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Towards Sustainable Rural Landscapes? A Multivariate Analysis of the Structure of Traditional Tree Cropping Systems along a Human Pressure Gradient in a Mediterranean Region

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Abstract

The worldwide increase of human pressure in rural areas has resulted in a progressive fragmentation of agro-forest landscapes. Relatively few studies have identified processes of landscape modification and patch fragmentation reflecting long-term human activity from those caused by recent urbanization stimulated by economic development, population growth and improved accessibility of rural areas. In rural districts dominated by high-quality crop mosaics and exposed to increasing levels of human pressure, urbanization-driven changes in the use of land have determined complex and non-linear processes of landscape fragmentation which deserve further investigation. Multidimensional procedures and data mining are appropriate to explore such transformations, basing on a comprehensive assessment of landscape metrics. The present study investigates changes in land-use and landscape structure (2000-2008) in three districts of Latium (central Italy) featuring different cropping systems, physiographic attributes and level of human pressure. A principal component analysis was run to identify a core set of metrics aimed at (i) evaluating the role of traditional cropping systems in the preservation of traditional agro-forest systems and (ii) inferring the relationship between spatial heterogeneity in rural landscapes and socio-ecological processes of change. Our results indicate that crop intensification has contributed to landscape homogeneity and simplification in all areas studied, in contrast with the effects of urban expansion resulting in a more fragmented and diversified landscape with relict tree crop patches. The findings of this study clarify the contribution of traditional tree crop systems to sustainable structures and functions of rural landscapes by preserving the place-specific eco-mosaic complexity.

Key-words: Eco-mosaic, Landscape metrics, Vineyard, Multivariate analysis, Central Italy.

1. Introduction

Agriculture is a human activity causing relevant impacts on natural ecosystems (Diogo et al., 2015). In long-established rural societies, traditional agro-forest systems frequently act as a dynamic interface between natural environments, intensive crop systems and built-up areas, providing economic, ecological and socio-cultural benefits to local communities (Smith and Smithers, 1993; Altieri et al., 1999; Lütz and Bastian, 2002; Robertson and Swinton, 2005; Porter et al., 2009; Hermann et al., 2011; Martínez Pastur et al., 2012; Wratten et al., 2013; Wu, 2013). Ecological and anthropogenic factors have been increasingly investigated to identify (apparent or latent) drivers of landscape transformation in the European rural areas (Theobald, 2004; Agnoletti et al., 2011; Galiana-Martin et al., 2011; Barbati et al., 2013). Among them, Mediterranean rural areas are known for the rich cultural and ecological biodiversity and for the peculiar landscape structures with multifaceted socio-environmental functions shaped by the millenary interplay between humans and nature (Van Doorn and Pinto Correia, 2007; Geri et al., 2010; Vimal et al., 2012; Recanatesi et al., 2015).

Since the early 1950s, crop intensification and land abandonment (taken as relevant environmental and socioeconomic transformations in Mediterranean rural systems) have caused a drastic homogenization of agricultural landscapes and fragmentation of natural habitats, often impacting areas with high species richness, soil quality and cultural heritage (Francis et al., 2003; Padilla et al., 2010; Brown and Schulte, 2011; Renwick et al., 2013; Biasi et al., 2015). More recently, urbanization has expanded into agricultural landscapes determining habitat fragmentation, loss in biodiversity and degradation of fertile soils (Antrop, 2004; Wasilewski and Krukowski, 2004; Verburg et al., 2006; Selman, 2009; Ceccarelli et al., 2014; Ferrara et al., 2016a). The decline of forests and arable land surfaces and the progressive fragmentation of olive groves and vineyards have been recognized as common land-use transformations especially in traditional Mediterranean agro-forest systems, impacting negatively complex rural landscapes and threatening natural habitats, agricultural practices and the local culture (Choisis et al., 2012; Mancinelli et al., 2015; Marull et al., 2015; Ferrara et al., 2016b).

The prominent role of agro-forest systems in the sustainable development of Mediterranean rural areas has been acknowledged widely (Savo et al., 2016) up the highest policy levels (e.g. in the 1698/05 European Council regulation on support for rural development by the European Agricultural Fund for Rural Development). Agro-forest systems also respond effectively to the rising demand for environmental services (Smiraglia et al., 2016). The permanent assessment of ecosystems services provided by traditional cropping systems is considered a relevant issue in the European Union Common Agricultural Policy (Recanatesi et al., 2015). Effective strategies preserving agro-forest systems require a permanent monitoring of land-use changes (Marull et al., 2015), with a specific focus on the relationship between landscape structure and ecological processes (Antrop, 2006; Verburg et al., 2009; Fu and Jones, 2013; Savo et al., 2014; Smiraglia et al., 2015). In this sense, the impact of landscape transformations on cultural, agronomic and environmental values should be carefully investigated (Dramstad et al., 2001; Zeng and Wu 2005; Geri et al., 2010).

