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In-between Sprawl and Fires: long-term Forest Expansion and Settlement Dynamics at the Wildland-Urban Interface in Rome, Italy

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Abstract

Mediterranean landscapes are emblematic cases for the long-established urban-wildland dynamics. Although dense and compact southern European cities were sprawling rapidly in the last decades, peri-urban areas still preserve biodiversity-rich habitats, traditional crop mosaics and high-quality relict forest stands. To assess long-term trends in forest land cover and urban expansion in Rome (Italy), diachronic forest and settlements maps were analyzed over two time intervals (1936-1974 and 1974-2006) reflecting different socioeconomic contexts on a local scale. Forests expanded into agricultural land during the whole period, following cropland abandonment and enforced land protection from urbanization. Forest composition changed over time in relation to urban expansion causing higher disturbance to forests (increase of fire frequency and severity, land fragmentation, soil sealing and invasive species). Forest diversity increased especially in areas with medium-density settlements. This indicates a tendency towards more heterogeneous forest structures at the urban-wildland interface compared to natural landscapes. Long-term monitoring of settlement dynamics and woodland expansion may inform strategies of sustainable forest management and becomes increasingly urgent for expanding Mediterranean peri-urban areas.

Key words: Urban fringe; Forestry; Land-use changes; Human disturbance; Mediterranean basin.

Introduction

The Wildland-Urban Interface (WUI) was considered an unstable and rapidly evolving environment that represents a challenging opportunity to assess landscape complexity and ecological disturbance factors (Stewart et al. 2007) and to plan strategies for sustainable land management (Theobald and Romme 2007). The WUI is formed by peri-urban areas where settlements and natural habitats (primarily forests) overlap. The WUI constitutes a fringe landscape with confusing boundaries threatened by forest fires, soil sealing, land degradation and the increase of invasive species and pollutants (Cohen 2000; Liu et al. 2003; Mc Afee et al. 2006). Taken as a process driven by population growth, economic development and social change, low- and medium-density settlement expansion is considered the most relevant cause of landscape transformation at the WUI (Nowak et al. 2005; Vince et al. 2005). Being one of the main threats to fringe natural habitats, fire risk is in turn triggered by deregulated urban expansion (Whitman et al. 2013).

The European landscape was shaped by rapid and intense transformations due to urbanization and infrastructural development during the last century (Antrop 2004). The Mediterranean region, traditionally characterized by a long-established interplay between nature and human activities (Sirami et al. 2010), was particularly affected by urbanization causing the abandonment of hilly and mountain areas. Such areas has experienced processes of land re-colonization by forests, while coastal and lowland areas were transformed into highly fragmented landscapes with relict natural patches embedded into a chaotic urban matrix (Bielsa et al. 2005; Busch 2006; Falcucci et al. 2007).

These transformations have contributed to the ecological and socioeconomic homologation of newly-formed landscapes, with ongoing processes of change being almost unknown (Scarascia Mugnozza et al. 2000; Antrop 2004; Plieninger et al. 2011). Quantifying changes in peri-urban landscapes resulting from urbanization, land abandonment and forest recovery is essential to develop measures mitigating the impact of forest fires (Fernandes 2013) and to stimulate strategies for urban containment in the light of sustainable land management (Styers et al. 2001).

Moreover, habitat fragmentation and ecosystems degradation driven by landscape transformations, are the main cause of biodiversity loss (Sanderson et al. 2002; Zipperer 2002; Antrop 2004). In most cases, land-use changes determined the fragmentation, simplification and deterioration of the traditional crop mosaic and relict natural land on the fringe (Vince et al. 2005; Salvati and Sabbi 2011; Herrero-Corral et al. 2012; Díaz-Palacios-Sisternes et al. 2014). This process is difficult to assess and manage in both anthropogenic landscapes and marginal land abandoned by the traditional agricultural activities (Antrop 2004; Hochtl et al. 2005; Munafò et al. 2010; Salvati et al. 2013). Together with the progressive replacement of abandoned cropland with forests and shrubland, recent urbanization - especially in the form of dispersed and discontinuous urban expansion - makes the boundary between urban and natural landscapes quite undefined (Antrop 2004).

