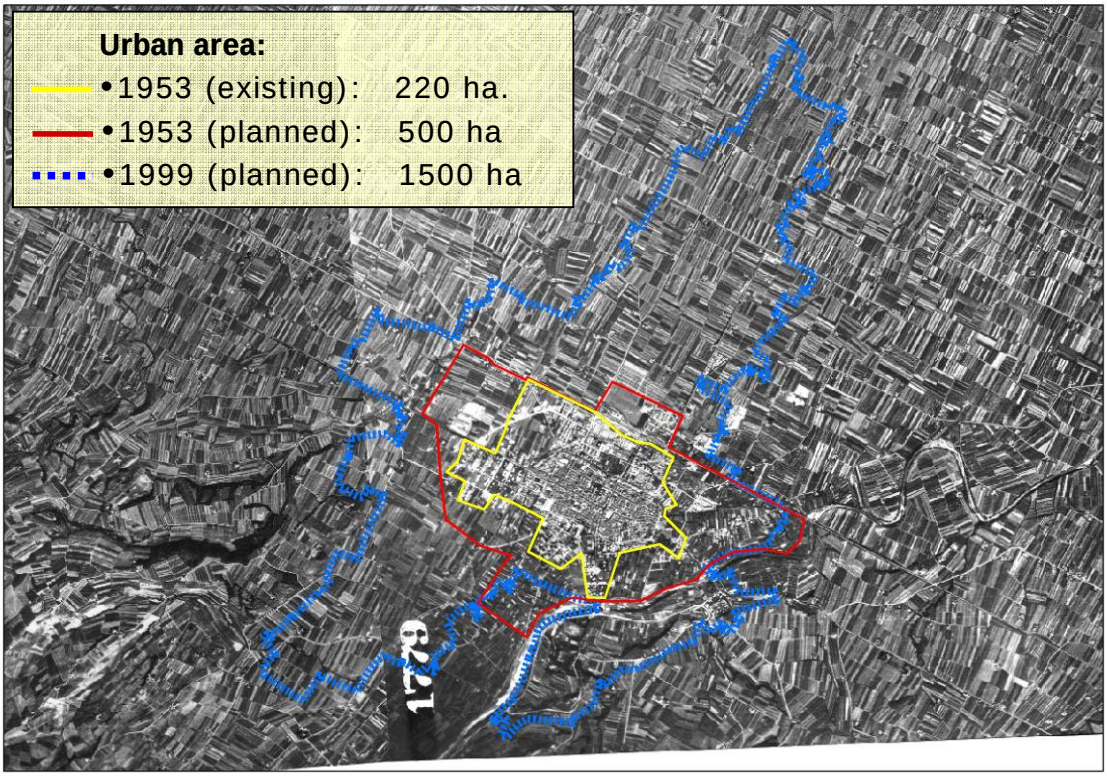

Figure 11. Expansion of the city of Imola's built-up perimeter according to the municipal development plans in various eras, shown on the basis of the aerial photographs of the territory from 1954.

The province of Bologna, on the other hand, underwent initial demographic growth from 1951 to 1971, followed by a slight reduction in the following two decades and then a recovery that currently confirms an increase of almost 5% over the past fifteen years. Within the New District of Imola, Imola is the only municipality never to have experienced negative growth rates and is also the main factor in the District's result of never having recorded a negative balance.

Firstly, it should be pointed out that the extent envisaged for the city in the general variant to the General Building Regulations Plan of 1999 is equal to almost 7 times that referring to the actual status documented in the 1953 plan. The compact shape of the city reported in 1953 was still slightly larger than the city walls, which date from the fourteenth century and of which only the odd trace now remain, following their almost total destruction in the late 1800s as a consequence of the city's new urban development.

The planned growth of the 1950s led to a geometrical expansion of the city and maintained its compactness, whereas its physical growth in more recent decades led to greater dispersion, characterised by fringes, filaments and sprawl phenomena. This type of arrangement contributed and continues to contribute to the formation of a system of agricultural fragments with a non-negligible overall entity, in terms of both extent and repercussions on a productive and environmental level.

4. CLOSING COMMENTS

The processing performed on the Italian study territories revealed how the integrated analysis of variables regarding the density of urbanised land and inhabitants allows a highly accurate description of development arrangements and their evolution.

The study thus shed light on the extent of land consumption for development purposes both as part of the current scenario and in terms of an increase compared to recent decades. These values are in line with those observed in other European situations through the analysis of scientific literature and shed light on the common need to adopt suitable sector policies aimed at rationalising land use and restricting the consumption of new resources. In actual fact, despite the progress achieved in recent decades in terms of both knowledge and legislative instruments on town/territorial planning issues, the planned transformations have often been implemented with a high consumption of environmental resources and producing the aforesaid effects of urban sprawl and landscape fragmentation.

Given the breadth of the general topic considered and the numerous critical aspects with their structured interaction, that have characterised and continue to characterise periurban contexts, the basic processing presented constitutes the instrumental bases for further conceptual investigations aimed at an interpretational synthesis requiring interdisciplinary contributions. Of these, a primary role would be played by economic and sociodemographic experts, with a view to developing methods that can be used as the cognitive tools supporting policy able to promote territorial specificity.

In this context this basic processing, besides leading to results that confirm trends and phenomena already known and generally applicable in the European context and identifying specific elements and patterns of the study areas surveyed, made it possible to formulate innovative methodological suggestions.

The current structure of periurban, fringe and urban sprawl areas is in many cases the result of transformations that took place in periods in which town planning legislation had long since envisaged the planning of the urban and rural territory and building activity regulation. The investigations performed therefore show how the building initiatives undertaken by private and public subjects within the planned urban-territorial scenarios translated in the medium-long term into landscape arrangements burdened by a structured situation of criticality. Overall, the realisation of these structural and infrastructural works, of which we now read the outcome in terms of an overall loss of landscape quality, has in many cases failed to achieve the quality of life levels that were at length thought as possible by both common people and public institutions through the diffusion of periurban development. The loss of integrity and identity suffered by those places that have been disrupted by certain forms of urban expansion and sprawl therefore represents the main reason for the deterioration of these contexts.

A new awareness of the limits that these territorial configurations present and the many problems this urban development arrangement is unable to tackle therefore has be formulated and diffused.

In ultimate analysis, the current situation presents both citizens and policy-makers with the urgent need to upgrade periurban landscapes, for which there are currently no codified and adequately mature intervention models. We also sense the need for a system approach that considers the relationships between urban space and rural areas and that leads to an authentic invention of new planning and programming criteria calling for creation and recognition on the periurban territory of certain cornerstones of human space organisation.

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The basic technical geodata was provided by the Emilia-Romagna Regional Cartography Archive.

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The map data relating to the 2001 ISTAT population census was provided by ISTAT.