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REVIEW ARTICLES

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LAND-USE STRUCTURE AND URBANIZATION-DRIVEN LAND FRAGMENTATION: REVISITING THE MONOCENTRIC MODEL IN A SPRAWLING REGION

1. INTRODUCTION

Human activity plays a crucial role in land-use changes throughout the world (Verburg *et al.*, 2004; Serra *et al.*, 2008). Changes in the use of land are among the most important human-induced changes impacting the functioning of the earth system (Lambin *et al.*, 2001; Gillanders *et al.*, 2008). Mediterranean landscapes are the result of the anthropogenic action exerted over millennia (Blondel, 2006; Blondel and Aronson, 1995) and habitat heterogeneity, due to both socioeconomic and biophysical factors, represents a source of the high level of biodiversity in the region. Actual trends in Mediterranean landscapes include loss of diversity, natural habitats and corridors due rapid urbanization processes. These mainly uncontrolled changes have a great impact on biodiversity, climate change and global warming (Francois *et al.*, 2008; Vallet *et al.*, 2008, De Aranzabal *et al.*, 2008), but land-use changes can also affect societal and territorial vulnerability to economic perturbations (Tyson *et al.*, 2001). The major drivers of land-use change are political, economic, demographic and possibly cultural factors (e.g. Antrop, 2000). For the consequences at both local and regional level, the spatial patterns of land-use changes are therefore as relevant as the aggregate amount of change (Verburg *et al.*, 2004). Based on these premises, there is a definite need to integrate spatio-temporal approaches to land-use

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science and permanent monitoring tools addressing the specificity of economically-dynamic suburban areas (Hasse and Lathrop, 2003).

Urban development can be conceived as a self-organising system in which natural constraints and institutional controls (e.g. through land-use policies) influence the way in which local decision-making processes modulate forms and socioeconomic structures of large urban regions (Krueger and Savage, 2007). Physical, ecological and socioeconomic processes create, maintain and destroy spatial patterns and, at the same time, spatial patterns facilitate, inhibit, or neutralize these processes (Zhang *et al.*, 2004). Urbanization is a striking form of irreversible land transformation affecting landscapes as well as people who live in and around cities (Luck and Wu, 2002; Aguilera *et al.*, 2011).

A main issue in land-use studies is to enhance the decision makers' understanding of the future urban patterns by providing perceptions of several possible scenarios against which decisions can be tested. For example, to achieve a more balanced socioeconomic development, local authorities need tools to monitor how the land is managed sustainably (Bouma *et al.*, 1998; Kumar Jat *et al.*, 2008). The competitiveness of urban regions can be lowered by unsustainable land management strategies because the potentialities of development can be deeply altered by ignoring potential conflicts in the use of land. Urban systems should be therefore studied as integrated landscapes in which context and spatial relations are important as both entities and processes (Zhang *et al*., 2004).

Most European cities kept their historical compact structure, being characterized by a dense historical core and a relatively small fringe surrounded by rural areas until the 1950s, when the economic growth caused the expansion outside of the inner city. Nowadays, urban sprawl is a common phenomenon throughout Europe and is expected to continue during the upcoming decades (Dieleman and Wegener, 2004; European Environment Agency, 2006; Kasanko *et al*., 2006; UNEP, 2010).

Salvati *et al*. (2013) hypothesized the existence of an homologation process influencing together composition, structure and spatial configuration of peri-urban landscapes due to the effect of diffused urban expansion in the originally compact, large city regions of the Mediterranean basin. This process may reduce the importance of the biophysical and socioeconomic factors which determined the traditional structure of the Mediterranean landscape with the well defined segregation in the anthropogenic, agricultural and natural land-use classes observed along the urban gradient (Brouwer *et al*., 1991). These changes may have important implications on landscape diversity, heterogeneity and, possibly, long-term resilience to environmental shocks. Unfortunately, despite the mass of papers devoted to study urban sprawl and land-use changes in peri-urban areas, this hypothesis was never tested explicitly in the Mediterranean region.

While sprawl processes have been widely investigated with the use of the 'population density *vs* distance' curve applied to the study of environmental, demographic and socioeconomic trends observed along the urban gradient

(Alberti, 2005), indicators of landscape configuration and structures, to the best of our knowledge, were never tested for mono-centricity in originally compact cities. The mono-centric model introduced by urban economics (O'Sullivan, 2002), results particularly useful in predicting long-term changes in a spatial configuration and provides evidence on the variation in steepness of the variable being considered, becoming more uniform throughout the distance from the city centre, produced by suburbanization. Furthermore, few studies have taken into account the suburban areas associated with urban expansion together with a landscape perspective (Cakir *et al*., 2008; Catalàn *et al*., 2008; Solon, 2009).