During the last fifty years a marked decrease of cropland together the expansion of urban and forest land was observed in the northern Mediterranean region (Blondel et al. 2010), and especially in Italy (Falcucci et al. 2007). Recent studies carried out in southern Europe (e.g. Badia et al. 2011; Herrero-Corral et al. 2012; Salvati 2013a) pointed out the urgent need to develop monitoring approaches to address the dynamic interplay between ecological processes and socioeconomic changes shaping fringe landscapes. In Italy, Rome's WUI (Latium, central Italy) was identified as one of the most dynamic landscapes in the country (e.g. Munafò et al. 2010). Rome's expansion progressively altered the traditional uses of land in the surrounding rural region and the spatial distribution of human settlements which was originally characterized by the polarization into a number of rural villages and few towns (Antrop 2004). Although 39 protected areas and 55 Natura 2000 sites were established in Rome's province (22% of the total surface area), the conversion of agricultural and natural land to urban uses was estimated by 0.4% *per year* during 1960-2006 (Salvati and Sabbi 2011).

Natural landscapes in Rome's province are affected by different processes of transformation: (i) the abandonment of marginal and mountain areas determining forest expansion, (ii) the intensification of agriculture in more accessible lowland and coastal areas, and (iii) population and activities decentralization towards satellite cities (Munafò et al. 2010). On the one hand, changes in the socioeconomic context have influenced land-use transformations, with low- and medium-density settlement expansion generating a complex fringe landscape with natural habitats and relict forest stands (Munafò et al. 2010). On the other hand, the traditional rural landscape surrounding Rome (the so called 'Agro Romano') has experienced a progressive homogenization during the last century, with a decrease of natural/forest land and the loss of unique cultural heritage (Blasi et al. 2008; Cavallo and Marino 2012; Salvati 2013b). However, although Rome is the most populated municipality in Italy, peri-urban environments still preserve biodiversity-rich landscapes formed by relict forests and the traditional crop mosaic (Attorre et al. 2000; Salvati and Sabbi 2011). Based on these premises, Rome's landscape represents an exemplificative case for the assessment of long-term urban-forest dynamics at the WUI in the Mediterranean region.

The present study assesses long-term trends in forest cover and urban expansion in Rome's province by integrating high-resolution forest and settlement maps. Two time intervals (1936-1974 and 1974-2006) have been investigated that reflect different socioeconomic contexts at the local scale (compact and dense growth: 1936-1974; medium/low-density expansion and repolarization around the main urban centres: 1974-2006). It was hypothesized that the two growth phases influenced peri-urban landscape transformations in a different way with contrasting effects on forest expansion (Salvati et al. 2013). Changes in forest diversity at the WUI were also evaluated to verify if long-term urban expansion and the consequent ecological disturbance have altered the structure and diversity of fringe forest stands (Torras et al. 2012). Long term monitoring of urban dynamics together with the assessment of evolving forest types may inform strategies for regional planning, environmental management and fire risk prevention (Badia et al. 2011).

Material and methods

Study area

The investigated area covers Rome's province (5355 km^2), 30% of which is flat and 20% mountainous. The most important mountain area is the Simbruini chain (maximum elevation: 1820 m above sea level) in the Apennine district. Flat areas (the so called 'Agro Romano') are placed over the alluvial plain of the Tiber river (Figure 1). Rome's

provincial land was administered by 122 municipalities, with Rome's municipality covering the largest area (1285 km^2). Using territorial and demographic indicators, a brief description of the study area is provided in Table 1.
Industrial areas were traditionally located in the eastern part of the ‘Agro Romano’ lowland close to the city of Rome, while traditional rural areas are more abundant in the western part of Rome's municipality, which is considered the greenest urban municipality in Europe (Munafò et al. 2010). Although urban areas occupy an important (and increasing) part of the region, the majority of the province’s land still consists of forests, pastures, shrubland and cultivations. Despite degraded by summer fires and the high environmental pressure determined by Rome's expansion, the original broadleaved forest vegetation is preserved in some stands especially in coastal flat and upland oak forests (Salvati and Sabbi 2011). The climate is typically Mediterranean, with rainfalls concentrated in autumn and spring and mild temperature recorded in winter. The average long-term (1961-1990) annual rainfall and mean temperature in Rome were 700 mm and 16°C respectively (Salvati 2013b).

