Multi-temporal analysis of urban and peri-urban land use changes in medieval towns of central Italy

Análisis multi-temporal de los cambios de uso de la tierra de las zonas urbanas y periurbanas en ciudades medievales del centro de Italia

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Fecha de recepción: 27-XI-2012 – Fecha de aceptación: 31-X-2013
Hábitat y sociedad (ISSN 2173-125X), n.º 7, noviembre de 2014, pp. 77-92.

Summary
Due to the reckless urbanization occurred in recent years, some towns of medieval origin risk to loose their architectural and social identity. In order to highlight the modifications occurred in the last 80 years, we studied the land use changes in the urban and peri-urban zones of two small medieval towns of central Italy (Viterbo province, Lazio region), performing a multi-temporal investigation by means of the photogrammetric restitution of historical flights (1934-2010). Results showed that inside the city walls a variable number of green spaces and small backyards remain in 2010 and in the suburban areas residual agricultural activities, mainly the cultivation of fruit and vegetables, probably for local market and/or home consumption. Urban planning should take into account these elements, in order to enhance the functional links among urban and agricultural areas, as relevant trade-offs for maintaining urban gardening and for a subsistence economy. The maintenance of these important habitats can help to preserve the historical peculiarities of medieval towns and to improve the quality of life of urban residents.

Key words
Urban morphology, historical landscapes, GIS, community allotments, urban agriculture

Resumen
Debido a la urbanización irresponsable ocurrida en las últimas décadas, algunas ciudades de origen medieval han visto perder su identidad arquitectónica y social. Con el fin de poner de relieve estas modificaciones, se estudiaron los cambios de uso del suelo en las zonas urbanas y periurbanas de 2 pequeñas ciudades medievales del centro de Italia (provincia de Viterbo, región de Lazio), a través de la realización de una investigación multi-temporal de la restitución fotogramétrica de los vuelos históricos (1934-2010). Los resultados mostraron que en el interior de las murallas de la ciudad un número variable de espacios verdes intersticiales y pequeños patios siguen existiendo en el año 2010 y en las áreas suburbanas perviven actividades agrícolas residuales, principalmente el cultivo de frutas y verduras, probablemente para el mercado local y/o el consumo doméstico. La planificación urbana debería tener en cuenta estos elementos, a fin de mejorar los vínculos funcionales entre las áreas urbanas y agrícolas, como las compensaciones pertinentes para mantener la agricultura urbana y de una economía de subsistencia. El mantenimiento de estos hábitats importantes puede ayudar a preservar las peculiaridades históricas de las ciudades medievales y mejorar la calidad de vida de los habitantes de las ciudades.

Palabras clave
Morfología urbana, paisajes históricos, SIG, huertos urbanos, agricultura urbana

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1. Background and theoretical considerations

The conservation of social functionality of medieval villages and towns is, nowadays, a very important objective for urban planners and policy-makers. They present specific constructive characteristics, with a range of micro empty spaces, once used for urban agriculture, gardening and water provisioning, but now used for a range of other purposes. In this context, the process of urbanization that occurred after World War II contributed to substantial changes in the original structure of ancient cities, changing also the forms of suburban and peri-urban landscapes (Schneider and Woodcock, 2008). These are the result of human actions, such as political representation (Sonne, 2003), social interaction (Gehl, 2001), economic symbolism (Frampton, 1991) and economic materialization (Chen, 2012). Due to these influences, in many cases changes occurred very rapidly, often with no connection with past landscapes, but as a result of consecutive land reorganizations to better adapt its use and spatial structure to changing societal demands.

Particularly the complex process of urbanization, which brought people from rural areas towards the towns, has affected a large part of the European Union's territory and by 2020 approximately 80% of Europeans will be living in urban areas, while in seven countries the proportion will be 90% or more (EEA, 2006). Furthermore, while during the past the growth of the cities has been driven by increasing urban population, at present there is little or no population pressure but a variety of other factors (such as means of transportation, land prices, individual housing and lifestyle preferences, demographic trends, cultural traditions and constraints, attractiveness of existing urban areas, etc.) are driving the growth of urban areas. Particularly due to improved transportation links and enhanced personal mobility, which minimize the time requirements and distances going in-and-out of the cities, this expansion is occurring in a scattered way. Because of this on-going process, during the 20th century very intense and profound changes in rural landscapes occurred mainly in the proximity of towns and cities.

In order to better appreciate how and why these processes have affected or will affect structural and architectural aspects of the city and its surroundings, an increasing number of studies regarding morphology and micro-morphology have been realized. Studies regarding urban geography, architecture, planning and conservation (Larkham, 1996; Samuels, 1999) were conducted mainly with the aim to improve urban landscape management, policy-making and design (Chen, 2012), and to predict urban expansion patterns (Moghadam and Helbich, 2013). Results of these researches showed that in many cases urbanization had led to sprawl beyond the urban core into the city outskirts, with disperse population in low-density development and disconnected buildings (Ewing *et al.*, 2002). This phenomenon has caused the fragmentation of surrounding agro-ecosystems with a loss of important ecosystem services for the cities (Salvati *et al.*, 2012).

The resulting peri-urban space has its own peculiar structure and function, in such a way that it cannot be simply considered as the geographical space between the city and the countryside, but rather a space that differs from both of them (Meeus and Gulinck, 2008). According to this, it has been proposed to treat the peri-urban landscape as an unique biosphere, i.e. a complex landscape mosaic of natural and

agro-ecosystems of unique characteristics and transformation dynamics (Alfsen-Norodom, 2004).