In the present study changes in land-use patterns along the urban gradient have been analyzed in Rome, Italy, during 60 years after World War II with the aim of testing if landscape structure, based on two simple class metrics (average patch size and shape index), follows the predictions of the mono-centric model. Urban planning and decision-making for sustainable development urgently need high-resolution data to establish the relationship between the socioeconomic performances of urban systems and their environmental impacts (Pauleit and Duhme, 2000; Zhang *et al.*, 2004). Rome is a Mediterranean city with a fairly increasing population and a tertiary-oriented economy (Mudu, 2006; Munafò *et al.*, 2010) experiencing, especially in the last years, low-density expansion at the fringe. Rome has been traditionally proposed as a model for urban concentration and economic polarization while, in the last years, planning was guiding the city towards a polycentric growth (OECD, 2006). Rome's suburban landscape is threatened by typical patterns of change characterizing sprawling cities, such as cost of urban services because of the distance between new settlements and the city centre (Burchell *et al*., 2002), increased travel and congestion (Ewing *et al*., 2003), increased volumes of water runoff (Stone and Bullen, 2006), loss of prime agricultural lands (Heimlich and Anderson, 2001), soil contamination and sealing (Stone, 2008). By linking a quantitative analysis of landscape patterns with a narrative approach describing the recent planning strategy developed by Rome's municipality, the present study discusses on the role of landscape monitoring to inform policies for urban containment and sustainable land management.

2. METHODOLOGY

2.1. Study Area

The investigated area (1,500 km^2) encompasses the boundaries of Rome's municipality (central Italy) and is characterized by homogeneous soils and climate; land topography consists of 90% lowlands and 10% uplands. In the early 1990s the area was subdivided in two municipalities (Rome: 1,285 km^2 and Fiumicino: 215 km^2). Half of the studied area still consists of forests, pastures, and high-quality cropland forming the traditional landscape of the ‘Agro Romano’ lowland surrounding Rome (Munafò *et al.*, 2010). More than 27% of Rome’s municipality surface area (nearly 410 km^2) is actually under land conservation measures (regional parks and natural reserves).

2.2. Land-Use Data

Land-use data were obtained from the elaboration of two compatible digital maps classified according to the Corine Land Cover classification system: the Italian Istituto Geografico Militare topographic map scaled 1: 25,000 and produced in 1949 and an original land-use map (scaled 1: 25,000) derived from photo-interpretation of digital ortho-images released from the Italian National Geoportal related to 2008. A nomenclature including nine homogeneous classes with a minimum mapping unit of 1 hectare has been selected as follows: (i) arable land, (ii) mixed cropland, (iii) vineyards, (iv) olive groves, (v) woodland, (vi) pastures, (vii) urban gardens, (viii) wetlands and (ix) built-up areas. The produced land-use figures have been checked for consistency with independent statistical (e.g. agricultural and building censuses) and cartographic data (Salvati *et al.*, 2013). In 2008, two classes of built-up areas were also identified (continuous urban fabric and discontinuous settlements) and used in the subsequent analysis.

2.3. Spatial Analysis

A transition matrix was calculated by class to study land-use changes observed during the investigated time period. The annual rate of change observed for each land-use class was further calculated. The share of unchanged surface area was calculated for each class by dividing the area classified at the same use in 1949 and 2008 to the total class area in 1949. The distance of the centroid of each landscape patch from a central place in Rome (Piazza Barberini) was calculated and averaged by year and class. To assess the impact of compact and dispersed urbanization on land-use changes in Rome, the proportion of land consumed over 1949–2008 by continuous urban fabric and discontinuous settlements was calculated for each class. Non-parametric statistics (Mann-Whitney U test and Spearman Rank Correlation test) were used to compare the distribution of landscape indicators between years and to correlate them pair-wise.

Previous studies propose landscape metrics to detect spatial patterns caused by urbanization (Luck and Wu, 2002; Verburg *et al.*, 2004; Zhang *et al.*, 2004, 2007). In the present study, the choice of variables, the procedure for the construction of indicators, and the identification of the thematic dimensions adequate to assess landscape characteristics (e.g. composition, structure, spatial distribution and configuration) at the regional level have been set up according to general criteria of comprehensiveness, reliability, and easiness in calculation. As far as landscape metrics, two well-known and simplified indexes have been calculated at the class level (patch size and shape index or area-to-perimeter ratio) with the aim of being used also by local stakeholders and planners not confident with spatial analysis and geographic information systems tools (Uuemaa *et al.*, 2009). Metrics were obtained by using ArcGIS 9.3 software (ESRI Inc., Redwoods, USA) through computation on 1949 and 2008 land-use maps. The two indicators selected provide a broad qualification of land-use composition, landscape characteristics and urban expansion (with special focus on dispersed and discontinuous settlements) observed in the investigated area. Using the distance of each patch from the inner city measured in 1949 and 2008, average metrics have been calculated for five concentric rings with (i) < 2 km further away from the centre of Rome, (ii) 2–5 km, (iii) 5–10 km, (iv) 10–20 km and (v) > 20 km. Finally, the pair-wise correlation of the two metrics with the distance of each patch from the inner city was calculated by year using the non-parametric Spearman rank statistic testing at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

3. RESULTS

3.1. Changes in Landscape Composition and Structure in Rome

A change detection analysis based on transition matrices between 1949 and 2008 by class allows identifying some important changes in the landscape composition and structure (figure 1). Modifications in the class area along the urban-to-rural gradient were analyzed together with the average distance from the inner city where these changes occurred (table 1). The most significant change was found in the transformation of arable land towards built-up areas (17.4% observed at an average distance of 19 km from the inner city) and forests (3.6% at 12.9 km).