Forest maps

We have considered three thematic land-cover maps covering Rome's province and spanning the time frame 1936 to 2006 with similar resolution (1: 100,000 nominal scale). The oldest layer considered is the Forest Map produced by the Italian Milizia Forestale (the Italian Forest Service during the Fascism period) as part of the first national forest inventory at 1:100,000 scale dated 1936. We geo-referenced the scanned maps by rubber-sheeting according to three independent layers (coasts, administrative boundaries and roads). For each map, we considered at least 100 control points to produce a direct georeferentiation in WGS84 and to restore all the thematic information through digitalization. Compared to the more recent maps considered in this paper, the Forest-Map 1936 investigated relatively few types of forests allowing for a thematic generalization in four classes: chestnut, beech, coniferous forests and a residual class including mixed broadleaved forests. These classes are compatible with the other maps considered in the present study.

The second layer considered here is the Agroforest map developed by Cartographical Office of Rome's province in 1974 (Salvati and Sabbi 2011). The map assessed the spatial distribution of 22 land-use classes with a scale and extent comparable to the Forest-Map 1936 (Falcucci et al. 2007). Four classes of the original legend (chestnut, beech, conifer forests and mixed broadleaved forests) were further extracted and analyzed. All the other (non-forest) classes were assigned to the matrix.

The third layer considered here is the Corine Land Cover (CLC) map produced in 2006. This map is part of the program started in 1985 by the European Community to generate pan European digital land cover maps with a legend of 44 and 92 classes at the third and fourth nomenclature levels, respectively (Salvati et al. 2013a). Polygons belonging to CLC 3.1 class were attributed to the 'forest' class and four classes of the original legend (chestnut, beech, conifer forests and mixed broadleaved forests) were extracted and analyzed. All the other (non-forest) classes were assigned to the matrix.

To check the accuracy of the information contained in the three maps adopted in the present study and to evaluate the reliability of the land cover changes measured for the 1930s, 1970s and 2000s, we have considered additional datasets providing estimates of forest cover in Rome's province: (i) the annual forest survey carried out by Italian National Institute of Statistics (Istat) since 1949, (ii) the two national forest inventories dated 1985 and 2003, (iii) a 25,000 topographic map produced by Italian Military Geographic Institute (Florence) and referring to 1949, (iv) the national Map of Land Cover developed by the National Research Council, the Italian Cadastre, and the Italian Touring Club (1952-1965) including 22 classes (three forest classes) with a scale of 1:200,000 (Falcucci et al. 2007), (v) the two 1:100,000 CLC maps dated 1990 and 2000 and producing information at third land cover nomenclature level and (vi) the 1:25,000 'land-use map of Latium region' produced in 1999 by the Cartographic Service of the Regional Authority of Latium through digital interpretation of aerial photographs.

Settlement maps

Diachronic settlement maps were obtained from the Geographical Information System (GIS) database supporting census operations produced by Italian National Census of Population and Buildings. This database consists of digital cartographical data which have been produced through aerial photograph processing at 1:10,000 scale in urban areas and 1:25,000 scale in rural areas, including the axis of the streets and the outlines of the blocks. Density of buildings was calculated in 1919, 1971 and 2001 from data collected in the framework of the national census of buildings. In the above-mentioned years, maps were derived from the digital cartography provided at enumeration district scale. The vector map obtained from Istat covers the whole study area and reports the geometry of more than 16,000 enumeration district polygons corresponding to three–four building blocks in urban areas. The surface area of each polygon was calculated by way of the ArcGIS "spatial analyst" tool (ESRI Inc., Redwoods, USA).

Building density was calculated at each enumeration district polygon for every considered year (Salvati 2013a). To estimate the spatial distribution of urban settlements, enumeration districts were grouped into eight density classes: (i) no buildings (i.e. pristine, natural land), (ii) < 0.5 buildings per hectare (i.e. sparsely inhabited rural areas), (iii) 0.6–1.0 (rural area, low density), (iv) 1.1–2 (rural area, intermediate density), (v) 2.1–5 (peri-urban area with dispersed and discontinuous settlements), (vi) 5.1–10 (peri-urban area, mixed settlements), (vii) 10.1-50 (urban area, compact settlements) and (viii) > 50 buildings per hectare (urban area, hyper-compact settlements). The total surface area of each class was calculated by summing up the surface area of each enumeration district within that class.