Moreover, in developing countries the urbanization process goes along with increasing urban poverty, environmental pollution, growing food insecurity and malnutrition (Orsini *et al.*, 2013). Sprawling cities are the opposite of compact cities – they are full of empty spaces that indicate the inefficiencies in development and highlight the consequences of uncontrolled and unplanned urban development, characterized by a low-density mix of land uses in the urban fringe. The landscapes created by the transformation of the countryside around urban centres, referred to as "peri-urban" or "urban fringe" landscapes, are considered highly dynamic, but remain poorly understood and concentric models used to describe the shaping of landscape in the urban fringe seldom can explain their real dynamics (Antrop, 2000).

The technical and scientific approach to the study of temporal changes in urban and peri-urban morphological features usually consisted of studying ancient maps representing street networks, buildings and land use, or the urban fringe belts (Louis, 1936; Conzen, 1960; Whitehand and Morton, 2004). The use of GIS for the production of thematic maps, derived from ancient maps or from remotely sensed data which can represent both actual and past conditions, is a main element in understanding landscape dynamics as well as natural and anthropogenic processes (Pelorosso, 2009; Veettil and Zanardi, 2012; Salvati, 2014). However, the lack of high spatial resolution images in the past decades was a limitation to make comparisons.

Some recent researches have also focused on distinctive social and economic traits of old urban types. By means of example, we can cite studies on the sustainable agrarian and low-density urbanism of Maya and Aztec cities (Isendahl and Smith, 2013), the settlement system and the form of architecture and civil engineering and its effect on sustainable urbanization in Iran (Kameli *et al.*, 2013), or urban agriculture, gardening and water provision in Byzantine Constantinople (Barthel and Isendahld, 2013). The structure of some ancient cities are examples of sustainable urbanization and therefore can represent models for the construction of future ones.

The urbanism of medieval cities has been studied from the historic (Žunić and Matuhina, 2012), archaeological (Loska and Christensson, 2012) and social (Petrica, 2010) point of view, but it has been rarely studied with modern techniques (Leone *et al.*, 2008; Fichera *et al.*, 2011; Salvati *et al.*, 2012), especially concerning land use changes that occurred in the last century. The Middle Ages were the time of a great expansion of agriculture both in the spaces around the city, as well as in the inner *horti*. Some typical cultivations, like those of olive tree and grapevine improved in terms of agronomical techniques and transformation technologies, i.e. oil and wine production (Cortonesi, 2002).

According to historians, central and northern Italy was characterized by the city-states, with great fragmentation and spirit of autonomy (Vigneswaran, 2007) which lasted from the Middle Ages to the Renaissance (Chittolini, 1989). These strong municipal structures, with a well-established territorial consolidation, have given rise to specific urban forms, which were shaped by the administrative and political organization (Liddy *et al.*, 2012).

Life in medieval towns and free communes was closely related to suburban and peri-urban areas, where citizens cultivated the fields and raised animals for home consumption. The cities were surrounded by

walls and often defended by a moat, with the function of protecting the citizens from attacks by neighbouring towns or from invaders. In central Italy, during the Renaissance, many gardens were planned as complement of the nobiliary residences; the structure of these historical gardens included portions for fruit orchards and forest products (Botti and Biasi, 2009). This urban form is still remaining in many cities in central and northern Italy, although it has been adapted and shaped by different political, economic, social and cultural rights that have occurred over the centuries.

A historical perspective is desirable for the comprehension of landscape origin and transformation processes and for the identification of traditional landscapes. The detection of land use/land cover changes and the consequent analysis of landscape dynamics has become more and more important and it is fundamental to comprehend the genesis of contemporary landscapes and changes in these for the design of landscape-oriented policies.

Our study illustrates the change of land use and land cover in the urban, suburban and peri-urban area of two mediaeval towns of central Italy, using medium-resolution aerial photographs of 1934, 1954 and 2010. While agriculture maintains its primary role in the rural spaces, in the urban and peri-urban space additional functions and forms arise. In developing countries urban agriculture still retains its function of producing food for the urban population (Gianquinto Prosdominici and Tei, 2010). In the European countries urban agriculture instead produces services, and especially ecosystem services, for the city (Zasada, 2011). Examples of these are counteracting the consumption or degradation of land, improving the quality of the atmosphere through carbon storage, preserving biodiversity, and maintaining cultural and social values. Against this background monitoring the transformation of land use inside and around the cities would represent a strategic tool for a sustainable urban planning.

The comparison of peri-urban landscape patterns of different periods allows us to comprehend present-day landscapes and to highlight the persistence of historical backyard gardens and functional links between urban and agricultural areas. The use of images from 1934 is particularly interesting to understand how the morphology of the medieval town has evolved over the last 80 years. In 1935, the Italian Land Register Department commissioned the survey of the whole Viterbo province (352,000 hectares) through aerial photographs. This material, forgotten for a long period, was recently rediscovered and moved to the Viterbo State Archive. This is by far the oldest Italian example (and one of the oldest in the world) of a large aerial photograph survey systematically covering a wide, continuous region. Furthermore, the photos were taken at a very low altitude, thus featuring a very high resolution. Thus, they are an invaluable resource to study the historical development of cultural and natural landscapes in Central-Italy (Ciapanna, 2012; Ripa *et al.*, 2013).

2. Description of the analyzed cities

The sites of the ancient cities in the Viterbo province (Lazio region, Italy) are among the most significant medieval testimonials of central Italy. The province is bordered to the north by the provinces of Grosseto and Siena, in the northeast with the provinces of Terni and Rieti,

in the west by the Tyrrhenian Sea and in the south by the province of Rome. This province is often unofficially (but commonly) called "Tuscia', from the name of the larger roman region of Etruria. It is an area of 3,612 km², and a total population of 300,000 inhabitants. There are 60 municipalities in the province, the majority of them of medieval origin.

