

Case Report

Toward a Dualistic Growth? Population Increase and Land-Use Change in Rome, Italy

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Abstract: The spatial mismatch between population growth and settlement expansion is at the base of current models of urban growth. Empirical evidence is increasingly required to inform planning measures promoting urban containment in the context of a stable (or declining) population. In these regards, per-capita indicators of land-use change can be adopted with the aim at evaluating long-term sustainability of urbanization processes. The present study assesses spatial variations in per-capita indicators of land-use change in Rome, Central Italy, at five years (1949, 1974, 1999, 2008, and 2016) with the final objective of quantifying the mismatch between urban expansion and population growth. Originally specialized in agricultural productions, Rome's metropolitan area is a paradigmatic example of dispersed urban expansion in the Mediterranean basin. By considering multiple land-use dynamics, per-capita indicators of landscape change delineated three distinctive waves of growth corresponding with urbanization, suburbanization, and a more mixed stage with counter-urbanization and re-urbanization impulses. By reflecting different socioeconomic contexts on a local scale, urban fabric and forests were identified as the 'winner' classes, expanding homogeneously over time at the expense of cropland. Agricultural landscapes experienced a more heterogeneous trend with arable land and pastures declining systematically and more fragmented land classes (e.g., vineyards and olive groves) displaying stable (or slightly increasing) trends. The continuous reduction of per-capita surface area of cropland that's supports a reduced production base, which is now insufficient to satisfy the rising demand for fresh food at the metropolitan scale, indicates the unsustainability of the current development in Rome and more generally in the whole Mediterranean basin, a region specialized traditionally in (proximity) agricultural productions.

Keywords: metropolitan expansion; per-capita urban area; per-capita cropland; land mismatch; population; Italy

1. Introduction

Land use/land cover changes (LULCCs) are due to a large number of factors encompassing climate change, occurrence of natural risk, regulation/conservation policies, and human disturbance mainly consisting in various forms of urbanization [1–9]. In this perspective, in urban areas, settlement expansion and landscape transformations were intimately associated, involving multiple research dimensions encompassing ecology, planning, economic issues, and social aspects [10]. For a comprehensive study of

urbanization-driven landscape changes, defining urban growth in terms of density, spatial morphology, socioeconomic implications, and environmental impacts is a difficult task [11–13]. Focusing on agglomeration, contemporary urbanization has been progressively shifted beyond the typical ideal city models in which the density of population, settlements, and economic activities display a significant decline moving away from downtown [14]. Urban sprawl was proposed as a comprehensive definition of this evolution: while sprawl comes across as a matter of degree not easily quantifiable, it is argued that in this case the density gradient of any urban function (population, buildings, and businesses) became less steep over time [15–17]. However, low-density development differs from place to place, thus defining of such a process is a mostly place-specific exercise [18]. Impacts of sprawl on fringe landscapes are also mixed and hardly predictable as land-use change in metropolitan regions is often the result of a complex interplay of socioeconomic factors and land constraints (e.g., accessibility, infrastructural development, land/house prices, and access to credit) [19–22].

The dynamic linkage between landscape transformations and population dynamics in advanced economies became increasingly multifaceted because of the mutual interplay of environmental, social, and planning dimensions that influence the level of sustainable development at different spatial scales from regions to local communities [23,24]. It was demonstrated how population dynamics have influenced sprawl less intensively than what occurred under more compact and dense stages of urban expansion in the past [25]. In fact, the current model of urban development (i.e., low-density settlements scattered on a natural or agricultural matrix) results in spatially articulated settlement morphologies leading to high rates of land consumption [26–28].

Following Couch et al. [2], urban sprawl has been increasingly treated as a process of urban change rather than a pattern of urbanization. In this sense, the definition given by Glaster and other scholars nearly twenty years ago [1] is the one that best allows sprawl to be intended as a process and not merely a spatial pattern. Within this approach, the simplest indicator for measuring the extent of sprawl in a metropolitan area is a ratio of two growth rates: the rate at which land development near the outer suburbs has increased divided by the rate at which the population of the metropolitan area has grown [29]. Measuring urban and suburban expansion in this context, a recent study defined exurban development as a process in which “the spread of development across the landscape far outpaces population growth” [30–32]. Similarly, another study notes that “if land is being consumed at a faster rate than population growth, then a metropolitan area can be characterized as ‘sprawling’. If population is growing more rapidly than land is being consumed for urbanization, then a metropolitan area can be characterized as ‘densifying’” [3]. Taking this approach, Wiewel and Persky’s work on Chicago’s suburban sprawl [13] demonstrated that between 1970–1990, urbanized land grew by 46%, while the population increased by only 4% (a ratio of 11.5 to 1). This is only an example of the possible use of per-capita indicators of land-use [33–38].