Only 2.2% of forests were transformed into arable land at an average distance of 16 km from the city centre, 0.9% into built-up areas at 15.6 km and 0.8% into pastures at 17 km. Crop mosaic has been transformed by 0.7% into arable land at 15.7 km and by 0.5% into built-up areas at 11.1 km. Olive groves were converted into arable land by 0.2% at an average distance of 18 km. Pastures were transformed respectively into arable land (2%) and built-up areas (1.7%) at 16.4 km and 14.2 km, on average. Forests invaded 0.7% of pastures at 17 km and vineyards turned by 0.7% into arable land and built-up areas respectively at 18.5 and 16.4 km.

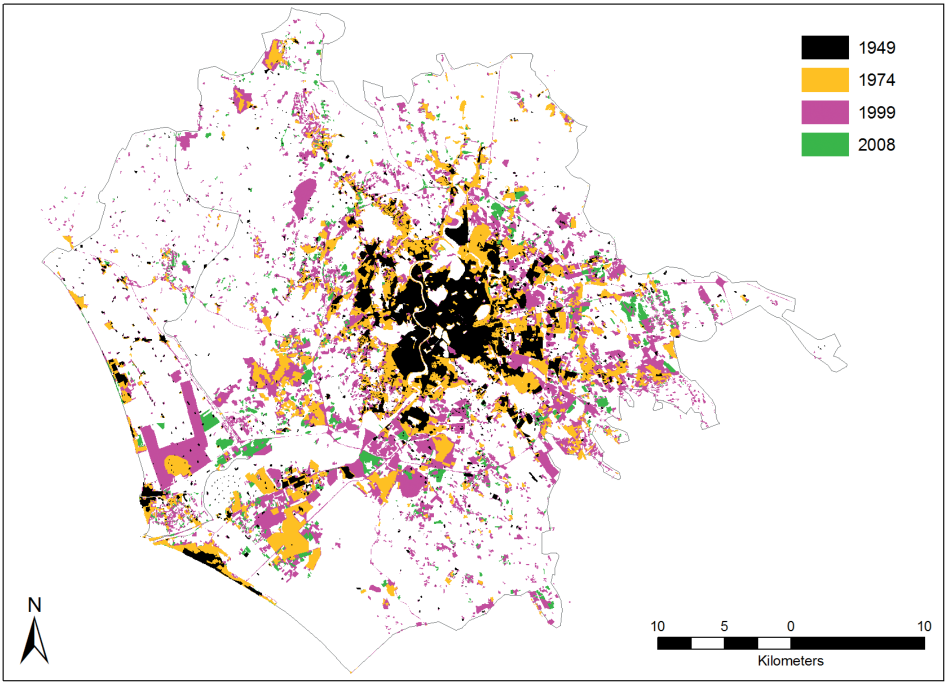

Fig. 1. A map of the study area illustrating the expansion of urban settlements between 1949 and 2008
Source: authors' elaboration

Table 1. Landscape transition matrices between 1949 and 2008 by land-use class (highlighted cells indicate stable uses of land: (a) percent class area, (b) average distance from the inner city

(a)

Class	Water bodies	Forests	Crop mosaic	Olive groves	Urban parks	Pastures	Arable land	Built-up areas	Vineyards	Total 2008
Water bodies	**0.7**	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.7
Forests	0.0	**7.1**	0.2	0.0	0.0	0.7	3.6	0.1	0.0	11.9
Crop mosaic	0.0	0.1	**0.1**	0.1	0.0	0.1	1.6	0.0	0.1	2.1
Olive groves	0.0	0.1	0.1	**0.1**	0.0	0.1	0.7	0.0	0.2	1.2
Urban parks	0.0	0.1	0.1	0.0	**1.1**	0.3	1.5	0.3	0.0	3.3
Pastures	0.0	0.8	0.1	0.0	0.0	**1.2**	5.5	0.2	0.1	8.0
Arable land	0.0	2.2	0.7	0.2	0.0	2.0	**38.0**	0.3	0.7	44.1

Class	Water bodies	Forests	Crop mosaic	Olive groves	Urban parks	Pastures	Arable land	Built-up areas	Vineyards	Total 2008
Built-up areas	0.0	0.9	0.5	0.0	0.4	1.7	17.4	**5.7**	0.7	27.5
Vineyards	0.0	0.0	0.0	0.1	0.0	0.0	0.7	0.0	**0.5**	1.3
Total 1949	0.7	11.2	1.8	0.4	1.6	6.1	69.2	6.6	2.4	100.0