For the purposes of this work, we have studied the structure of the urban and peri-urban space of two of these municipalities: Vitorchiano and Oriolo Romano (**Fig. 1**). We can consider these two cities sufficiently representative of central Italian medieval towns, for example their urban centres have grown slowly over time according to a precise and shared urban concept, although going back to a geometric pattern (Oriolo Romano) or with regular structures determined only by the topography of the site (Vitorchiano). However, the two municipalities are quite different both in terms of environmental characteristics (geology, morphology, vegetation) and from a socio-economic point of view, which is reflected in the shape of the towns and their settlement model. The town of Vitorchiano is situated very close to the city of Viterbo on a tufaceous bank and also during the past centuries remained more closely linked with the main town which is nowadays reinforced by infrastructural networks. Oriolo Romano is more connected with Rome and it represents an uncommon example of ancient urban planning, in fact, the ancient town was designed by Vignola from 1560 onwards. Due to these peculiarities, different models of growth and different urbanization trends are expected.

Figure 1: Location of the studied medieval cities.

These two medieval towns have also been selected for the representativeness of their agricultural land use. This is based on the cultivation of the most typical crops of the Italian traditional landscape, i.e. viticulture, olive groves and arable crops, as well as on the presence of historical gardens that are potentially important sites for the cultivation of many species and the preservation of agrobiodiversity.

2.1. Vitorchiano

Vitorchiano owes its name to the old Etruscan town Vicus Orclanus, which would reveal a supposed dependence from the center of Norchia (or Orcla) at Vetralla, a sacred place dedicated to the Etruscan goddess Norzia. The city (285 metres above sea level, 4,800 inhabitants) is situated among the Cimini mountains in the green Vezza valley, just 7 km from Viterbo and 90 km from Rome. The cliff of Vitorchiano was already inhabited during the Bronze Age, and successively by Etruscans and Romans and then became a fortified urban centre in the southern part of Tuscia Longobardorum.

Vitorchiano expresses centuries of history influenced by the long and powerful expansionist policy of the nearby city of Viterbo. In 1232 the people of Viterbo took over the country and devastated it. In later

years the fortifications of the city by Giovanni Annibaldi were commissioned, which still exist. The urbanistic scheme is radiocentric, presenting a circular contour with radial or concentric roads. This old mediaeval town is famous for a typical grey stone (*peperino*) that is used since the Etruscan age for buildings and other artistic activities. A hilly landscape with wood lands and rivers with a rich wild fauna and flora characterize the surroundings.

Many roads and paths cross these hills and wood lands, making Vitorchiano an ideal place for nature tourism and leisure. Added to the beauty of the landscape are the outstanding typical quality products such as mushrooms, olive oil, nuts, wines, cheeses and hams. The whole territory is extremely rich of expressions of its ancient historical heritage, above all that from Etruscan, Roman and Medieval times.

2.2. Oriolo Romano

Oriolo Romano has about 3,500 inhabitants and is located about 400 m above sea level among the Sabatini mountains, 53 km from Rome and 39 km from Viterbo. The territory stretches over a hilly area full of forests with tall trees, along the Via Clodia, an old road that connected the north of Rome with Saturnia.

The original urban structure of Oriolo Romano has a precise geometric configuration with an ideal center, which is the Palazzo Altieri of the family of Pope Clement X. The town is divided by a minor difference in ground level in two urban districts: Poggio and Borgo. In the lower part of town a beech forest is present. In 1573, in the west of the city, a water mill was built to enable the inhabitants to grind their grains. The urbanistic scheme is quite elementary, since the settlement developed in a linear way. This type of arrangement is present throughout Europe (in Germany it takes the name of *Langstrassendorf*) and in Oriolo Romano it also presents a widening of the road to form a square.

In both cities the increase in population has resulted in a change in urban planning, as the centre alone has not been able to absorb population growth. Since the 1980s new residential areas have been located on the outskirts of the villages, that can house more than two thousand people against the a few hundred that the historic centres accommodate.

3. Research design and methods

With the aim to detect changes in urban, suburban and peri-urban land use and land cover of these two towns, a multi-temporal approach of analysis was used. To better investigate the totality of the transformations, the dynamics of land use in an area of 1 km from the city centre were studied, using aerial images acquired approximately every twenty years, from 1934 to 2010. More specifically, we have used black and white images from 1934 (S.A.R.A. Nistri), 1954, 1971 and 1989 (Istituto Geografico Militare Italiano) and color images from 2010 (A.G.E.A.) (**Figs. 2 and 3**). Particularly interesting are the 1934 and 1954 images, because they represent a kind of "window on the past" with a presumably unchanged land use over the centuries before the beginning of industrialization and the implementation of agricultural policies at national and international level.

All images were georeferenced and orthorectified using ArcGIS® software by Esri. Photo-interpretation of the main uses and land cover