Data analysis

The procedure carried out in this study was based on pair-wise overlay (Salvati 2013b) of the three forest maps with the three building maps previously described (1936 forest maps with 1945 building map, 1974 forest map with 1971 building map, 2006 forest map with 2001 building map). Using the ArcGIS (ESRI Inc., Redwoods, USA) 'intersect' tool, an intersection map of forest polygons with the building map polygons was generated. Forest land area by settlement density class was calculated separately for three years (1936, 1974 and 2006). Forest land composition at each class was finally calculated.

A diversity index was calculated to assess changes in the distribution of four forest types (chestnut, beech, conifers and mixed broadleaved) along the urban-forest interface in 1936 and 2006 using Shannon's diversity (H') and Pielou's evenness (J) indexes. Starting from the calculation of Shannon's diversity index ($H' = -\Sigma\, p_i * \ln p_i$) applied to the percent composition of the four wood types by class of settlement density (p_i), J was derived as the ratio of H' to the maximum potential H' values according to the number (W) of wood types ($H_{max} = \ln(W)$) observed in each settlement class (ranging from 1 to 4). Pielou's index ranges between 0 (low evenness) and 1 (high evenness) indicating a more diverse and mixed forest composition with increasing J values.

Results

Changes in forest cover (1936-2006) in Rome's province

Two time intervals (1936-1974 and 1974-2006) were investigated with the objective to assess changes in forest land cover during the last seventy years in Rome's province. Forest land increased from 18.3% in 1936 to 19.7% in 1974 and to 19.8% in 2006. Chestnut and coniferous forests increased respectively from 13.8% and 1.7% of forest land in 1936 to 18.4% and 3.1% in 2006. Beech forests were substantially stable composing 10.1% and 9.9% of forest land respectively in 1936 and 2006. Mixed broadleaved forests decreased from 74.4% to 68.6% during the study period. Changes in the spatial distribution of forest land (Figure 1) reflect different socioeconomic processes observed along the urban gradient in Rome. Land abandonment stimulated natural forestation in upland and mountain areas while urbanization in peri-urban areas (especially along the coast and in the most accessible land) fragmented the relict forest patches close to Rome.

Settlement expansion (1919-2001) in Rome's province

Non-urbanized land amounted to nearly 89% of Rome's province area in 1919 and fell to 30% in 2001 (Table 2). The surface area of the other settlement classes increased during the investigated period indicating urban expansion with intermixed concentration and dispersion waves. Land with > 5 buildings per hectare increased from 0.2% in 1919 to 3.7% in 2001 providing evidence of the compact growth observed in the last century.

The increase of low- and medium-density classes (0.5–5.0 buildings per hectare) was even more evident (from 0.6% in 1919 to 13.0% in 2001). Morphological indicators were calculated using the percent class area of selected settlement types. While 'fragmentation' index increased during the study period, 'densification' and 'dispersion' indexes showed contrasting trends during the two intervals.

Long-term trends in forest cover and urban expansion

Forest land in Rome's province shows diverging trends over time depending on settlement density (Table 3). More than 75% of forest cover concentrated on pristine land in 1936 but this percentage declined to 49% in 1974 and 46% in 2006. Conversely, the percentage of forests in areas with medium-high settlement density (> 10 buildings/ha) increased from 1.1% in 1936 to 4.5% in 1974 and 11.7% in 2006. However, the largest increase was observed in the intermediate density classes (2-5 and 5-10 buildings/ha). These classes identify mixed urban-rural landscapes characterized by settlement dispersion, habitat fragmentation and cropland abandonment. The analysis of changes in forest cover confirms these findings and points out a contrasting pattern of forest re-colonization along the urban gradient. In pristine land, forests expanded by 2% per year during 1936-1974 declining by 0.9% during 1974-2006. In sparsely inhabited rural areas (< 0.5 building/ha) forest cover increased by 0.34% during 1936-1974 being stable in the subsequent time interval. The highest rate of growth in forest cover was observed in three settlement classes (0.6-1, 1.1-2 and 2.1-5 buildings/ha) in 1974-2006. These results reflect the different patterns of urban expansion found in the two time intervals in Rome. In the former period compact and dense urban growth stimulated deforestation and forest fires. Discontinuous settlement expansion in the latter period determined an increased rate of agricultural land conversion to urban uses at larger distances from consolidated urban areas.