(b)

Class	Water bodies	Forests	Crop mosaic	Olive groves	Urban parks	Pastures	Arable land	Built-up areas	Vineyards	Average 2008
Water bodies	**13.3**	24.1	23.2	16.3	4.9	15.1	13.1	11.3	–	13.8
Forests	13.0	**17.2**	17.2	18.5	13.2	17.0	15.6	12.9	20.4	16.3
Crop mosaic	13.0	17.8	**17.0**	20.8	5.8	16.1	17.3	11.3	19.9	17.0
Olive groves	–	16.9	16.8	**17.1**	9.1	15.8	17.1	13.6	18.3	16.9
Urban parks	7.0	14.2	8.3	23.0	**6.6**	10.9	10.4	7.4	13.8	9.3
Pastures	12.0	17.3	12.9	16.4	11.2	**15.9**	14.7	11.8	16.3	15.0
Arable land	15.1	16.4	15.7	18.1	10.9	16.4	**15.5**	14.5	18.5	15.8
Built-up areas	15.6	15.6	11.1	17.8	6.1	14.2	13.5	**10.3**	16.4	12.9
Vineyards	–	19.6	21.3	19.4	19.0	20.4	19.0	15.1	**18.4**	19.1
Average 1949	13.5	16.7	13.5	18.1	7.1	15.3	14.6	11.1	17.5	14.5

Source: authors' elaboration.

3.2. Urbanization-Driven Landscape Changes

A scatterplot representing changes in the percent class area and average distance from Rome by land-use class between 1949 and 2008 (figure 2a) identified three main categories: (1) natural or semi-natural classes (forests, pastures and water bodies) showing moderate changes in both variables, (2) agricultural classes (vineyards, arable land and crop mosaic), characterized by a stable or weakly decreasing class area and a marked increase in the average distance from the inner city, and (3) anthropogenic classes (continuous and discontinuous built-up areas, urban parks and gardens) with a rapid growth in class area and a moderate increase in the average distance from the inner city. Olive groves showed a moderate increase in class area with a modest decrease in the average distance from Rome.

A scatterplot showing the differences in the average distance from Rome between unchanged patches during 1949–2008 and total land in 1949 and the class percentage of unchanged land (1949–2008) on 1949 class area (figure 2b) identified three