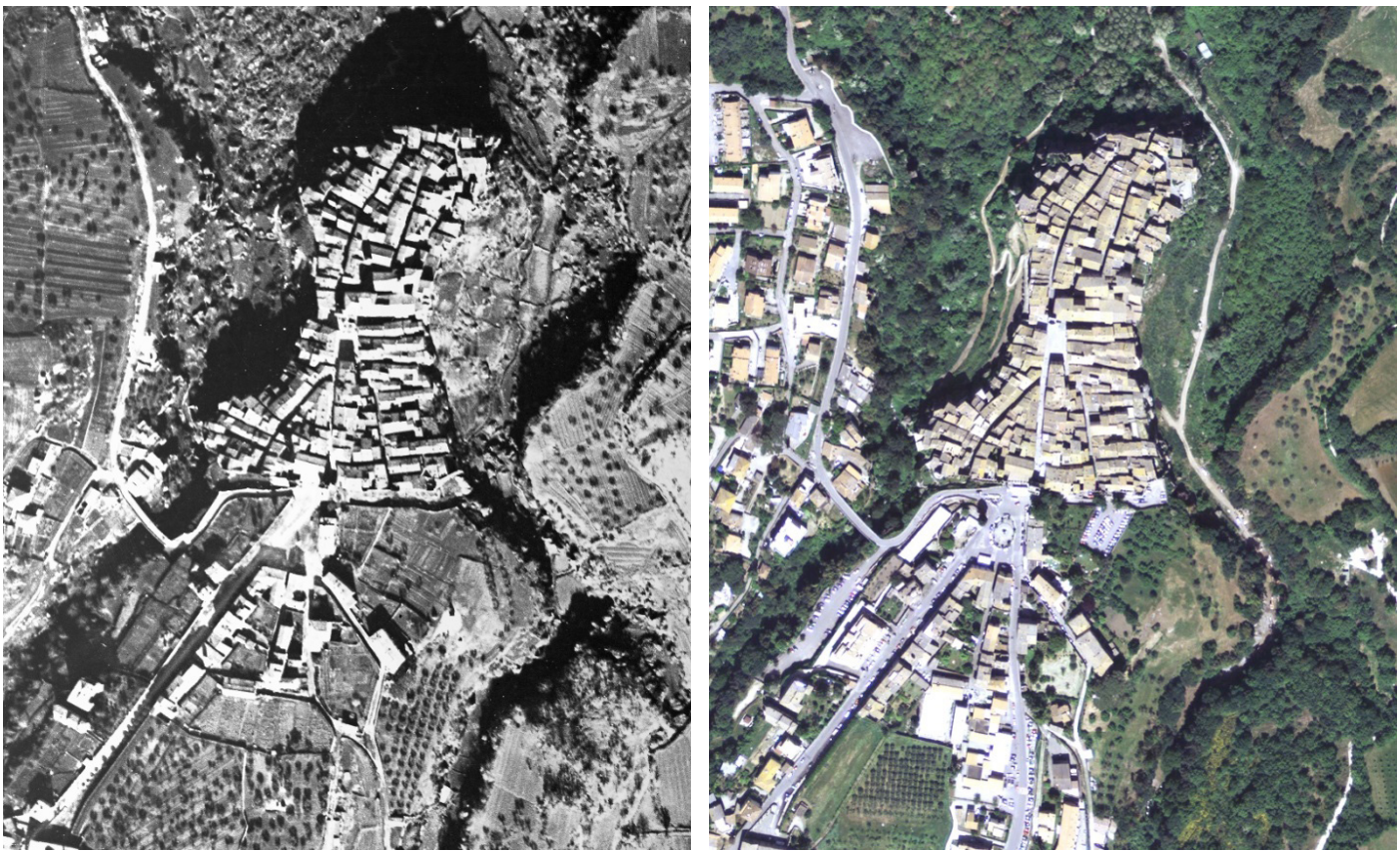

Figure 2: Detailed maps of Vitorchiano (1934 on the left and 2010 on the right).

Figure 3: Detailed maps of Oriolo Romano (1934 on the left and 2010 on the right).

for each flight were performed according to the Corine Land Cover nomenclature (4th level), as shown in **Box 1**, in order to ensure homogeneous spatial information. The scale of interpretation and classification is 1:1,000, since aerial photos with good resolution were used. The classes represent urban (1), crop land (2) and natural (3) land uses as macro-categories. Other classes, like bare surface or water bodies, have not been included because they have not been considered significant within the study area.

The two study areas were overlaid with a grid of hexagons in order to take advantage of their compact and regular form (De Clercq e*t al.* 2007). The area of each hexagon measured 0.1 ha, thus resulting in 4,405 hexagons for Vitorchiano (440.57 ha) and 4,966 for Oriolo Romano (496.69 ha). The land cover of each hexagon has been calculated in m^2. The hexagons were the statistical units. A dynamic matrix of soil uses was implemented, reporting information about the change of cropland, natural and urban land use for each unit pixel area.

Land use classes	**Code**
Continuous and discontinuous residential units	1
Scattered residential units	1123
Main and secondary roads	1221
Arable land	21
Orchards (intensive cultivation)	22
Orchards (extensive cultivation)	24
Woods	31
Bushes and shrubs	32

Box 1: Land use classification. Code numbers refer to Corine Land Cover classification (4th level).

3.1. Statistical analysis

All the data and graphic representations were implemented in MS Excel 2013® (Microsoft Corporation, Redmond, USA) spreadsheets. The statistical analysis of the data were performed using STATISTICA 7.0 (StatSoft Inc., Tulsa, USA) software package. The factorial analysis of all the dependent variables for the categorical predictors was conducted using a GLM-type approach, in order to describe variability among the observed and correlated variables, in terms of a potentially lower number of unobserved variables (factors).

The significance of the differences was tested using the F statistic. Within the relevant factors, the differences were evaluated using the Fisher LSD test (Lowest Significance Differences). A residual probability value of 5% (P=0.05) was adopted as the minimum level of significance.

Dynamics of soil use changes were valued for the four reference intervals (1934-1954; 1954-1971; 1971-1989; 1989-2010) and for the entire period (1934-2010), using cross tabulation process of ArcGis 10.1 (ESRI, Redlands, CA, USA).