A large imbalance between a place’s spatial expansion and its population change (where the former increases much more rapidly than the latter) is not unusual in advanced economies [39]. Growth of this sort produces a lower density outcome with people and their residential and commercial buildings using more space often at the expense of forests and farmland [40]. Examining landscapes from the other side of the fringe, exurban development has produced fragmented and chaotic natural landscapes that are progressively losing their characteristic traits (e.g., as far as the composition, configuration, and structure are concerned) [41]. While land-use change in metropolitan regions was the subject of earlier studies delineating knock-on effects on the environmental matrix [42–44], the relationship between land-use change and urban cycles has not yet been adequately studied, especially in regions where human pressure has increased more rapidly in recent years [45].

Based on earlier studies [46], a complete urban cycle is usually represented as a sequence of four development stages with different demographic characteristics from urbanization to suburbanization and from counter-urbanization to re-urbanization [47].

The downtown population increased in both the first and the fourth stage; the suburban population increased in the second stage; and the rural population in metropolitan regions increased in the third stage [48]. Per-capita land-use indicators seem to be an appropriate solution to better delineate the temporal outline of different stages of a complete urban cycle, in turn quantifying the incipient mismatch between population growth and urban expansion [49]. This evidence indicates, likely better than other indicators, the shift from compact models to a more dispersed settlements' structure [50]. By linking (urban) form and (ecological) functions in peri-urban areas, a long-term analysis of per-capita land-use indicators provides the necessary informative base to any policy aimed at containing urban expansion [51–54]. In this direction, spatial planning is urgently required to finely tune urban expansion with population increase and growth in economic activities, limiting settlement diffusion (e.g., in shrinking cities) [55].

The drastic spread of official statistics, land-use maps, and geo-spatial databases support a refined landscape analysis investigating per-capita land-use indicators over a sufficiently long-time interval [56]. Per-capita indicators of land-use change represent a suitable tool to test assumptions on the relationship between urban cycles and landscape transformations over different waves of metropolitan expansion [57]. In this direction, exploratory multivariate data analysis contributes to reveal the complex linkage between compositional changes in relict, fringe landscapes, and the increase of resident population, considered an anticipatory indicator of the specific stage of a given city life cycle [58,59].

Grounded on this theory, our study provides a long-term analysis of per-capita land cover changes at the fringe of a metropolitan region in southern Europe. In light of different models of urban expansion from compact and radio-centric urbanization to dispersed expansion of low-density settlements, the present study documents urban and peri-urban changes over nearly 70 years (1949–2016). As a novel contribution to land-use science, the present work delineates the prevalent mode of urban expansion in Rome (Italy) considering both socioeconomic functions (whose changes are reflected in the sequential stages of the city life cycle) and morphological shifts (e.g., compact vs. dispersed). The Rome metropolitan area is a typical semi-compact and dense city in southern Europe experiencing different waves of settlement expansion and represents an example of metropolitan transformations in the Mediterranean [60–62]. The empirical results of this study allow for the discussion of the (supposed) unsustainability of current urban expansion compared with past settlement structures as far as land fragmentation and loss of relict habitats and traditional crops at the fringe are concerned.

2. Materials and Methods

2.1. Study Area

The investigated area covers a large part of Rome's province (Latium region, Central Italy) encompassing the municipalities of Rome and Fiumicino (1500 km², see Figure 1). The study area is mostly flat and corresponds with the so called 'Agro Romano', a cultivated district with traditional rural landmarks, biodiversity, and cultural heritage surrounding the historical city of Rome along the alluvial plain of the Tiber river [60]. Climate regime in Rome is typically Mediterranean with rainfalls concentrated in the fall and spring and mild temperatures in the winter. Average annual rainfalls and mean daily temperatures were nearly 700 mm and 16 °C in the period between 1960–1990, although in the last decades the study area is becoming drier and warmer as a consequence of reduced precipitation and increased temperatures.

During the investigated period (1949–2016), this area has been subjected to considerable transformations due to a mix of drivers. Among them, Common Agricultural Policy, local market conditions, demographic trends, and conservation measures (e.g., Natura 2000 network) have stimulated on the one hand a strong intensification and simplification of the agricultural productions; on the other, an expansion of land abandonment phenomena, all contributing to an increased environmental fragility of these areas [63,64]. A pivotal role has been played by urban growth impacting agricultural lands and compromising

their distinctive socioecological features. The low-density discontinuous settlement that developed on the edges of Rome (Figure 2) penetrates into the Agro Romano, fragmenting its agro-forestry matrix. The negative effects of this expansion can be cumulative and can increasingly affect large areas as shown by the regional distribution of per-capita land consumption computed at the municipal scale.