Forest type dynamics and urban expansion

The four investigated forest types showed spatial patterns similar to what was observed for the cumulated forest cover. Using an indicator of forest concentration (percent cover of each forest type in the two settlement classes with density < 0.5 building/ha), it was observed that beech forests declined only moderately in pristine land (from 99% in 1936 to 83% in 2006). This can be explained by the fact that beech is strongly associated to undeveloped, less accessible mountain areas. On the contrary, chestnut and mixed broadleaved forests are the classes more frequently associated with low- and medium-density settlements while conifer forests occupy an intermediate position (Figure 2).

Dynamics of forest diversity and settlement density

Forest diversity (Shannon H') revealed an explicit spatial behaviour increasing moderately with settlement density. The same pattern was observed for Pielou evenness (J). The highest values of both indexes were found at both high settlement density (> 10 buildings/ha) and pristine land class (Table 4). Both indexes increased rapidly during the study period with rates ranging between 0.22% and 0.65% per year. Diversity indexes decreased (-0.61%) in one class only (10-50 buildings/ha). The highest increases were observed in both rural, low-density areas (0-0.5 building/ha) and peri-urban, medium-density areas (2-5 buildings/ha).

Discussion

Sustainable land management strategies are becoming increasingly urgent for Mediterranean urban regions. In these areas, long-term land-use changes are determined by multifaceted environmental and socioeconomic transformations involving processes typical of mixed urban-rural areas (Antrop 2004; Bielsa et al. 2005; Blondel et al. 2010). This complicates the joint assessment of urban/forest expansion in peri-urban areas. While confirming the expansion of forests during the last seventy years in Rome, the present study identifies forests at the urban-wildland interface as the primary target for policies mitigating the impact of settlement's expansion on the surrounding natural areas (Novak et al. 2005). As already stated in previous studies (e.g. Falcucci et al. 2007), natural forestation driven by cropland abandonment concentrated on mountain, marginal and disadvantaged areas (Salvati and Sabbi 2011). At the same time, forest land showed a moderate decline (followed by higher patch fragmentation and stand heterogeneity) in lowlands around Rome (Salvati 2013a).

The integrated analysis of forest land cover and settlement density provides a useful tool to monitoring long-term landscape changes and environmental quality on both local and regional scales (Vince et al. 2005). More than 75% of forest cover concentrated on land with no buildings in 1936 decreasing rapidly to 49% in 1974 and to 46% in 2006. On the contrary, land with medium-high settlement density (> 5 buildings per hectare) concentrated in 1936 only 1.5% of forest cover increasing to 8% in 1974 and to 20% in 2006. This indicates the increasing human pressure observed on Rome's peri-urban forests in the last century.

Different urban-forest dynamics at the WUI were identified during the first (1936-1974) and the second (1974-2006) time interval. While forest fragmentation occurred in both periods, forests expanded at different rates into agricultural land. Between 1936 and 1974, forests increased in mountain areas and declined in coastal areas. Between 1974 and 2006, forest cover was stable - but possibly with a higher fragmentation (Salvati and Sabbi 2011) - in the mountain belt, increasing slightly along the coastal area surrounding Rome. However, some woodlots disappeared in the 'Agro Romano' lowlands or underwent further fragmentation due to urbanization (Salvati 2013b).

Rome's compact and dense growth - together with forest fires - was the major factor shaping the wildland-urban interface especially during 1936-1974. Building density, the spatial configuration of discontinuous and medium/low density settlements and the characteristics of Mediterranean woodlands (low and intermediate vegetation cover, high sensitivity to fires, degraded soils and semi-arid climate regimes) affected forest cover at least until the late 1980s. Since the early 1990s, however, forest land experienced distinct paths depending on the distance from urban areas (Munafò et al. 2010). Settlements and natural land became progressively less distant contiguous because of the joint effect of urbanization and the forestation of abandonment cropland in flat areas (Salvati and Sabbi 2011).