4. Results and discussion

The results obtained indicate that the process of urbanization has substantially changed the land use in the two study areas, with a significant

Oriolo Romano				
To / From	Urban	Crop-land	Natural	1934
Urban	**43,94**	0,28	0,00	44,22
Crop-land	4,48	**255,74**	6,13	266,35
Natural	0,32	8,82	176,98	186,12
1954	48,74	264,85	**183,10**	496,69
To / From	Urban	Crop-land	Natural	1954
Urban	**48,16**	0,51	0,07	48,74
Crop-land	22,58	**213,93**	28,25	264,76
Natural	3,74	3,54	**175,63**	182,91
1971	74,48	217,98	203,95	496,69
To / From	Urban	Crop-land	Natural	1971
Urban	**71,10**	2,62	0,76	74,48
Crop-land	30,98	**165,44**	21,40	217,82
Natural	5,68	12,26	**185,98**	203,92
1989	107,76	180,32	208,14	496,69
To / From	Urban	Crop-land	Natural	1989
Urban	**99,72**	4,41	3,63	107,76
Crop-land	34,75	**120,59**	24,98	180,32
Natural	13,30	14,52	**180,32**	208,14
2010	147,77	139,51	208,93	496,69
To / From	Urban	Crop-land	Natural	1934
Urban	**42,31**	0,73	1,19	44,23
Crop-land	92,52	**129,58**	44,25	266,34
Natural	13,09	9,49	**163,54**	186,12
2010	147,91	139,80	208,98	496,69

Vitorchiano				
To / From	Urban	Crop-land	Natural	1934
Urban	**34,07**	0,09	0,02	34,18
Cropland	1,53	**295,09**	7,46	304,08
Natural	0,60	1,18	**100,54**	102,32
1954	36,20	296,36	108,01	440,57
To / From	Urban	Crop-land	Natural	1954
Urban	**35,50**	0,35	0,35	36,20
Cropland	7,31	**277,13**	11,92	296,36
Natural	3,37	9,72	**94,92**	108,01
1971	46,18	287,21	107,19	440,57
To / From	Urban	Crop-land	Natural	1971
Urban	**45,24**	0,83	0,11	46,18
Cropland	14,93	**263,42**	8,87	287,21
Natural	4,85	10,24	**92,09**	107,19
1989	65,02	274,49	101,07	440,57
To / From	Urban	Crop-land	Natural	1989
Urban	**57,85**	4,13	3,04	65,02
Cropland	39,05	**213,49**	21,95	274,49
Natural	11,02	13,56	**76,48**	101,07
2010	107,92	231,19	101,47	440,57
To / From	Urban	Crop-land	Natural	1934
Urban	**29,86**	2,42	1,89	34,17
Cropland	61,93	**209,93**	32,22	304,09
Natural	16,13	18,84	**67,35**	102,32
2010	107,92	231,19	101,47	440,57

Box 2: Changes for the defined land cover types: dynamics from 1934 to 2010 in the two areas (area in ha).

transformation in the types of coverage. **Box 2** represents the transition matrix for each macro-category in the chosen intervals. The values (in ha) shown along the diagonal (bold character), represent the areas in which there has been no change, while other cells contain the estimates of the areas that have undergone a transformation.

Figure 4 shows the dynamics of changes that occurred during the four reference time intervals (1934-1954; 1954-1971; 1971-1989; 1989-

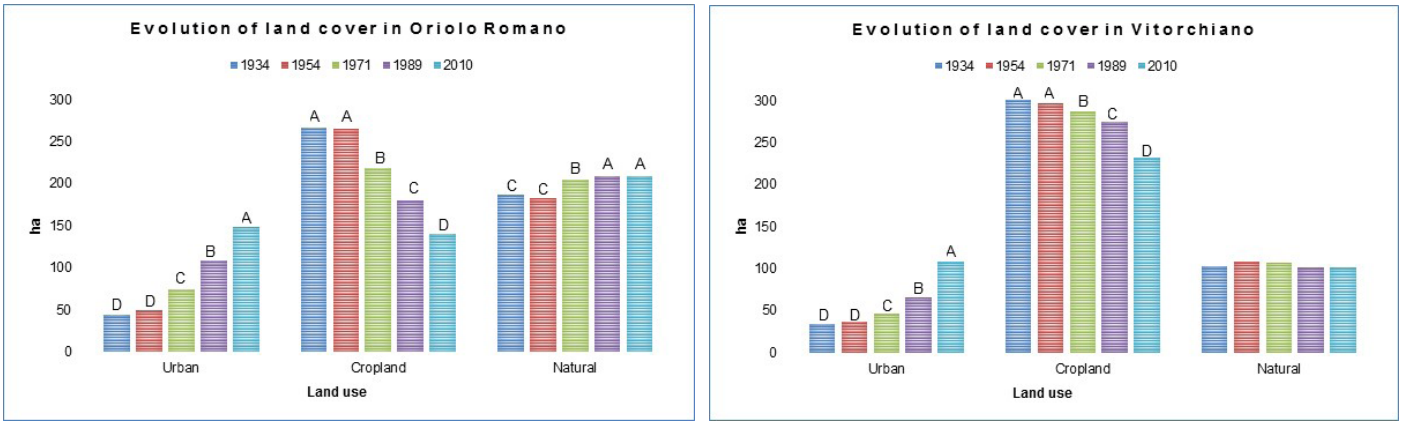

Figure 4: Dynamics of changes during the reference intervals (area in ha) in the two study areas (A, B, C, D, E denote significant differences at P<0.001)

2010). The study of the detailed categories of land use (**Boxes 3 and 4**) highlights that within the category "urban" the increase of scattered residential units plays a significant role after 1954. For the class "crop land" an increase in intensive orchards was noted, with a reduction of arable areas and extensive orchards. For the class "natural" an increase of woods was noticed, while bushes and shrubs were strongly reduced.

To / *From*	1	1123	1221	21	22	24	31	32	LC types subtotals [1934]
1	**25,48**	0,33	7,18	0,37	0,00	0,00	0,35	0,03	33,75
1123	1,91	**1,05**	0,11	0,28	0,04	0,00	0,25	0,00	3,64
1221	0,59	0,15	**5,50**	0,04	0,00	0,00	0,54	0,01	6,84
21	39,85	26,76	0,46	**86,86**	9,30	0,83	21,99	11,58	197,63
22	0,02	0,11	0,00	0,63	**0,00**	0,00	0,18	0,12	1,06
24	13,82	11,39	0,12	23,52	8,20	**0,24**	6,78	3,59	67,65
31	4,27	1,40	0,68	1,23	0,55	0,00	**140,45**	1,76	150,34
32	1,58	4,13	1,03	6,66	1,05	0,00	15,49	**5,84**	35,77
LC types subtotals [2010]	87,52	45,31	15,09	119,58	19,14	1,07	186,05	22,93	Total area 496,69

Box 3: Total land cover change for the defined land cover types: Oriolo Romano dynamics from 1934 to 2010 (area in ha).