Monitoring agro-forest systems formed by mixed crop mosaics and natural patches also constitutes a relevant information base in the assessment of the ecological and economic value of rural landscapes (Galli et al., 2010; Mancino et al., 2014; Colantoni et al., 2015). Improved field survey techniques, remote sensing and geographical information systems have increased our ability to quantify changes over time in the use of land using diachronic approaches and multi-temporal data sources (Ellis et al., 2004; van Doorn and Pinto Correia, 2007; Ortega et al., 2012; Ceccarelli et al., 2014). Landscape metrics and spatial statistics are useful tools for monitoring land-use changes (e.g. Bajocco et al., 2015). Advances in technology and computational power have enabled researchers to more efficiently combine metrics with spatial statistics to quantify and categorize complex landscape structures (Lausch and Herzog, 2002; Zeng and Wu, 2005; Ferrara et al., 2012). Results from various landscape ecological studies have shown the power of this combination where ecological patterns and processes have been revealed (Antrop and Van Eetvelde, 2000; Turner et al., 2001; Weng, 2007). Over the last two decades landscape metrics have been increasingly used to detect structure (size and distribution of patches), heterogeneity (density, richness and diversity of patches) and complexity of rural landscapes (Forman, 1995; Turner et al., 2001; Lausch and Herzog, 2002). However, some metrics revealed inherently redundant because they measure aspects of landscape structure or composition which are partly correlated (Riitters et al., 1995; Cushman et al., 2008; Ferrara et al., 2012). A core set of indicators quantifying transformations in rural landscapes is needed to ascertain the latent relationship between landscape functioning and ecological processes and to infer the role of various drivers of land-use change (Ferrara et al., 2016b). A comprehensive assessment of the socioeconomic factors underlying landscape transformations in rural areas may also inform more focused policies of land conservation (Galli et al., 2010; Agnoletti et al., 2011; Cullotta and Barbera, 2011).

Patch fragmentation is likely the most evident result of the human's action shaping rural landscapes and traditional cropping systems (e.g. Heaton and Merenlender, 2000; Dramstad et al., 2001; Antrop, 2004). However, relatively few studies have distinguished processes of patch fragmentation caused by long-term human activity from landscape processes stimulated by recent urbanization in turn driven by population and economic growth (Salvati and Zitti, 2009). In areas dominated by crop mosaics, urbanization-driven landscape transformations usually determine complex and non-linear processes of patch fragmentation which deserve further investigation. Multidimensional analysis and data mining are particularly appropriate statistical techniques to explore such transformations, basing on a comprehensive set of landscape metrics (Skånes and Bunce, 1997; Verburg et al., 2006; Salvati, 2013).

A comprehensive analysis of changes in land-use and landscape structure (2000-2008) in three Mediterranean areas (Latium, central Italy) was proposed to investigate the impact of distinct socioeconomic forces on traditional cropping systems. Given the historical land-use change of Italy, this region has long been undergoing severe land changing pressures from urbanization, industrialization and tourism development or environmental perturbations, e.g. due to climate variability (Biasi et al., 2015). Two main forces (crop intensification and urbanization) shaping the use of rural land were considered here. Three areas (a strictly rural landscape, a traditional cropland along the Tyrrhenian sea coast and a peri-urban area close to Rome) were chosen as representative of (more or less intensive) cropping systems, physiographic attributes and varying levels of anthropogenic pressure. Multivariate statistical techniques were used to select a core set of landscape metrics with the aim (i) to evaluate the role of traditional cropping systems in preserving traditional rural landscapes and (ii) to infer the latent relationship between heterogeneity of rural landscapes and socio-environmental processes of change. We finally discuss the contribution of this study in the identification of relevant components of traditional agro-forest systems that preserve structural complexity and biodiversity of Mediterranean rural landscapes. Results of the exploratory data analysis provide an information base for the development of specific conservation policies mitigating human pressure on traditional and ecologically-vulnerable agro-forest districts.