In particular, despite the fact that Rome exhibits intermediate values for the extent of urban areas on the total municipal area and for per-capita built-up areas partially due to a huge municipal area, the neighboring municipalities exhibit a sprawling urbanization with variable settlement densities that are frequently higher than those observed in the central municipality. Settlements traditionally organized on radial axes around the consolidated city are characterized by variable sealing rates with very heterogeneous percentages in the regional area, particularly high around the county seats (not only in Rome but also in the other Latium provinces), representing sub-centers in expansion. Simultaneously, the original settlement structure in the rural districts of the Agro Romano has been transformed into a medium and low-rise fabric spatially decomposed as a result of urban de-concentration processes only partially devised with consequent spatial colonization of areas located at 20–40 km from the central city.

Urban settlements in Rome can be divided into 2 main districts: (1) the consolidated urban fabric hosting 63.4% of the population (as the percentage share in the total population) with a population density of 4873 inhabitants/km² and (2) the suburbs hosting the 36.6% of the population (as the percentage share in the total population) with a population density of 1037 inhabitants/km² (2011 census).

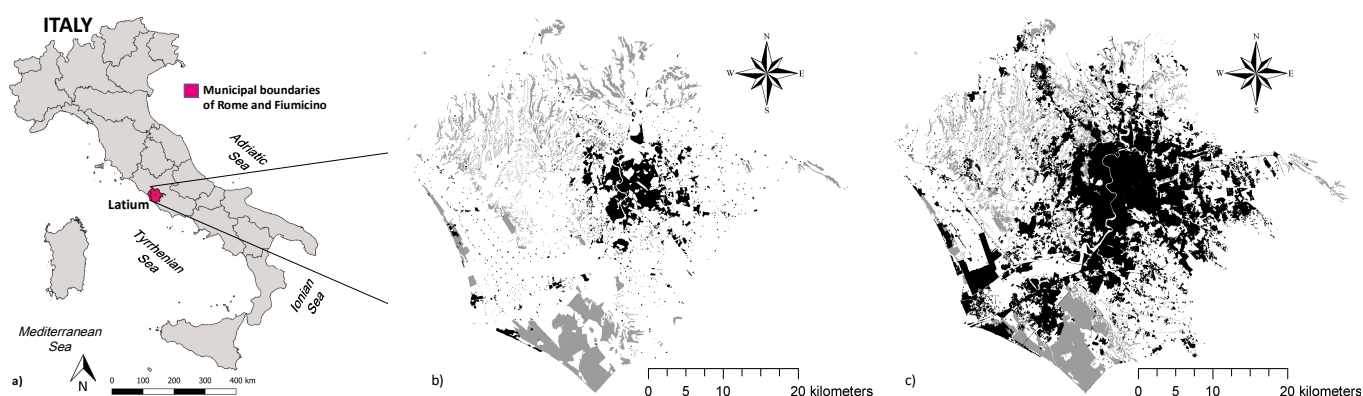


Figure 1. A map indicating the position of the study area (Rome and Fiumicino municipality) in Central Italy (a) and two maps illustrating the spatial distribution of basic land-use classes (black: urban settlements; grey: woodlands; and white: agricultural areas) in Rome 1949 (b); 2016 (c). Urban settlements include impervious land and urban parks; agricultural areas include arable land, crop mosaic, vineyards, and olive groves; and woodlands include forests, pastures, and water bodies.