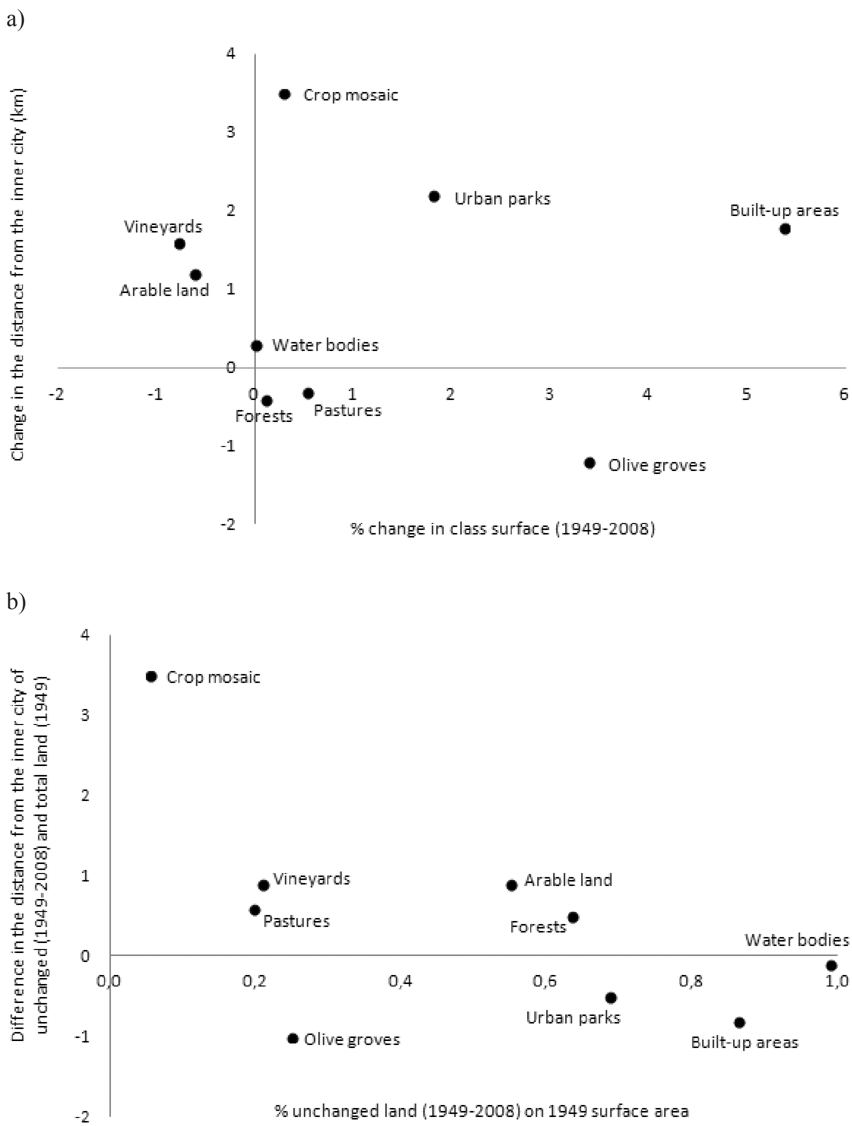

Fig. 2. Scatterplots illustrating (a) changes in percent class area and average distance from Rome by class of land-use between 1949 and 2008 and (b) difference in the average distance from Rome of unchanged (1949–2008) and total land (1949) and percentage of unchanged land (1949–2008) on 1949 surface area by class of land-use
Source: authors' elaboration

classes whose average distance from Rome decreased over time (built-up areas, urban parks and olive groves) from the remaining natural and agricultural classes which experienced a progressive decline. The percentage of unchanged land during the investigated period is a class-dependent attribute of the landscape which was not influenced by the initial class area (Spearman Rank test, $p > 0.05$, $n = 9$). By contrast, the class percentage of unchanged land showed a negative correlation with the distance from the inner city (Spearman Rank test, $p < 0.01$, $n = 9$) and changes in the class average distance observed during 1949–2008 are negatively correlated with the class average distance observed in 1949 (Spearman Rank test, $p < 0.05$, $n = 9$).

Moreover, the analysis of land-use changes allows defining the typology of urbanization (i.e. continuous or discontinuous) causing landscape transformations between 1949 and 2008 (figure 3). Woodlands were converted mostly into discontinuous

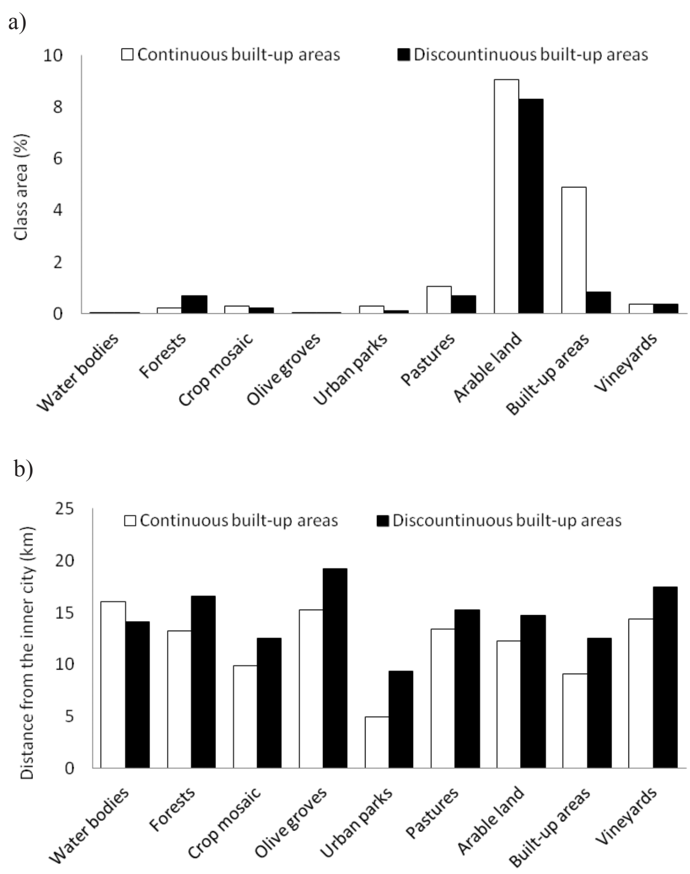

Fig. 3. Typology of urbanization (continuous or discontinuous settlements) derived from the landscape transformations observed between 1949 and 2008: (a) percentage of transformed land, (b) average distance of transformed land from Rome (km)
Source: authors' elaboration

settlements at greater distances from the city centre compared with the other land-use classes. For crop mosaic, pastures, arable land and green urban parks, land converted into continuous settlements was observed at a lower distance than patches transformed into discontinuous settlements. Vineyards were converted into continuous settlements at smaller distance from the inner city compared with discontinuous settlements. With the exception of forests and vineyards, land consumed by continuous settlements was always greater that that consumed by discontinuous settlements although with different proportions observed for each class. Overall, discontinuous settlements were found at significantly greater distances from the centre of the city than the continuous settlements (Mann-Whitney U test, $p < 0.01$, $n = 9$).

3.3. Patch Size

The average patch size greatly varied in each examined class between 1949 and 2008 (table 2). A marked increase in both forest and built-up patch size has been observed over time.