2. Study area

The present study investigates three areas with traditional agro-forest systems situated in the administrative region of Latium (Rome, central Italy). The region has experienced recently an increased vulnerability to climate aridity and soil degradation together with massive changes in the use of land, especially in the Rome's metropolitan area (Salvati and Zitti, 2009; Biasi et al., 2015; Colantoni et al., 2015). Climate regime is typically dry Mediterranean, with rainfalls (ranging between 600 mm and 1000 mm on a year base) concentrated in autumn and spring and mild air temperatures averaging 17°C on a year base (Salvati et al., 2012). Homogeneous landscape units extending each 36 km^2 were selected in the three study areas as examples of the structural complexity of Latium's rural systems (Figure 1). An inland hilly district situated 110 km north of Rome (Montefiascone, Tuscia) was chosen as representative of a traditional rural system with relatively low human pressure (< 100 inhabitants/km^2) and elevation ranging between 220 m and 630 m at the sea level; the prevailing segment of the population residing in the area works in the primary sector; population density is largely variable over space, with compact and small rural village alternated with dispersed residential settlements and sparse rural houses. A coastal district 40 km northwest of Rome (Cerveteri, Maremma Laziale) was chosen as representative of a rural system extending flat and moderately steep land (elevation ranging between 0 m and 480 m at the sea level) with intermediate (and moderately increasing) human pressure (200-400 inhabitants/km^2). The area has undergone latent urbanization with mixed compact urban centers and discontinuous settlements. The prevailing segment of the population residing in the area works in the industrial sector. Finally a peri-urban district 20 km southeast of Rome (Frascati, Castelli Romani) was selected as representative of a relict rural system of the 'Agro Romano' district (the typical green belt around Rome) situated in a mixed flat-hilly area (elevation ranging between 130 m and 480 m at the sea level). The area has recently experienced dispersed urbanization being exposed to a relatively high human pressure (500-1000 inhabitants/km^2); the prevailing segment of the population residing in the area works in the tertiary sector. Despite (more or less) intense human pressure, traditional cropping systems in all the investigated areas are still intertwined within other major Italian cultural components, including historical monuments, local culture and geographically-protected agricultural and handicraft products (Biasi et al., 2015).

3. Methodology

3.1. Land-use maps

High-resolution land-use maps for the three landscape units were derived from geo-referenced panchromatic aerial photographs provided by the Italian Ministry of the Environment, Land and Sea Protection (Rome) at a disaggregated spatial scale (1: 2000) and referring to the years 2000 and 2008. Aerial photographs were interpreted on screen by one author (EB) with an extensive knowledge of the study areas. Land patches were digitized within a Geographic Information System producing comparable land-use maps with 0.25 ha minimum mapping unit (Ferrara et al., 2016a). Class legend was determined following the Corine Land Cover (CLC) hierarchical nomenclature system based on 16 categories (Table 1). Field validation was performed on a sample of 50 control plots in each study area. The overall advantage of the use of aerial photographs in land-use studies covering relatively small areas is the combination of high spatial resolution and a synoptic view of the landscape (e.g. Skanes and Bunce, 1997; Geri et al., 2010; Bajocco et al., 2015). In the present study, landscape structure was assessed using specific metrics derived from 2000 and 2008 land-use maps (see section 3.2).

3.2. Landscape metrics

The structural analysis of rural environments has become an important issue in landscape ecology, and metrics are routinely performed in the assessment of land-use changes (Lausch and Herzog, 2002; Cushman et al., 2008; Brown and Schulte, 2011; Ceccarelli et al., 2014). A total of 15 class-level metrics were used in this study to assess patch characteristics (size, shape and edge) and landscape diversity (Forman, 1995): percent Class Area (CA), Number of Patches (NP), Patch Density (PD, number of patches *per* hectare), Total Edge (TE, m), Edge Density (ED, edge length (m) *per* hectare), Mean Patch Size (MPS, hectare), Patch Size Standard Deviation (PSSD, hectare), Patch Size Coefficient of Variation (PSCoV, %), MedPS (Median Patch Size, hectare), Mean Patch Edge (MPE, m *per* hectare), Mean Perimeter-Area Ratio (MPAR, m *per* hectare)Mean Shape Index (MSI), Area-Weighted Mean Shape Index (AWMSI), Mean Patch Fractal Dimension (MPFD), and Area Weighted Mean Patch Fractal Dimension (AWMPFD). Shannon and Simpson's diversity indexes (SHDI and SIDI) were used to respectively assess class richness (Shannon and Weaver, 1949) and evenness in the spatial distribution of land-uses (Simpson, 1949). These indexes quantify the probability that two equal-sized, randomly selected landscape sub-units, belong to different classes. Both indexes increase under conditions where the number of classes (landscape richness) increases, or where class distribution (landscape evenness) is homogeneous. ArcGIS 9.3 software (Environmental Systems Research Institute, Redlands, USA) with FragStat 4.0 extension was used to compute the selected metrics.