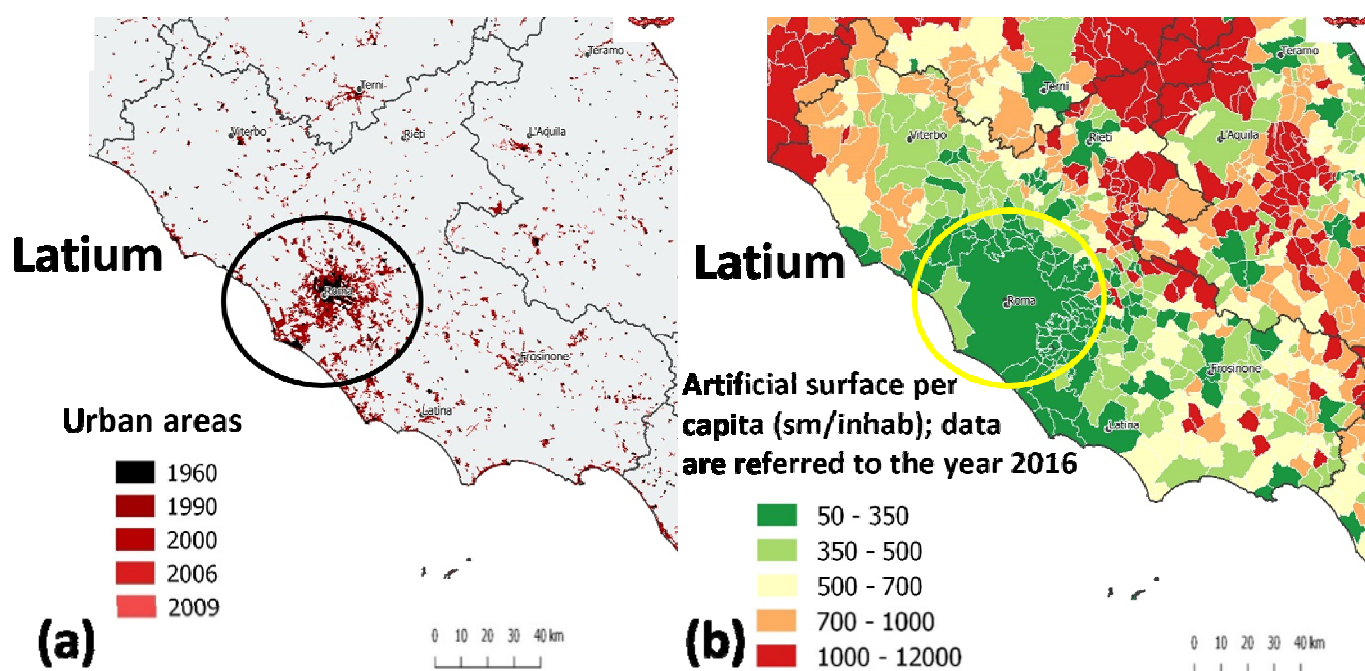


Figure 2. Boundaries of the Latium region located at the heart of Italy. Within the circle the municipalities of Rome and Fiumicino are shown with their corresponding urban areas (1960–2009, sub-figure (a)) and 2016 artificial surface per-capita (sub-figure (b)). These figures are taken from the annual report (2017) that ISPRA (Italian National Institute for Environmental Protection and Research) draws up on soil consumption, territorial dynamics and ecosystem services [65].

2.2. Land-Use Maps

Following earlier studies [26], a database reporting the surface area of several land-use classes was derived from elaboration of 3 compatible maps with a land nomenclature based on a simplified Corine Land Cover classification system [57–59,61,62]: (i) the Italian Istituto Geografico Militare topographic map (1:25,000 scale) produced in 1949, (ii) a land-use map (1:25,000) produced by the Cartographical Service of the Rome’s province authority derived from field surveys and in-house photo-interpretation of digital ortho-photographs taken for cadastral purposes, and (iii) land-use maps (1:25,000) realized by the Cartographical Service of Latium regional authority from photo-interpretation of digital ortho-images released from the Italian National Geoportal. In addition, a first map was originally produced for 1999 and subsequently updated for 2008 and 2016 with new images referring to the same years. Eight homogeneous classes with a minimum mapping unit of 1 hectare have been considered: (i) arable land, (ii) crop mosaic, (iii) vineyards, (iv) olive groves, (v) woodlands, (vi) pastures, (vii) water bodies and wetlands, (viii) impervious land, and (ix) urban parks.

2.3. Land-Use Indicators

In this work, we used per-capita indicators as suggested by the United Nations [66] for the achievement of the Sustainable Development Goals (SDGs). In particular, the 2030 Agenda strongly encourages the adoption of the indicator “relationship between land consumption and population growth”. In addition, Italy has adopted this indicator in the annual report of soil consumption drawn up by ISPRA (Italian National Institute for Environmental Protection and Research, see Reference [65]). For each investigated year (1949, 1974, 1999, 2008, and 2016), a per-capita indicator of surface area by land-use class was constructed considering (i) the total extension (ha) of land devoted to a given class and (ii) the total population residing in the study area (municipalities of Rome and Fiumicino). Total population was derived from integration of population census data (conducted every 10 years in Italy on behalf of the National Statistical Institute, Istat) and results from the national population registry available for each country’s municipality.

Annual rates of change over time were also calculated separately for each time interval (1949–1974, 1974–1999, 1999–2008, and 2008–2016) and land-use class.

To summarize long-term land-use patterns and trends in the study area, a Principal Component Analysis (PCA) was run on a matrix composed of two indicators' sets: (i) the relative proportion of the 9 classes (see above) by year (i.e., class area in total landscape, labelled with 'c') and (ii) per-capita surface area (ha) of each land-use class by year (labelled with 'p'). PCA is a multivariate exploratory technique aimed at analyzing two-way data matrices, inspecting the latent relationship among variables organized by rows and columns together. In our case, PCA provides delineates a dynamic representation of land-use change in the study area considering year-by-year class transformations by evaluating both landscape composition (class area) and land-use intensity (per-capita class area). The input matrix was constituted of 9 land-use classes (columns) and 2 indicators (percent class share in the total landscape and per-capita surface area by class) quantified at five years each (rows) and occupying ten rows. Components were extracted on the base of the absolute eigenvalue. Components with eigenvalue > 1 were regarded as significant and analyzed further for loadings and scores' structure. A biplot was realized with the aim of illustrating the statistical distribution of component loadings (land-use classes) and scores (indicators and years), evidencing the apparent linkages between land-use composition and landscape structure. This plot provided a refined and summary outlook of similarities and differences in landscape transformations across the study area.