Table 2. Average patch size and shape index in Rome by class and year

Distance	Forests	Pastures	Crop mosaic	Olive groves	Viney-ards	Arable land	Built--up areas	Urban parks	Total
Average patch size (km²)									
1949									
0–2	–	0.01	–	–	–	–	1.65	0.22	0.64
2–5	0.05	0.18	0.02	–	–	0.36	0.22	0.21	0.22
5–10	0.05	0.14	0.05	0.04	0.03	1.13	0.05	0.12	0.13
10–20	0.13	0.29	0.12	0.08	0.20	5.51	0.02	0.74	0.59
20–40	0.48	0.44	0.15	0.16	0.16	1.89	0.03	0.19	0.35
Total	0.19	0.27	0.09	0.11	0.15	3.16	0.06	0.20	0.37
2008									
0–2	–	–	–	–	–	–	0.03	0.34	0.31
2–5	0.18	0.18	0.15	–	–	0.08	3.12	0.26	0.98
5–10	0.11	0.15	0.07	0.04	0.02	0.36	0.41	0.09	0.23
10–20	0.13	0.08	0.05	0.03	0.10	1.22	0.12	0.08	0.22
20–40	0.55	0.08	0.06	0.05	0.06	0.68	0.10	0.05	0.19
Total	0.22	0.10	0.06	0.04	0.09	0.94	0.21	0.11	0.23

Distance	Forests	Pastures	Crop mosaic	Olive groves	Viney-ards	Arable land	Built-up areas	Urban parks	Total
Shape index (Area to perimeter ratio)									
1949									
0–2	–	0.008	–	–	–	–	0.093	0.075	0.067
2–5	0.023	0.051	0.025	–	–	0.068	0.053	0.059	0.055
5–10	0.030	0.051	0.034	0.037	0.033	0.075	0.026	0.061	0.034
10–20	0.032	0.061	0.048	0.051	0.044	0.089	0.025	0.116	0.039
20–40	0.068	0.080	0.053	0.067	0.042	0.098	0.027	0.064	0.052
Total	0.039	0.061	0.041	0.056	0.041	0.085	0.028	0.064	0.041
2008									
0–2	–	–	–	–	–	–	0.032	0.064	0.061
2–5	0.026	0.044	0.041	–	–	0.053	0.066	0.052	0.051
5–10	0.027	0.038	0.044	0.034	0.029	0.050	0.052	0.042	0.043
10–20	0.025	0.033	0.035	0.028	0.035	0.046	0.040	0.041	0.036
20–40	0.034	0.032	0.035	0.031	0.034	0.054	0.033	0.036	0.035
Total	0.027	0.033	0.036	0.029	0.035	0.049	0.041	0.043	0.037

Source: authors' elaboration.

Overall, forests increased by 15.8% with a maximum growth in the 2–5 km distance class, while they remained substantially unchanged in the 10–20 km class. Despite a decrease in the range 0–2 km, the remaining distance classes are characterized by expanding built-up areas, with a maximum increase in patch size observed in the range 2–5 km. Arable land is the class showing the highest decline in patch size (by more than 70%), with a maximum decrease observed in the 2–5 and 10–20 km classes. Overall, olive grove average patch size decreased by 63% being stable only in the 5–10 km class; the highest decline (68.7%) was observed in the range 20–40 km. The average patch size of pastures decreased by 62%: between 1949 and 2008 pastures disappeared in the range 0–2 km and a decrease by more than 70% was observed between 10 and 40 km. Interestingly, the average patch size remained quite stable in the range 2–10 km. Overall, urban parks decreased by 45%, with a reduction of 89% between 10 and 20 km from the city centre. Only in the 2–5 km range a marked increase (+54%) was observed. Vineyards average patch size decreased by 40% from 15 to 9 ha with a considerable decline (–90%) in the 20–40 km range. Crop mosaic is the class with the lowest variation in patch size over time (–33%). However, while crop mosaic between 2 and 10 km increased slightly, a decrease up to 60% has been observed at greater distances from the inner city.

3.4. Shape Index

The shape index substantially varied along the urban gradient in almost every land-use classes, with the exception of built-up areas, for which the shape index increases by 46%, with the maximum increase observed in the range 5–10 km, while declining in the first distance class (table 2). For olive groves, the average shape index decreased by 48% declining gradually with the distance from the inner city. Pastures showed a decrease by 46% in the shape index, which declined with the distance, until 60% on the 20–40 km distance class. The shape index for arable land decreased by 42%, with the maximum variation observed in the 10–20 km range. Urban park shape index decreased by 33% especially in the 10–20 km distance class. Forests showed a decrease by 30% in the shape index by increasing only in the 2–5 km class, while declining with the distance from the inner city. The shape index for vineyards declined by 14%, with a maximum decrease observed in the 10–20 km distance class. Crop mosaic showed less fragmentation, with the shape index declining by 12%.