3.3. Statistical analysis

A parametric linear Pearson correlation analysis and a non-parametric Spearman rank correlation analysis were run pair-wise between landscape metrics to identify highly redundant variables. When the correlation coefficient of a variables' pair was found higher than |0.9|, one of the two metrics composing the correlation pair was randomly excluded from the subsequent analysis (Ferrara et al., 2016a). This preliminary approach allowed to select a core set of ten metrics with low or moderate (linear or higher-order) redundancy (Riitters et al., 1995): CA, PD, MSI, MPAR, AWMPFD, ED, MPE, MPS, AWMSI, and PSCoV. A Principal Component Analysis (PCA) was run on the selected metrics for each of the three areas and for 2000 and 2008 separately (six distinct analysis runs). Statistical analysis was developed using R (version 2.11.1). The PCA was carried out with the aim to investigate latent patterns and changes over time (2000-2008) in the relationship between land-use composition and class metrics. Relevant components with eigenvalue > 1 were chosen after computation on the correlation matrix (Salvati and Ferrara, 2015). The Keiser-Meyer-Olkin (KMO) measure of sampling adequacy, testing whether the partial correlations among variables are small, and Bartlett's test of sphericity, testing whether the correlation matrix is an identity matrix, were considered in the assessment of PCA quality (Salvati and Zitti, 2009). These two tests indicate if the multivariate model is appropriate to analyze the original dataset. A scatterplot comparing the distribution of component scores (i.e. land-use classes) for 2000 and 2008 was prepared with the objective of exploring latent spatial patterns in the three areas separately (Colantoni et al., 2015). Land-use classes placed close each other in the scatterplot indicate spatial association, while entities placed far each other indicate spatial segregation (Salvati, 2013). Lines indicate the observed landscape transition between 2000 and 2008. Component loadings (i.e. landscape metrics) were also tabulated separately by year and study area.

4. Results

4.1. Land-use changes

Changes in the use of land (2000-2008) in the three areas are mapped in Figure 2 and summarized in Table 2. A homogeneous cropland mosaic dominated by olive groves, vineyards and arable land, was the predominant cover class in the inland hilly district. This area featured a relatively low diversity in land-uses, a high percentage of natural and semi-natural classes in the landscape (forests extend more than 23% of the total area) and an intermediate percentage of built-up areas in the landscape (11%-12%). The coastal area preserved a quite simplified rural landscape with an imbalanced distribution of land-use classes dominated by single crops, especially arable land and modern viticulture. The simplified landscape structure may reflect a relatively high vulnerability to environmental degradation as a result of agricultural intensification and increased human pressure. Natural land was scarcer than in the inland hilly area and built-up areas increase by nearly 7% (from 10% in 2000 to 17% in 2008). Land fragmentation with high class evenness was especially observed in the peri-urban area as a result of scattered urban expansion, increasing by 5% over the study period (from 20% in 2000 to 27% in 2008). The most important landscape transformation in the area was associated to the decline of crop mosaics formed by arable land, modern viticulture, olive groves and hedge vegetation. Although representing less than 10% of the total landscape, relict patches of natural land were preserved in some parts of the study area.

4.2. Landscape metrics

The descriptive analysis of landscape metrics indicates the presence of a homogeneous and highly fragmented crop mosaic in the inland-hilly area (Table 3). Land patches cultivated with modern (i.e. intensive) viticulture systems were associated to high PD values, while small MPS values for various cropland types indicate a high (and sometimes increasing) level of fragmentation and patch dispersion. High PD and MPS values were commonly observed for ecological infrastructures (linear woody features and hedges, riparian vegetation). Changes over time in edge density indicate relevant landscape modifications driven by latent transformations of traditional agro-forest mosaics into intensive cropland. In particular, edge density decreased for traditional crops and increased for orchards and olive groves, considered traditional cropping systems in the area.

The coastal area (Table 4) experienced a moderate rate of land take mainly caused by compact urban expansion. This is confirmed by the increase in the MPS for all artificial classes - particularly for dense urban fabric. Dense urbanization resulted in the spatial heterogeneity of crop mosaics, and is reflected in the decrease of the edge density. Annual crops associated with olive groves and vineyards contributed positively to landscape complexity and show the highest values of edge density. Based on these results, dense urbanization contributes to the simplification of the ecological network, especially in terms of tree-belts and hedges, possibly reducing ecological connectivity between traditional farming systems.

In the last decade, the peri-urban area (Table 5) experienced dispersed urbanization determining higher value of MPS and PD especially for built-up areas. Complexity indexes illustrate a heterogeneous landscape with relatively high values of patch density, size, variability and shape for almost all cropland classes. Traditional cropping systems based on mixed vineyards and olive groves incorporate fragments of natural habitats and ecological infrastructure preserving the residual agro-forest mosaic.

Taken together, the most important landscape changes over time were observed for artificial surfaces, especially for scattered urban fabric in both the coastal and peri-urban area. Relevant changes were also observed for riparian vegetation, possibly revealing the contribution of ecological corridors to landscape connectivity and habitat biodiversity. The structure of natural classes such as tree belts and hedges, has evidenced important modifications between 2000 and 2008 particularly in areas where traditional cropping systems decreased in the last decade (e.g. coastal and inland-hilly districts). These classes were characterized by specific dynamics of edge and shape metrics for all studied areas, possibly indicating the contribution of tree belts in the preservation of landscape heterogeneity, traditional agricultural systems and biodiversity.