3. Results

The study area has experienced land-use changes over time (Figure 3). Urban growth with sequential acceleration and deceleration waves has been associated with a moderate increase in the forest area. Landscape transformations have negatively impacted the traditional agricultural matrix that has contracted significantly. Urban fabric, initially compact and concentrated around the central city, has gradually expanded into rural areas occupying more than 30% of the surface area administered by Rome's municipality in 2016 and developing a spatially heterogeneous shape. Based on the landscape structure in 1949, the agricultural matrix formed a natural interface between urban areas and forests. In 2016, it was extremely fragmented, no longer acting as a buffer zone between settlements and woods, and now placed in close contact in most cases. These changes have transformed Rome's morphology, initially dense and organized mono-centrally around the historical town. During the study period, urban development progressively lost its radio-centric and additive character. In 2016, Rome's morphology was found more dispersed and spatially discontinuous. Taken together, these preliminary results highlight a transition from a compact form to a more dispersed and fragmented morphology common with other Mediterranean cities.

The long-term transformation of Rome's landscape (1949–2016) coincided with intense population growth in the study area (Figure 3). However, combining urban expansion and population growth rates, different rates of change were observed in the four sub-periods of investigation. The first period (1949–1974) was characterized by a sustained rate of urban expansion (about 4% per year) associated with an equally high rate of population growth (about 3% per year) and their ratio is about 1.5. This period reflects compact, dense, and radio-centric urbanization leveraged by demographic growth. The second time interval (1974–1999) delineated a massive urban expansion (about 3% per year) that did not correspond to a similar demographic trend, though, as the population grew very weakly with a ratio reaching the tremendous value of about 188. This period coincides with a phase of suburbanization, the result of which was the suburban expansion of low-density and spatially dispersed settlements in the metropolitan area. The largest mismatch between urban expansion and population growth was observed at this stage. The two subsequent periods (1999–2008 and 2008–2016) were rather similar, characterized by moderate urban growth in the face of modest demographic dynamics. In relative terms,

the mismatch between the two growth rates remained high with ratio values of about 6 and 3.5, respectively.

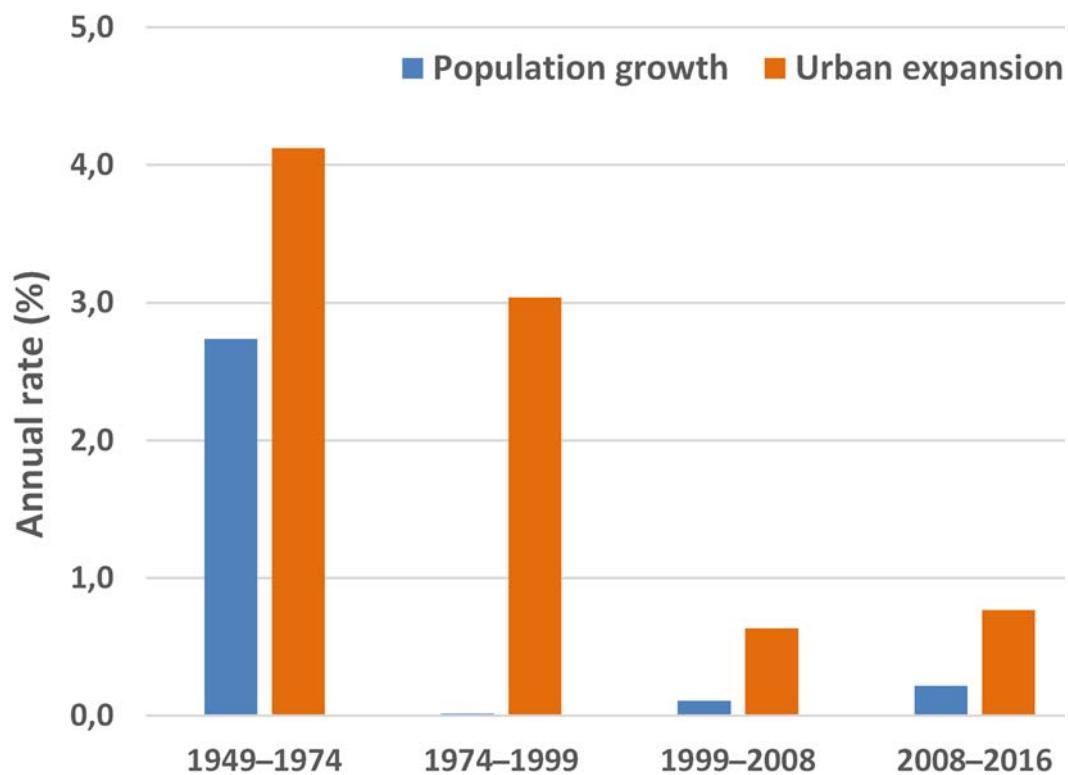


Figure 3. Percent annual rate of growth (population: blue; settlements: orange) by time interval in Rome. Urban expansion includes impervious land and parks/gardens within the city.