3.5. Changes in Landscape Configuration along the Urban Gradient

According to the results mentioned above, landscape structure diverged in 1949 and 2008 according to the distance from the inner city (table 2). In the 0–2 km distance class, pastures disappeared and built-up areas decreased by 98%. An increase by 54% in urban parks was observed and overall patch fragmentation grew up by 15%. In the range 2–5 km, a significant increase in built-up areas, crop mosaic and forests was observed, with arable land decreasing by 77%. Forests, crop mosaic and built-up areas showed a higher shape index, while pastures, arable land and urban parks showed increasing patchiness and morphological complexity. In the 5–10 km distance class, a large expansion in patch size was observed for built-up areas, forests and crop mosaic, while average patch size decreased for vineyards (–33%), urban green areas (–25%) and arable land (–68%). The shape index increased for built-up areas (100%) and crop mosaic (29%) while decreasing for the other classes: this indicates a more fragmented landscape structure in peri-urban areas.

Important differences were found in the pair-wise correlation between the distance from the inner city and patch size (or shape index) during the investigated period (table 3).

In 1949 the average patch size increased with the distance from the inner city, while shapes remain relatively homogeneous in the case for forests, pastures and crop mosaic. A decline in class area was observed for pastures and crop mosaic in 2008 together with land fragmentation while forests experienced fragmentation together with a drastic increase in class area. The shape index for arable land, built-up areas and urban parks declined with the distance from the inner city indicating higher fragmentation. Notably, in 2008 the decrease of patch size and shape index along the urban gradient was found higher for built-up areas and urban parks.

Table 3. Spearman rank correlation test between the distance from the inner city and (a) patch size or (b) shape index in Rome by class and year (bold indicates significance at $p < 0.01$)

Class	(a) Patch size		(b) Shape index	
	1949	2008	1949	2008
Forests	0.22	0.04	0.17	0.05
Pastures	0.16	–0.17	0.14	–0.13
Crop mosaic	0.12	–0.13	0.17	–0.14
Olive groves	0.23	–0.04	0.23	–0.07
Vineyards	–0.09	0.00	–0.09	–0.02
Arable land	–0.09	–0.11	–0.07	–0.08
Built-up areas	0.00	–0.29	0.03	–0.33
Urban parks	0.11	–0.29	0.16	–0.24

Source: authors' elaboration.

4. DISCUSSION

Rapid and conflicting transformations in land-use are shaping urban and peri-urban landscapes in the last years: the demand for building land is becoming increasingly acute and the deterioration of urban centres due to traffic congestion, lack of green and open spaces, air pollution and socioeconomic matters together with drastic changes in the real estate market are playing a crucial role in intensifying sprawl processes (Bruegmann, 2005). Just to provide an example relative to Europe, the inhabitants of urban areas have passed, in 2008, the resident population living in rural areas and more than 80% of Europeans will be living in urban areas by 2030 (United Nations, 2006). Over the past 50 years, we assisted to a growth of cities characterized by mainly discontinuous settlements, defined by the European Environment Agency (2006) as the physical pattern of low-density expansion of large urban areas, under market conditions, into the surrounding agricultural areas, supported by the dependence of the population of its private car and of its preference for one-family-housing. The implications of this kind of development include traffic and increasing demand for mobility (Ewing *et al*., 2003; Cameron *et al*., 2004; Kahn, 2000), land-use fragmentation and loss of biodiversity (Alberti, 2005), reduced landscape attractiveness (Sullivan and Lovell, 2006) and alterations of the hydrological cycle and flooding regimes (Carlson, 2004). Moreover, urbanization-driven land-use change is one of the main causes of political and social conflicts at various scales (Plotkin, 1987).

As underlined in recent studies, urban sprawl in the Mediterranean region is determining a transition from a polarized landscape in urban and rural areas towards a diffused and mixed pattern of urban and peri-urban areas that spreads over the available land consuming both agricultural and semi-natural areas with important ecological implications (Dieleman and Wegener, 2004; European Environment Agency, 2006; Salvati *et al*., 2012). By comparing the land-use structure observed in Rome in 1949 and 2008, the present study has shown a trend towards fragmentation of both agricultural and forest land-use classes driven by low-density dispersed urbanization together with a spatial rearrangement of land-use classes whose distribution appears less associated with the distance from the inner city than it was in the past.

With built-up areas increasing along the urban gradient, results show a significant rate of edification for arable land. Moreover, a decrease in class area with greater fragmentation was observed for agricultural areas as a whole. While continuous settlements mainly consumed agricultural and pasture land, which are the most available and suitable cover type to building (Kasanko *et al*., 2006), discontinuous built-up areas derived mostly from the conversion of forests at a progressively greater distance from the inner city. Forests are moderately increasing in almost every distance classes possibly due to the abandonment of arable land and pastures, but they show a greater fragmentation compared to the past. Forest fragmentation may indicate an increasing environmental fragility, because large and intrinsically-connected forest patches have a critical role in providing habitat and sustaining ecosystem functions (Christian *et al*., 1998; Lindenmayer *et al*., 1999).