The massive transformation of land use from agricultural to urban began after 1954, in both towns. The surface of natural areas (forests and natural areas) remained almost unchanged, highlighting an increase in Oriolo Romano after 1954. During the four periods analyzed, the urban land cover type has almost triplicated (passing from 7.8% to 24.7% in Vitorchiano and from 9.1% to 30.0% in Oriolo Romano respectively), mostly to the detriment of cropland, which has suffered the major effects of the expansion of built-up areas (decreasing from 69.0% to 52.3% and from 53.6% to 27.9% in Vitorchiano and Oriolo Romano respectively).

One of the reasons of this conversion is the population growth of both cities. The resident population of the two cities has not undergone major changes until the 70s, but in the last 4 decades there has been a substantial increase, higher than the average regional and provincial levels. This is mainly due to the improvement of the road network that has allowed to connect them to the closeby larger cities (Rome and Viterbo), but also to the lower cost of living and houses and to different

To / From	1	1123	1221	21	22	24	31	32	LC types subtotals [1934]
1	**6,81**	0,69	0,19	0,00	0,02	0,00	0,04	0,05	7,80
1123	1,34	6,01	0,18	0,63	0,71	0,44	0,27	0,55	10,13
1221	0,16	0,60	13,89	0,22	0,34	0,07	0,81	0,17	16,24
21	9,91	11,36	1,03	33,41	22,94	4,01	11,51	8,34	102,51
22	2,97	1,81	0,30	6,15	8,08	2,51	0,54	0,18	22,54
24	10,45	23,12	0,98	52,09	57,09	23,66	5,67	5,97	179,04
31	2,09	1,83	0,39	1,92	3,84	0,18	37,73	4,72	52,70
32	5,21	5,97	0,63	5,01	7,44	0,46	16,43	8,47	49,62
LC types subtotals [2010]	38,94	51,38	17,59	99,41	100,46	31,32	73,01	28,46	Total area 440,57

Box 4: Total land cover change for the defined land cover types: Vitorchiano dynamics from 1934 to 2010 (area in ha).

housing requirements. Many people moved from the ancient houses of the historical towns towards new residential areas in the urban fringe that better meet the new needs of population.

In the territory of Vitorchiano the urban sprawl predominates over a compact growth of the town. This can be ascribed to the building of an important highway which crosses the territory of Vitorchiano and connects the city of Viterbo with an important highway junction. Nearby the highway, the development of some residential areas that can be quickly approached from the town has been promoted. Nevertheless, it must be noted that also in the photos of 1938 there is a dispersed presence of buildings, suggesting a different settlement pattern of which the origin could be looked for in the history of the territory. Additionally, in Vitorchiano we also detect an urban expansion which does not represent real population growth, because the new residential area is far more than a kilometer from the city centre and it is not covered in our study area.

Figure 5 shows the dynamics of changes in detailed categories that occurred during the studied period. The detailed analysis of changes

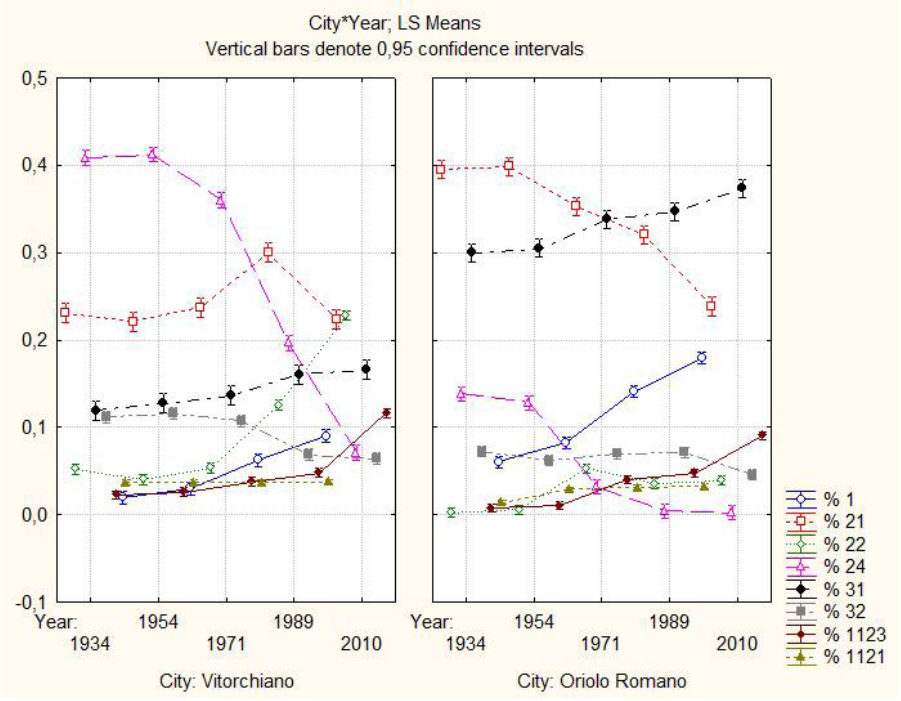

Figure 5: Dynamics of changes in micro-categories during the reference intervals (%) in the two study areas (significant differences are not shown).