Considering the availability of different land-uses per-capita as an indicator of long-term transformations in urban, agricultural, and forest landscapes (Table 1), a substantial reduction in per-capita arable land was observed over time. Impervious lands (urban settlements) exhibit opposite dynamics similar to what has been observed for urban parks and gardens, a class physically associated with settlements and therefore dependent on their dynamics over time.

Table 1. Per-capita surface area (hectares) by land-use class in Rome, 1949–2016.

Class	1949	1974	1999	2008	2016
Arable Land	6.277	2.777	2.505	2.342	2.199
Crop Mosaic	0.161	0.178	0.070	0.111	0.112
Vineyards	0.221	0.126	0.068	0.069	0.070
Olive Groves	0.039	0.056	0.056	0.062	0.063
Woodlands	1.018	0.551	0.634	0.631	0.631
Pastures	0.549	0.770	0.433	0.425	0.422
Water Bodies	0.062	0.036	0.035	0.036	0.035
Impervious Land	0.594	0.800	1.388	1.460	1.530
Urban Parks	0.144	0.090	0.172	0.174	0.174

Following a significant decrease in the first time interval (1949–1974), forests have exhibited slight increases in more recent periods. Despite the significant contraction of agricultural areas, the cropland mosaic has undergone an important spatial reorganization. Some agricultural systems exhibited a decrease (vineyards and pastures), while other classes exhibited a slight growth (olive groves). In every case, trends over time have been non-linear, highlighting a substantial heterogeneity that corresponds to very different

dynamics over space according to the different phases of urban expansion as better demonstrated in the following analysis. The empirical analysis of per-capita land-use change in the four phases of metropolitan development outlined above highlights different dynamics in the first two time periods, corresponding with two sequential stages of the urban cycle in Europe (urbanization–suburbanization). By contrast, land-use change rates are fairly homogeneous in the two most recent periods (Table 2). These periods represent a rather heterogeneous phase of the urban cycle that combines elements of counter-urbanization (slow but constant land consumption at progressively greater distances from urban centers) and re-urbanization (slow recovery of the population even in central areas). More specifically, urbanization in Rome (1949–1974) coincided with a significant contraction of the per-capita surfaces of almost all agricultural and forest land-use (except olive groves, pastures, and crop mosaics) in favor of urban settlements. In the context of suburbanization (1974–1999), a slower (per-capita) contraction of all agricultural land-use was observed in favor of both urban settlements and forests. In the face of a continuous growth of urban settlements, the natural landscape responded in a very different way in the most recent phases. Arable lands continued to decline significantly. This extensive use of agricultural land characteristic of the study area has constituted a stock of buildable area over the entire study period considering the modest value added.

Table 2. Percent change over time (annual rate) in the per-capita surface area by land-use class in Rome, 1949–2016.

Class	1949–1974	1974–1999	1999–2008	2008–2016
Arable Land	−2.23	−0.39	−0.72	−0.77
Crop Mosaic	0.41	−2.42	6.42	0.05
Vineyards	−1.72	−1.86	0.24	0.09
Olive Groves	1.79	−0.06	1.22	0.21
Woodlands	−1.84	0.61	−0.05	−0.01
Pastures	1.61	−1.75	−0.21	−0.10
Water Bodies	−1.70	−0.05	0.09	−0.23
Impervious Land	1.39	2.94	0.57	0.60
Urban Parks	−1.51	3.67	0.11	0.03

The agricultural mosaic together with vineyards and olive groves demonstrated evident signs of recovery. This result is in line with a generalized fragmentation of rural spaces at the fringe. Expansion of tree crops coincided with the consolidation of agricultural mosaics, a highly fragmented landscape that retains important elements of naturalness. The future challenge for fragmented landscapes will be to preserve this type of land-use from further isolation, fragmentation, and degradation resulting from urban growth. On the contrary, pastures have undergone a slow but steady decrease in line with what has been observed for arable lands. In the Mediterranean, fringe pastures have traditionally represented a reservoir of land potentially buildable or convertible to other (economically more profitable) uses. From this perspective, the expansion of pastures in 1949–1974 confirms the massive urban pressure typical of that period when pastures, often representing a human-driven evolution of arable lands, were frequently regarded as a ‘temporary’ land use pending ‘speculative’ conversion to more profitable uses. In the subsequent periods, pastures mostly acted as the largest stock of land to be converted, sometimes along with arable land.