4.3. Multivariate analysis

The PCA extracted two components with more than 50% cumulated variance for all investigated areas and time points (Table 6). The distribution of component loadings and scores was respectively shown in Figures 3-5 separately for the three study areas. The two components for the inland hilly area explained 72% of the total variance in both 2000 and 2008. Component 1 illustrates the structure of rural landscapes according to a gradient based on composition and configuration metrics (CA, ED, MPE, PSCoV: positive loadings; PD and AWMPFD: negative loadings). Component 2 illustrates the complexity of rural landscapes and reflects different levels of human disturbance (MSI, AWMSI and AWMPFD). The intensity of metrics' loadings on both components 1 and 2 was substantially stable or moderately increasing between 2000 and 2008. Especially CA, MPS and MPE loadings (component 1) increased moderately indicating a consolidation of the gradient mentioned before.

The two components extracted for the coastal area explained 51% and 60% of the total variance respectively in 2000 and 2008. Component 1 illustrates the configuration of the dominant rural landscape according to a gradient based on class area, size variability and patch shape (positive loadings assigned to CA, PSCoV and MPAR). Component 2 represents a gradient of complexity and fractality possibly associated to human disturbance, caused primarily by compact urban expansion. The metrics associated with the highest (negative) loadings to component 2 were MSI, AWMPFD, MPE, and AWMSI. The structure of metrics' loadings changed quite rapidly over the study period, possibly indicating a progressive simplification in the structure of crop mosaics: components 1 and 2 were associated respectively to fragmentation metrics (CA, MPE and MPS) and fractality metrics (MSI, AWMPFD and AWMSI).

The two components extracted for the peri-urban area explained 69% of the total variance for both time points. Component 1 reflects the heterogeneous composition of crop mosaics with positive loadings assigned to CA, MPAR, ED and PSCoV and negative loadings assigned to PD. Component 2 illustrates the increasing complexity of the rural landscape driven by dispersed urbanization (negative loadings assigned to MSI, AWMPFD, MPE, and AWMSI). The structure of component 1 loadings was stable over time. By contrast, loading's intensity along component 2 decreased between 2000 and 2008 possibly indicating uneven fragmentation and 'fractalization' of the rural landscape.

5. Discussion

Rural landscapes worldwide are increasingly threatened by environmental degradation. Climate change, soil resource depletion, biodiversity loss, urbanization, crop intensification and land abandonment, outline the urgent need of an integrated strategy for sustainable development of rural areas with traditional cropping systems and exposed to increasing human pressure (Gritti et al., 2006; Hobbs et al., 2008; Hermann et al., 2011; Fu and Jones, 2013). Preserving relict agro-forest systems from urbanization and the intensification of agriculture is a priority target for sustainable land management (Selman, 2009). Agro-forest systems in southern Europe form a green infrastructure that mitigates the negative impact of human activities (Martínez Pastur et al., 2012). The structure of Mediterranean agro-forest systems has been frequently seen as the joint result of multiple socioeconomic factors (Cullotta and Barbera,

2011) and biophysical conditions (Biasi et al., 2015) impacting landscapes at different spatial scales (Recanatesi et al., 2015) and exerting a key influence on the use and management of neighboring land with both agricultural and urban use (Scarascia Mugnozza et al., 2000).

A better knowledge of the main factors causing transformations in landscape structure and composition has a crucial role in both land resource planning and biodiversity conservation. Landscape structure and diversity reflect a complex ensemble of biophysical and socioeconomic factors rapidly evolving as a function of both internal and external conditions (Antrop, 2004; Brown and Schulte, 2011; Smiraglia et al., 2016). Especially natural-agricultural systems formed by diversified crop mosaics mixed with relict forests and shrubland, pastures and open areas, need dedicated assessment of their ecological complexity and economic value (Porter et al., 2009; Lovell et al., 2010; Hermann et al., 2011). To influence implementation of agro-forest systems, an effective land-use monitoring strategy would be required to understand relationships between landscape structure (e.g. agro-forest systems) and associated ecological processes. This monitoring strategy would facilitate the development of additional analyses that quantify impacts on cultural, agronomic and environmental values. In this ambit, the use of quantitative approaches to compile environmental indicators in the fields of biodiversity conservation and land-use planning is widely accepted (Mancino et al., 2014).

The present study contributes to the permanent assessment of traditional agro-forest systems in a dynamic socioeconomic context with crop intensification and dispersed urbanization threatening rural landscapes. In this sense, we have proposed a simplified procedure for diachronic assessment of agro-forest systems using a multivariate analysis of landscape metrics. Results of this study constitute a relevant information base for the design of effective conservation strategies at both the local and regional scales. Our analysis has identified a land-use gradient resulting from different levels of human disturbance. Rural landscapes along this gradient reflect typical patterns, functions and dynamics of the agro-forest mosaic depending on the different share of vineyards and olive groves in the utilized agricultural area (Mancinelli et al., 2015).