Conclusions

Our results underline the urgent need of planning strategies specifically designed for fringe forests. Wildland-urban interfaces are expanding rapidly in the Mediterranean basin; this reflects both discontinuous urbanization and the abandonment of agricultural areas surrounding the main cities. With the decline of traditional cropland (usually acting as a buffer between forest patches and built-up areas), the distance between forests and human settlements decreased with possibly negative implications for the composition, structure and diversity of forest landscapes. This process may determine a higher fire risk, which should be managed through specific forest plans preventing fuel accumulation (Whitman et al. 2013). More frequent and severe fires may trigger a downward spiral causing biodiversity loss and habitat fragmentation around low-density settlements (Cohen 2000; Haight et al. 2004; Vince et al. 2005). Planning strategies controlling the expansion of forests into agricultural land (Bielsa et al. 2005; Busch 2006) should be developed considering the specific structure of fringe landscapes (e.g. intrinsic fragmentation, discontinuity, dispersion, diversification, fractality). Finally, forest conservation strategies should integrate specific measures for the protection of relict pastures and cultural heritage.

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Table 1. Selected demographic variables in Rome's province by year.

Variable	1936	1971	2011
Land surface (km^2)		5 353	
Resident population	2 775 380	3 761 067	4 110 035
Population density (inhabitants km^{-2})	518	703	768
Population annual growth (%)	2.9	0.2	0.5
Suburban/urban population (%)	26.9	35.5	47.3
Urban population density (inhabitants km^{-2})	1 460	1 852	1 862
Urban population annual growth (%)	3.2	-0.2	-0.1
Suburban population density (inhabitants km^{-2})	152	256	342
Suburban population annual growth (%)	1.8	1.5	1.5

Table 2. Percent distribution of land in Rome's province by class of settlement density (buildings/hectare) and year.

Density class	1945	1971	2001	Annual change (%) 1945-1971	Annual change (%) 1971-2001
0	74.0	41.2	30.3	-1.7	-0.9
0 - 0.5	23.8	49.2	52.9	4.1	0.3
0.6 - 1.0	0.7	3.0	3.4	12.6	0.4
1.1 - 2.0	0.7	2.5	4.3	9.9	2.4
2.1 - 5.0	0.3	2.3	5.4	25.6	4.5
5.1 - 10.0	0.3	1.2	2.6	11.5	3.9
10.1 - 50	0.1	0.4	0.7	11.5	2.5
> 50	0.1	0.2	0.4	3.8	3.3
*Densification index**	*0.8*	*1.0*	*1.6*	*1.3*	*1.8*
*Fragmentation index***	*0.3*	*1.2*	*1.7*	*10.4*	*1.5*
*Dispersion index****	*10.0*	*15.0*	*14.3*	*1.9*	*-0.2*

* The ratio of percent land > 10 buildings/ha to the percent land > 0 buildings/ha. ** The ratio of percent land with 0 - 0.5 buildings/ha to the percent land with no buildings. *** The ratio of percent land with 0.6 - 10 buildings/ha to the percent land > 10 buildings/ha.

Table 3. Percent forest cover by class of settlement density (buildings/hectare) and year.

Year	0	0 - 0.5	0.6 - 1.0	1.1 - 2.0	2.1 - 5.0	5.1 - 10.0	10.1 – 50	> 50
1936	76.3	12.8	4.1	2.5	2.7	0.5	0.7	0.4
1974	48.9	13.6	11.2	9.1	9.7	3.2	2.4	2.1
2006	46.1	8.6	4.3	5.5	15.2	8.6	10.2	1.5
Changes in forest land (% per year)								
1936-1974	2.01	0.34	0.11	0.07	0.07	0.01	0.02	0.01
1974-2006	-0.86	0.02	0.22	0.20	0.22	0.08	0.05	0.05
1936-2006	0.70	0.19	0.16	0.13	0.14	0.05	0.03	0.03

Table 4. Shannon diversity (H') and Pielou evenness (J) in the investigated forest types by year and their changes over time by settlement density class (buildings/ha).

Year	0	0 - 0.5	0.6 - 1.0	1.1 - 2.0	2.1 - 5.0	5.1 - 10.0	10.1 – 50	> 50
Shannon diversity index (H')								
1936	0.82	0.58	0.56	0.62	0.57	0.57	1.01	0.77
2006	1.02	0.84	0.65	0.79	0.83	0.67	0.58	0.94
Pielou's evenness index (J)								
1936	0.59	0.42	0.41	0.44	0.41	0.41	0.73	0.55
2006	0.73	0.61	0.47	0.57	0.60	0.48	0.42	0.68
Annual change (%) in H and J indexes								
1936-2006	0.35	0.65	0.22	0.40	0.64	0.26	-0.61	0.32

Figure 1. A map of the study area with elevation and the boundaries of local municipalities (upper left) and three maps illustrating the spatial distribution of forests in Rome's province by year.