Based on the previous results, a PCA was developed to summarize the main transformations in fringe landscapes and compare the latent trends in terms of the total area and area per-capita for each land-use class (Figure 4). The PCA extracted two axes cumulatively explaining more than 90% of the total variance. Component 1 (71.9%) clearly discriminates the total dynamics (negative scores) from the per-capita land-use indicators (positive scores), differentially depicting trends in the agricultural landscape. In fact, arable lands are considered in opposition to other agricultural land uses. This result highlights how

the greatest transformations of the agricultural landscape in the study area concerned the arable lands, which have undergone a strong downsizing in per-capita terms. In contrast, all other uses of agricultural land have experienced much more modest changes. Component 2 (18.7%) demonstrates a marked similarity between urban settlements and forest areas, the two land uses that exhibited increases (more or less strong) during the survey period and to the detriment of agricultural areas. Component 2 also discriminates between earlier periods (p49 and p74) and more recent times (p99, p08, and p16), suggesting a substantial diversification in the three phases of urban development previously outlined (urbanization, suburbanization, and a mixed stage between counter-urbanization and latent re-urbanization).

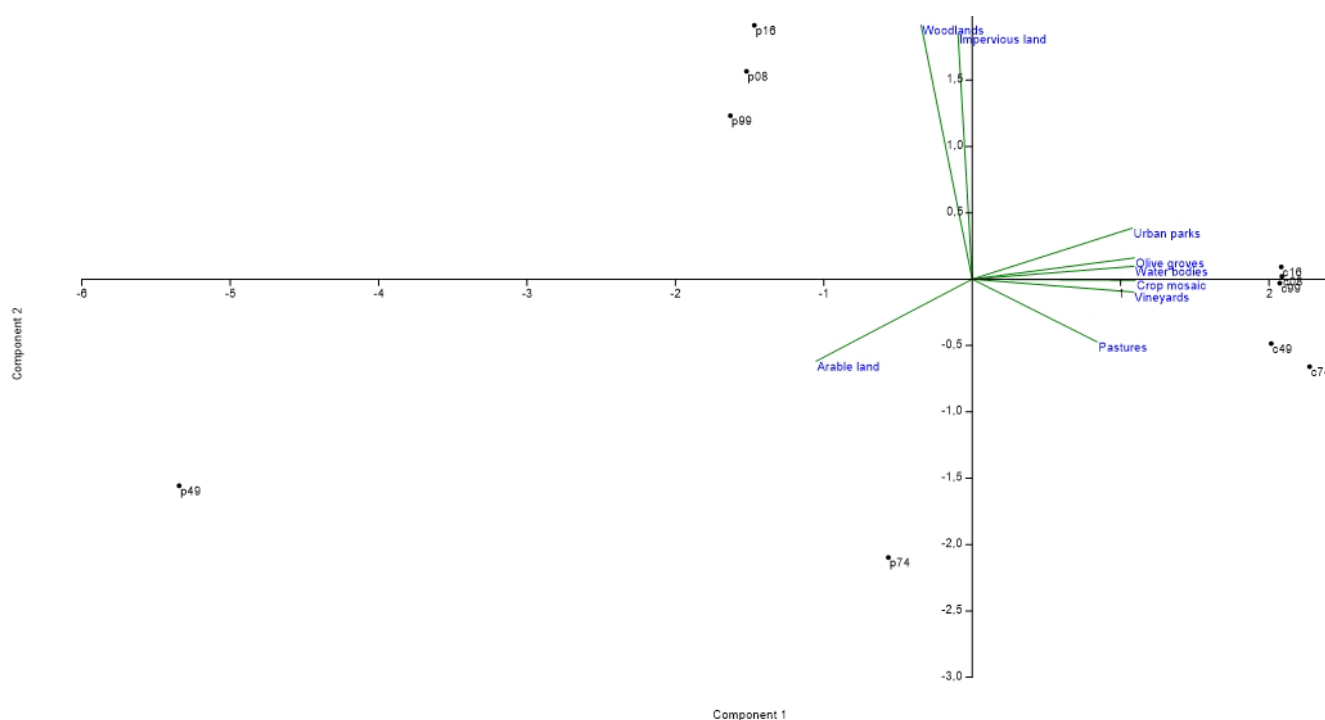


Figure 4. Results of a Principal Component Analysis run on the matrix including percent rates of change in land-use and per-capita land-use in Rome, 1949–2016.