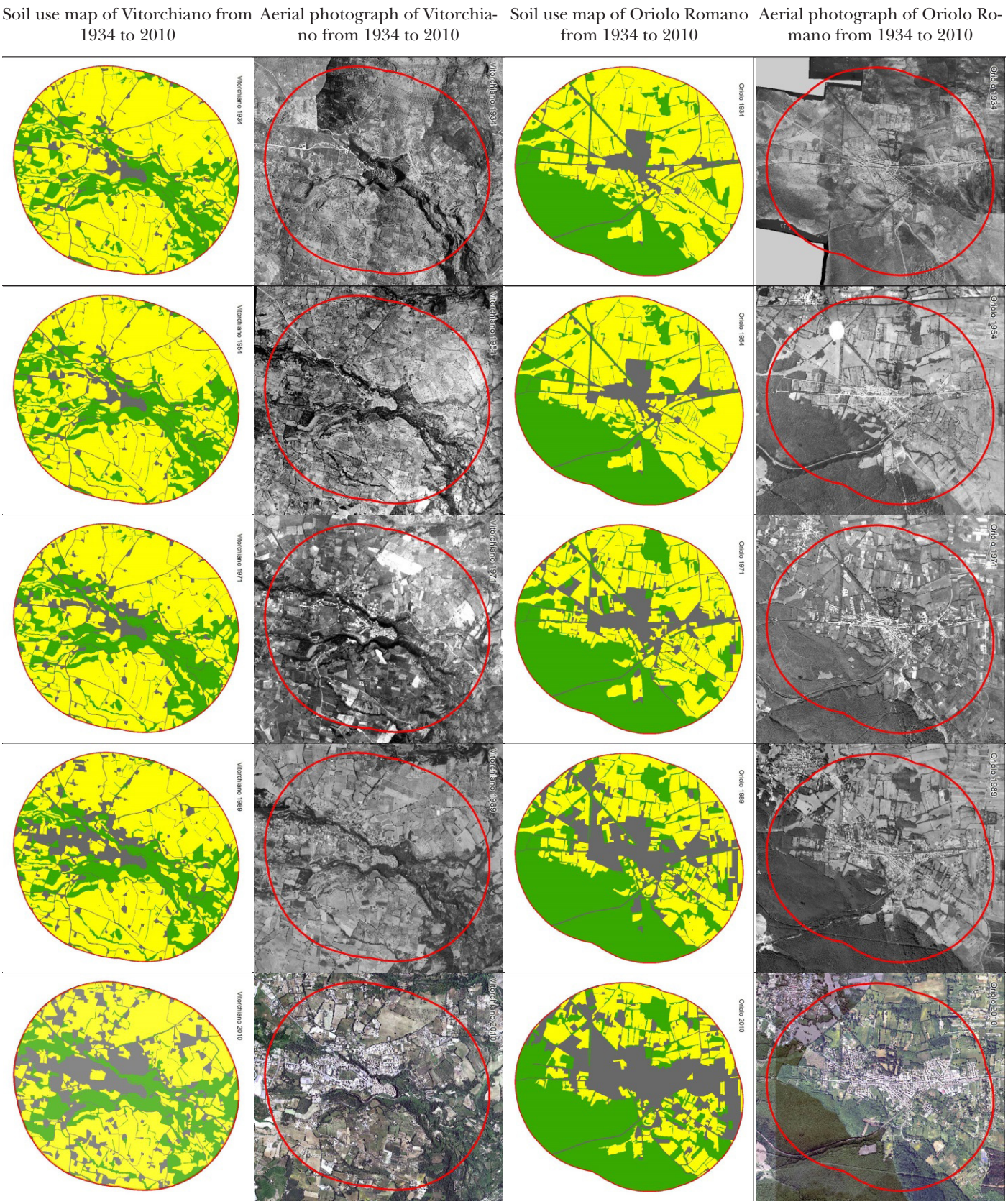

Figure 6: Images of study areas from 1934 to 2010. Land use map representing urban (gray), cropland (yellow) and natural (green) areas.

in land use classes shows that the percentage of continuous and scattered buildings is increased in both study areas since the 70s. The land use classes that significantly have lost presence are "extensive orchards" and "cropland", which have been replaced (apart from by buildings) by intensive orchards, especially in Vitorchiano. It also appears that the increase of wooded areas is determined by the expansion of original