Crop mosaics usually feature medium-high landscape complexity in central Italy (Agnoletti et al., 2011); in our sample, the highest heterogeneity was found in the peri-urban area 20 km far from Rome, where traditional cropping systems are more abundant and highly fragmented due to dispersed urbanization. Sprawl accelerated in the 2000s with the uneven expansion of isolated buildings, small residential settlements and clusters of detached houses with gardens and swimming pools, fragmenting the structure of agricultural landscapes and resulting in an increased entropy and fractality in the use of land. At the same time, relict agro-forest systems around Rome constitute a sort of green belt providing an effective buffer containing dispersed urban expansion and mitigating the environmental pressure derived from human activity (Barbati et al., 2013; Salvati, 2013; Recanatesi et al., 2015). These processes also imply the loss of linear landscape elements, traditional crops and cultural landmarks (e.g. Choisis et al., 2012). In the remaining two areas, a relatively homogeneous landscape structure was observed together with a lower proportion of traditional cropping systems in respect to the peri-urban area. For example, (intense) herbaceous cropping systems in the coastal area and in the inland hilly area respectively extend 60% and 43% of the study area forming the largest patches in the landscape.

Our results indicate that landscape complexity is mostly associated with traditional tree crop systems. These findings confirm the hypothesis formulated by Mancinelli et al. (2015) that identified the mean patch size of tree crops as a reliable proxy of land quality and socioeconomic sustainability of rural landscapes. Previous studies have also underlined the relationship between landscape complexity and traditional agro-forest systems (Heaton and Merenlender, 2000; Tscharntke et al., 2005; Hobbs et al., 2007; Jackson et al., 2007; Galli et al., 2010). Richness and diversity of land-use patches (e.g. NP and SDI metrics) reach the highest values in areas where traditional cropping systems dominate the landscape (Cullotta and Barbera, 2011). In line with these assumptions, agricultural intensification in the inland hilly area was mainly related to the reduction of natural infrastructures (hedges and tree belts), often considered unproductive in an intensive agricultural vision. By contrast, traditional cropping systems in both coastal and peri-urban areas, seem to have improved the ecological connectivity and quality of relict rural landscapes. These transformations - especially those driven by urban expansion - need dedicated policy responses as they fragment and isolate high-quality habitats, impacting negatively a vast range of sustainable agricultural practices, simplifying species composition and possibly modifying hydrological systems and nutrient cycling (Herzog, 1998; Francis et al., 2003; Mancinelli et al., 2015). Taken together, our findings suggest that traditional cropping systems contribute to maintain a sustainable structure and composition of rural landscapes preserving eco-mosaic complexity and, possibly, key ecosystem services (Hermann et al., 2003; Porter et al., 2009; Padilla et al., 2010).

Although well adapted to poor soils and dry climate, Mediterranean agro-forest landscapes are possibly less resistant to high (and increasing) human pressure (Altieri et al., 1999; Gritti et al., 2006; Jackson et al., 2007). However, it has been demonstrated how landscape transformations act in different ways according to the geographical position of any given region (Jackson et al., 2007; Wu, 2013; Bajocco et al., 2015). Based on these premises, the informed assessment of land-use change requires an in-depth analysis of each local context, especially in regions where traditional agro-forest systems are the dominant attribute of rural districts (Biasi et al., 2015). As a matter of fact, the main structural and functional traits of traditional rural landscapes frequently reflect some key attributes of the local socioeconomic systems. In this sense, "landscape ‘homologation’, polarization in ecologically high- and low-quality areas and the simplification of land cover spatial relationships are typical - albeit subtle - processes observed in regions with high human pressure and continuous urban expansion" (Salvati and Ferrara, 2015). However, in our case different forms of human pressure resulted in distinct short-term landscape processes; on the one hand, agricultural intensification has contributed to landscape homogeneity and simplification of cropping systems; on the other hand, diffused urbanization has shaped a more fragmented and diversified fringe landscape with relict - while sometimes better preserved - traditional cropping systems. A progressive shift from spatially-heterogeneous and diversified agro-forest systems towards a more simplified landscape, e.g. polarized in medium- and low-quality areas with homogeneous (natural and urban) uses of land, has demonstrated to impact negatively ecosystem functions determining an increased socio-environmental fragility (Barbati et al., 2013).

According to Herzog (1998), "the development of agroforestry for industrialised countries can be furthered by an understanding of the history and present functioning of traditional systems". In this sense, regional planning is increasingly required to preserve forest patches, pastures and other elements forming green infrastructures and improve their connection with crop mosaics in landscapes affected by urbanization, land fragmentation and soil consumption. It was demonstrated how Mediterranean agro-forest systems may act as buffer zones contributing to the containment of land degradation at the urban-wildland interface (Recanatesi et al., 2015). Based on these premises, our results prove the usefulness of a multi-target policy approach (Weng, 2007) that guarantees a homogeneous and efficient protection regime to different land patches characterized by different economic use, spatial configuration and ecological value (Francis et al., 2003; Gritti et al., 2006; Selman, 2009). A multi-target conservation strategy may better preserve the integrity of high-diversity crop mosaics typical of the Mediterranean basin by (i) improving ecosystem functionality of relict, highly natural patches, (ii) maintaining the aesthetic and recreational value of forest fragments and linear landscape elements and, finally, (iii) protecting traditional crop and long-established agronomic practices (Tscharntke et al., 2005).