4. Discussion

The analysis of landscape transformations conducted through the use of per-capita surface indicators by land use class provided an integrated view of environmental and socioeconomic nature. As far as built settlements are concerned, per-capita land-use indicators quantified the mismatch between urban expansion and population growth, outlining distinctive phases of the metropolitan cycle [67]. In the study area, this indicator has assumed profoundly different values in correspondence with (i) compact urbanization and (ii) low-density suburbanization, assuming intermediate values in the most recent period characterized by the coexistence of re-urbanization and counter-urbanization impulses. With regard to non-urban land-use, per-capita indicators provide an even more significant view; in the case of agricultural landscapes, the negative evolution of per-capita cropland indicated the impossibility to satisfy the growing (local) demand for fresh food. These contexts, however, were known for centuries for their specialization in primary production, which experienced a significant decline in the most recent decades [68]. Therefore, a recent analysis [69] argues that there is a need to focus more on the form and quality of urbanization processes rather than simply on the volume and speed of urbanization. Thus, the measure of the amounts of land in urban use and their spatial configuration remains crucial to provide useful information on anticipating future needs and to ensure an

adequate supply of public goods such as infrastructure, open spaces, and common facilities for urban expansion [70].

The multivariate analysis clearly indicates the long-term competition between land-use, highlighting the relationship between ‘predators’ (urban settlements and more recently forests) and ‘prey’ (arable land and more recently pastures). This interpretation, in line with earlier studies developed in the Mediterranean basin, highlights the substantial dichotomy between ‘predators’ with a competitive advantage (urban settlements) and more marginal actors (forests) that opportunistically occupy landscape niches left free from abandonment of agricultural land as a result of real estate speculation [70]. This dynamic is visible in marginal areas, while being occasionally observed at the fringe, for example in contexts where physical (e.g., steepness and accessibility) and/or regulatory (planning/zoning) constraints to building are more pronounced [71–73]. Simultaneously, our analysis establishes how agricultural landscapes do not experience homogeneous dynamics [74–76]. In the face of the originally dominant arable lands that systematically acted as a ‘prey’ between 1949–2016, other land-uses have consolidated their spatial distribution with a significant increase in per-capita surface area. Among these, per-capita increase in olive groves, a ‘synanthropic’ crop in the Mediterranean basin, appears very significant, having occupied peri-urban voids generated by a fragmented growth of low-density settlements [77,78]. The rapid suburbanization process during the 1960s, 1970s, and the following period became a dominant form of urban growth and mainly contributed to the spatial dispersion of urban centers towards the urban fringes. However, remarkably, the dispersal of the employment was slower than that of the city during this period, therefore the commuters’ distances have increased. During 1980s and 1990s, settlement accesses have grown along road infrastructures, encouraging the emergence of new commercial, industrial, and leisure areas. The expansion of urban towards peripheries preying on more arable lands was fueled by the increase of car ownership, the expansion of transport infrastructure, and the emergence of new commercial and industrial areas that have served as new suburban job hubs [79]. The local context was at the base of landscape transformations, having land speculation, second homes, tourism development, and migration as characteristic roles in landscape changes at the fringe [80]. In these regards, socioeconomic factors have demonstrated to influence metropolitan growth in Rome. Assuming the relevance of a comparative analysis of land-use change over a sufficiently long term, a joint monitoring of landscape transformations and population supports sustainable development policies in metropolitan regions [79]. In comparison with northern, central, and western counterparts, southern European metropolises have experienced landscape fragmentation in a context of increasing ecological fragility. Urban sprawl has demonstrated to influence fringe landscapes with changes in the intimate structure of both agricultural and forest mosaics [81]. The intrinsic relationship between landscape transformations and different waves of urban expansion was also illustrated, distinguishing at least three developmental waves, namely urbanization, suburbanization, and a more mixed phase with impulses of counter-urbanization and re-urbanization. Per-capita indicators of land-use change clearly documented the complete unsustainability of recent urban expansion. The intrinsic mismatch between population growth and urban expansion enlarged in recent times, particularly evident during both suburbanization and the most recent developmental wave.

5. Conclusions

Comparative analysis delineating latent patterns and trends in land-use has recently benefited from indicators that assess the intrinsic mismatch between landscape transformations and population growth. Rising availability of high-resolution datasets supports such investigation, allowing for the construction of new indicators and refining empirical approaches to land-use science. An extensive use of per-capita land-use indicators will contribute to monitor the effectiveness of adopted policy measures and forecast possible future land-use changes in a spatial planning perspective. When evaluating long-term transformations of fringe landscapes, the empirical results of our study indicate the in-

creasing mismatch between settlement expansion and population growth that can be easily captured through the ratio between the two growth rates. This ratio goes from the value of just 1.5 for the period of 1949–1974 to the enormous peak of 188 in the time frame of 1974–1999, and then reaches the values of about 6 and 3.5 in the subsequent periods (1999–2008 and 2008–2016, respectively). In combination, this developmental mode reveals all its traits of unsustainability, leading to landscape fragmentation and abnormal consumption of soil resources. Spatial planning (and primarily town master plans) should envisage practical action to contain the unavoidable effects of recent urban growth on the capacity of ecosystems to maintain a complete provision of services and goods in metropolitan region.

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