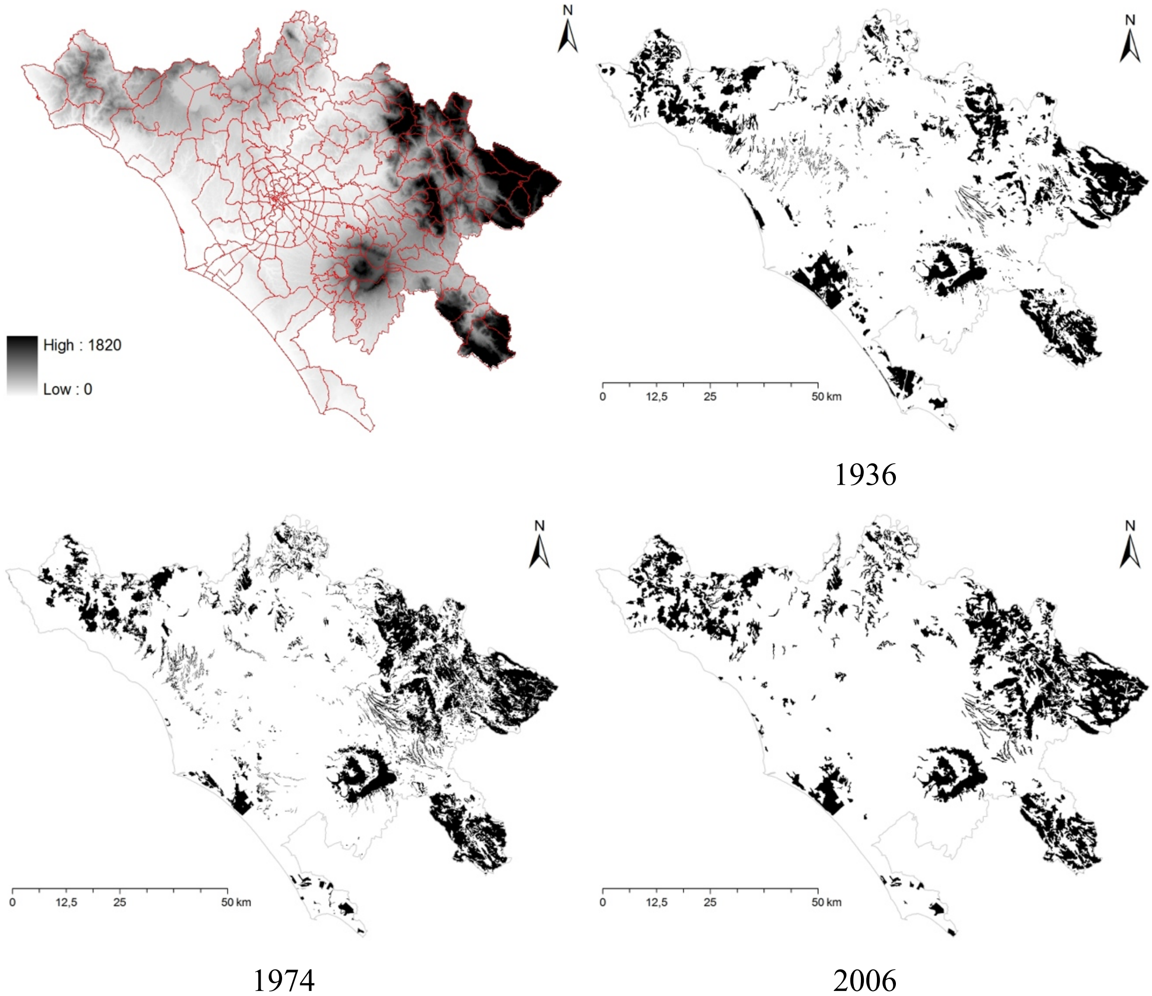

Figure 2. Forest concentration index in pristine natural land and sparsely inhabited rural areas (settlement density < 0.5 building/ha) by year and forest type.