6. Conclusion

The present study has contributed to a better understanding of structural dynamics in rural landscapes dominated by crop mosaics relating land-use changes, different land functions and traditional agro-forest systems. These dimensions have been recognized as strategic conservation targets in the development of sustainable and multifunctional agricultural systems capable to provide ecosystem services and traditional products (Porter et al., 2009), according with the goals outlined by the European Common Agricultural Policy (Renwick et al., 2013). Investigating the structure of traditional agro-forest landscapes allows identifying productive models associated to high landscape complexity (Lovell et al., 2010). Our study identifies crop intensification and urbanization as primary drivers of landscape transformation in rural districts. Socioeconomic policies targeting these two processes jointly may contribute to the design of sustainable management strategies for rural landscapes with positive impact on landscape diversity and environmental quality. The continuous assessment of stability (or change) in the structure and composition of rural landscapes will definitely benefit from a cross-regional comparative perspective that integrates environmental studies with socioeconomic, political and planning dimensions.

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Table 1. Land-use/land cover classification adopted in this study (left column) and a comparison with the Corine Land Cover (CLC) nomenclature system by hierarchical level.

Class	CLC Level 4	CLC Level 3	CLC Level 1 (bold) and 2
			1. Artificial surface
Urban fabric	1.1.1.1 Residential continuous dense urban fabric	1.1.1 Continuous urban fabric	
Scattered urban fabric	1.1.1.2 Residential continuous medium dense urban fabric	1.1.2 Discontinuous urban fabric	**1.1 Urban fabric**
Sparse urban fabric	1.1.2.2 Residential discontinuous sparse urban fabric		
			2. Agricultural areas
Modern vineyards	2.2.1.1 Vineyards	2.2.1 Vineyards	
Traditional vineyards	2.2.1.2 Other Vineyards		
Orchards		2.2.2 Orchards	2.2 Permanent Crop
Olive grove		2.2.3 Olives grows	
Annual crop associated with olive	2.4.1.1 Annual crops associated with olives	2.4.1 Annual crops associated with permanent crops	2.4 Heterogeneous agricultural areas
Pastures	-	-	2.3 Pastures
Arable land	2.1.1.1 Arable land without dispersed vegetation	2.1.1 Non-irrigated arable land	2.1Arable Land
	2.1.1.2 Arable land with scattered vegetation		
Greenhouses	2.1.2.4. Greenhouses		
			3. Forests and seminatural Areas
Forest	-	-	3.1 Forest
Riparian vegetation	3.2.2.2 Riparian vegetation	3.2.2. Moors and heath land	3.2 Shrub and/or herbaceous vegetation associations
Maquis	3.2.3.1 Maquis	3.2.3 Sclerophyllous vegetation	
Hedges	-	3.4.1 Hedges	3.4 Hedges and Tree-lined
Tree lines	-	3.4.2 Tree lines	

Table 2. Percent surface area by land-use class, year and study area.

Class	Inland hilly area		Coastal area		Peri-urban area	
	2000	2008	2000	2008	2000	2008
Urban fabric	3.71	4.62	1.00	6.10	13.50	14.16
Scattered urban fabric	6.50	7.49	9.10	11.59	7.11	12.73
Sparse urban fabric	0.22	0.68	0.57	2.01	1.10	1.38
Olives	7.34	9.02	1.21	1.85	5.00	4.29
Annual crop associated with olive	3.11	2.77	2.33	3.78	3.19	4.06
Modern vineyards	5.22	5.78	10.57	9.81	23.99	20.14
Traditional vineyards	2.23	1.57	0.34	0.46	1.44	1.41
Arable land	42.74	37.62	60.45	54.43	33.58	29.19
Orchards	1.28	2.19	0.65	0.40	0.22	0.44
Tree lines	0.18	0.13	0.66	1.74	0.71	1.75
Hedges	3.51	3.12	1.17	1.89	2.43	2.12
Riparian vegetation	0.97	1.75	1.98	1.90	1.05	0.96
Forest	22.98	23.25	0.39	0.93	6.28	6.69
Maquis	0.00	0.00	8.55	1.50	0.33	0.56
Greenhouses	0.00	0.00	0.60	1.03	0.00	0.00
Beaches, dunes, sands	0.00	0.01	0.41	0.58	0.07	0.11

Table 3. Landscape metrics (excluding class area, see Table 2) by land-use class and year in the inland hilly area.