With the exception of built-up areas and forests, the other classes (pastures, crop mosaic, olive groves, vineyards and arable land) showed a decrease with fragmentation mostly at higher distances from the inner city. While in 1949 the average patch size of agricultural land-uses increased with the distance from the inner city, cultivated land in 2008 showed a significant reduction in the class area and fragmentation at higher distances from Rome. These results confirm the assumptions of the mono-centric model and point out the environmental implications of land fragmentation in terms of landscape resilience, soil degradation and biodiversity loss (Baker *et al*., 2001; McIntyre *et al*., 2001). The conservation of peri-urban agriculture is an indirect measure for biodiversity conservation, soil resources preservation and maintenance of high level of human wellbeing. Moreover, Rome is the largest rural municipality in Italy (ISTAT, 2009): in such a context, the conservation of ecological corridors is fundamental to mitigate the ecological consequences of urban sprawl (Blasi *et al*., 2001).

Table 4 summarizes the results obtained in the present study in the light of mono-centric model's assumptions. While in 1949 three and six land-use classes followed the prediction of the mono-centric model respectively for average patch size and mean shape index, in 2008 this number reduced to 1 and 2. Interestingly, the shape index of built-up areas followed the mono-centric model in 1949 only, suggesting that landscape configuration in 2008 became more mixed and interspersed due to diffused settlement expansion. The same trend was observed for forests, crop mosaic and olive groves following a mono-centric pattern in 1949 and a mixed one in 2008. Only pastures showed a mono-centric behaviour in 2008 for both metrics. The landscape complexity described above, coupled with a multifaceted system of territorial actors and functions, makes the strategies to containing sprawl and land consumption partly ineffective (Gemmiti *et al*., 2012).

Table 4. A synopsis table for assessing the mono-centric model in Rome by class, metrics and year (summary results from tables 1 and 2; +: continuously increasing with distance; – = continuously decreasing with distance; m = mixed trend)

Class	Patch size		Shape index	
	1949	2008	1949	2008
Forests	+	m	+	m
Crop mosaic	+	m	+	m
Olive groves	+	m	+	m
Urban parks	m	m	m	–
Pastures	m	–	+	–
Arable land	m	m	+	m
Built-up areas	m	m	–	m
Vineyards	m	m	m	m

Source: authors' elaboration.

Rome's development after World War II was driven by policies supporting traditional tertiary sectors and depressing the industrial growth (Costa *et al.*, 1991; Krumholtz, 1992; Insolera, 1993; Fratini, 2000). Rome's municipality (1,285 km^2: one of the largest in Europe) was subdivided into nineteen districts with a population similar to many middle-size Italian cities (i.e. 100,000–200,000 inhabitants) and endorsed with restricted governance functions. Due to policy fragmentation at the regional scale, excessive bureaucracy and planning centralization in a municipality administering an unusually large area, Rome was neither faced by an efficient local governance system, nor by effective forms of territorial cooperation that could be seen as an expression of polycentrism, competitiveness and sustainability (e.g. Tewdwr-Jones and McNeill, 2000; Feiock, 2004). In fact, the capacity of local authorities in developing sustainable land management strategies was limited by the institutional framework.

5. CONCLUSIONS

Urbanization is not only a physical characteristic of the landscape but reflects also cultural and social changes caused by transformation of rural life styles into urban like ones, changing the vision people have about their environment and the way they use it (Antrop, 2000). The increasing landscape fragmentation, like in the case of Rome, produces a loss of rural attributes that constituted the identity of a territory with specific values and traditions. Consequently, people do not have a sense of belonging to the area and this results also in declining social cohesion and environmental awareness. Sustainable land management should contribute to the preservation of the relict patches of green and agricultural areas by encouraging self-contained urban growth and containing land fragmentation.

Sustainable land management should contribute to the preservation of the relict patches of forest and agricultural areas on the fringe by stimulating self-contained urban growth and mitigating habitat fragmentation. Urban voids and abandoned brown-field sites are signals of landscape deterioration and confirm, in some cases, the low effectiveness of land protection policies and planning prescriptions. In some European countries, land-use plans prescribe the design of greenbelts seen as physical boundaries separating urban and rural areas. In many cases, greenbelts have proved to be effective in the containment of sprawl (Bengston and Youn, 2006). However, most of those policy strategies – when applied – have revealed only partly effective in northern Mediterranean cities because of the lack of explicit goals (Bengston *et al.*, 2004; Koomen *et al.*, 2008; Salvati *et al.*, 2013). Nevertheless their application demonstrates the importance of strategies considering a 'building zone' opposed to a rural area inside urban municipalities (Gennaio *et al.*, 2009). Such an institutional control on building activity could be a crucial point in the case of large Mediterranean cities (Giannakourou, 2005) where illegal building or isolated properties often make place to new built-up areas.

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