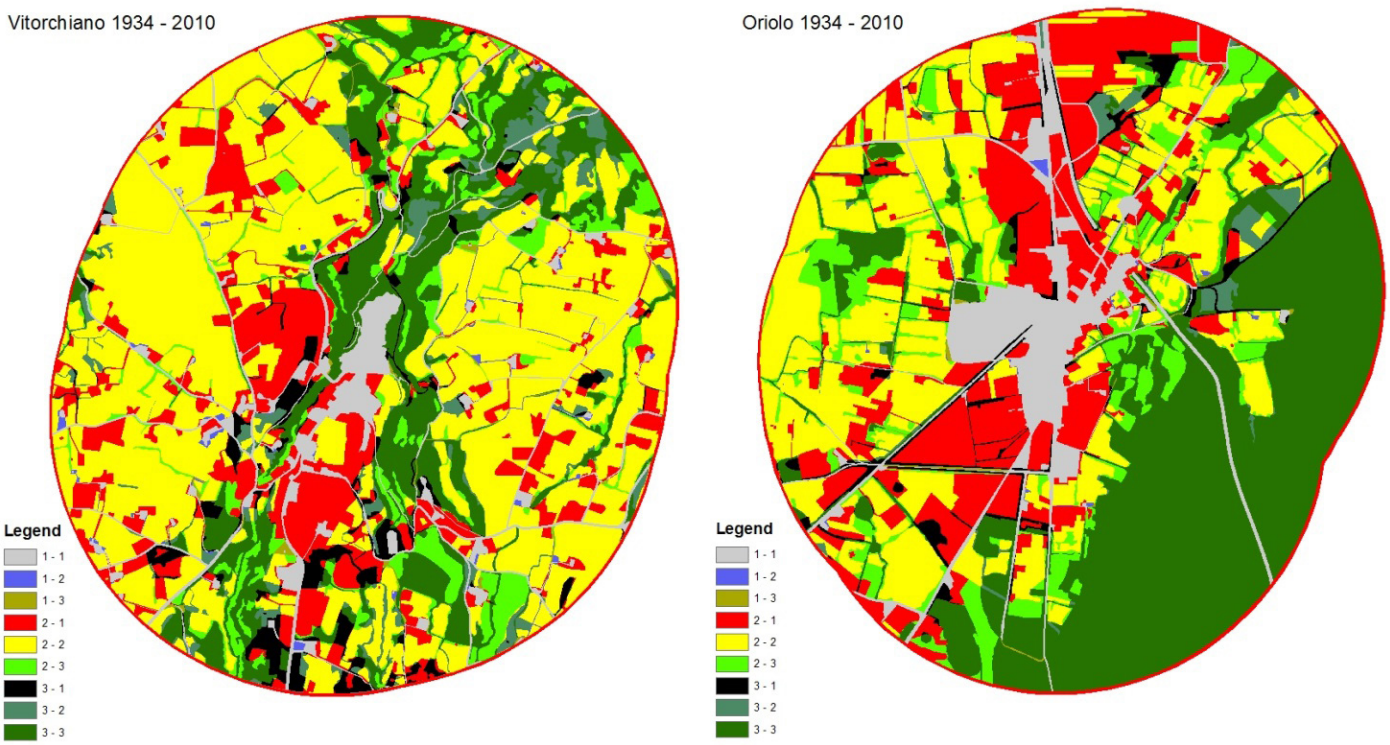

Figure 7: Maps showing land cover changes (1934-2010) in the study areas (Vitorchiano on the left and Oriolo Romano on the right). Numbers in the legend represent the land use classes for macro-categories urban (1), crop land (2) and natural (3).

forest cores, probably due to the processes of urbanization, but also by afforestation and natural processes of secondary succession on fallow land and the retreat of agriculture from unfavourable sites.

Figure 6 shows photographic images and land use maps of the analyzed years. **Figure 7** on its turn shows the global dynamics of land cover transformations that occurred during the period 1934-2010 using the described approach. As we can see from the images, near the historical centre of both cities green spaces persist, which are currently used as public gardens and parks. As we move away from the urban centre, green spaces become partially planted with orchards and vegetable gardens, or wooded and uncultivated areas. In the future urban planning in response to urban sprawl these areas must be preserved as much as possible, as they can have social functions as meeting place and for recreation of citizens. It must be considered that both study areas are rich in traditional agriculture whose multifunctionality, i.e. its ecological, social and cultural role, has been well established (Antrop, 2005; Biasi *et al.*, 2010). The erosion of these complex rural landscapes due to crop intensification and urban expansion may therefore compromise the ecological connectivity, as well as the richness of cultivated and natural local biodiversity.

5. Conclusions and further research

The obtained results are quite satisfactory although they are still preliminary and further analysis and deepening are necessary. From the methodological point of view, the first goal of setting up a methodology for processing and analyzing the 1934 aerial photographs has been very satisfactorily achieved. If compared with the 1954 "Volo GAI" images, they have a much higher resolution and quality, and they were taken before the socio-economic changes of the 1950's —including the land reform of the "Riforma Fondiaria" which started in 1951—. They

therefore can provide a snapshot of the whole territory before many changes in agricultural patterns and management occurred.

From these preliminary results a similar trend of landscape transformation can be observed for both the study areas, which is quite common in many areas of our country. It can be summarized in an increase of urban areas, a slight increase of wood lands and natural areas with shrubs and bushes, and a decrease of agricultural areas. Nevertheless, some important differences in the spatial pattern of growth of urban areas can be observed. From a visual comparison, two different growth models can be observed: more compact for Oriolo Romano and more dispersed in the urban fringe of Vitorchiano. These differences cannot be explained by urban planning instruments and regulation. For both study areas, current urban planning instruments date back to the 1990s and they deal mainly with the regulation of new buildings disregarding the relict open green spaces that still remain. Further analysis should be implemented in order to better point out and describe this phenomenon through methods of landscape metrics.

This article provides a useful technique to understand the phenomena of land transformation in areas of the urban-rural fringe, through detailed analysis of space-time changes with the aid of GIS software. Spatial information of land use/land cover types and their change detection in time series represent an important means for urban planning, as well as to encourage sustainable development (Zhang & Guindon, 2006) or to predict future transformation (Hardin *et al.*, 2007). Knowledge about the location and importance of green spaces that are still left in cities, allow urban planners to program new buildings taking into account the future availability of parks and public gardens. Crop land areas may be preserved and assigned to citizens as community allotments, as already happens in Spanish cities (Fernández de Casadevante and Moran Alonso, 2012).

The incorporation of agriculture in urban planning may maximize its social, educational and ecological value. Maintaining natural and cultivated spaces can assure that ecosystem services are provided to cities, also in small towns, for example by preserving a high biodiversity for better environmental quality and by conserving typical products that are important for small, local economies. Architectural and engineering solutions can integrate innovative farming terraces, roof gardens, and suburban agricultural production spaces into the urban context in order to allow an easy use by everyone and beautify cities. Since there are strong parallels between agricultural and urban systems, it is necessary to join different fields of research, such as urbanism, ecology, agriculture, biology, social science, cartography, etc. in order to better understand the interaction between urbanization, citizenship and green spaces.

The inadequacy of current urban planning instruments should be overcome in order to preserve the green areas that are still present in the urban fringe and that are fundamental for the sustainable development of these towns. The results presented in this paper highlight the need for guidance, strategies and regulation aimed at promoting a sustainable model of urban growth.

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