Class	Inland hilly area								
	PD	MSI	MPAR	AWMPFD	ED	MPE	MPS	AWMSI	PSCoV
					2000				
Urban fabric	199.68	1.50	1062.07	1.41	26.57	358.89	0.50	1.86	147.77
Scattered urban fabric	23.56	2.08	532.07	1.39	22.25	1453.16	4.24	2.55	129.54
Sparse urban fabric	373.31	1.36	1204.86	1.39	1.95	233.04	0.27	1.45	107.55
Olives	105.87	1.49	953.94	1.37	36.23	466.48	0.94	1.77	150.30
Annual crops associated with olives	125.20	1.43	745.90	1.36	16.26	417.27	0.80	1.51	140.10
Modern vineyards	188.70	1.44	1022.49	1.38	34.04	345.42	0.53	1.60	112.72
Traditional vineyards	184.88	1.40	849.79	1.37	14.06	341.23	0.54	1.48	114.69
Orchards	98.19	1.36	632.77	1.34	5.69	454.56	1.02	1.48	107.17
Tree lines	258.54	2.89	2233.80	1.55	2.73	576.82	0.39	3.12	137.42
Hedges	253.72	2.75	1953.90	1.55	53.63	602.02	0.39	3.24	107.95
Riparian vegetation	128.60	3.09	1582.69	1.53	0.78	944.71	11.83	3.57	95.16
Forest	20.23	2.35	697.30	1.36	69.71	1499.57	4.94	2.41	215.97
Beaches, dunes, sands	595.13	2.75	2380.30	1.61	0.11	399.96	0.17	2.75	32.88
Arable land	38.36	1.93	7258.46	1.39	155.13	946.14	2.33	2.41	173.32
					2008				
Urban fabric	176.66	1.58	1463.29	1.41	33.16	406.48	0.57	1.90	125.62
Scattered urban fabric	33.36	2.02	736.69	1.39	26.30	1166.21	3.00	2.43	131.71
Sparse urban fabric	271.25	1.43	1091.75	1.39	5.25	285.92	0.37	1.54	115.12
Olives	115.08	1.52	3677.71	1.38	48.34	465.53	0.87	1.83	140.19
Annual crops associated with olives	114.38	1.46	841.43	1.35	13.36	421.09	0.87	1.56	168.42
Modern vineyards	172.31	1.44	1106.40	1.37	33.81	339.19	0.58	1.62	246.78
Traditional vineyards	207.20	1.36	943.51	1.36	10.22	313.86	0.48	1.41	86.67
Orchards	105.32	1.35	787.42	1.33	9.74	421.71	0.95	1.41	103.07
Tree lines	673.76	2.44	2616.73	1.59	2.94	329.65	0.15	2.71	80.98
Hedges	316.97	2.63	2170.30	1.56	51.30	519.01	0.32	3.19	110.08
Riparian vegetation	163.45	3.06	1694.54	1.54	23.41	816.25	0.61	3.26	86.18
Forest	20.12	2.53	844.81	1.39	73.62	1573.93	4.97	3.15	341.71
Beaches, dunes, sands	191.09	4.05	2259.33	1.62	2.10	1079.78	0.52	4.90	68.31
Arable land	70.56	1.65	6017.94	1.36	56.00	1374.12	19.68	1.90	149.65
					% change (2000-2008)				
Urban fabric	-11.53	5.81	37.78	0.32	24.77	13.26	13.04	2.00	-14.99
Scattered urban fabric	41.59	-3.01	38.46	0.27	18.21	-19.75	-29.37	-4.44	1.68
Sparse urban fabric	-27.34	4.87	-9.39	-0.24	169.95	22.69	37.63	5.97	7.04
Olives	8.70	2.07	285.53	0.71	33.43	-0.21	-8.00	2.91	-6.73
Annual crops associated with olives	-8.65	2.13	12.81	-0.42	-17.82	0.92	9.46	3.19	20.22
Modern vineyards	-8.69	0.02	8.21	-0.76	-0.68	-1.80	9.51	1.21	118.93
Traditional vineyards	12.07	-2.87	11.03	-0.23	-27.28	-8.02	-10.77	-4.93	-24.43
Orchards	7.27	-0.38	24.44	-0.45	71.14	-7.23	-6.78	-4.64	-3.82
Tree lines	160.60	-15.62	17.14	2.91	7.59	-42.85	-61.63	-13.27	-41.07
Hedges	24.93	-4.39	11.08	0.63	-4.35	-13.79	-19.95	-1.38	1.97
Riparian vegetation	27.10	-1.05	7.07	0.16	2910.10	-13.60	-94.83	-8.71	-9.43
Forest	-0.53	7.39	21.16	1.95	5.60	4.96	0.53	30.76	58.22
Beaches, dunes, sands	-67.89	47.13	-5.08	0.56	1790.05	169.97	211.44	78.07	107.78
Arable land	83.94	-14.88	-17.09	-2.24	-63.90	45.23	743.47	-21.18	-13.66

Table 4. Landscape metrics (excluding class area, see Table 2) by land-use class and year in the coastal area.

Class	Coastal area								
	PD	MSI	MPAR	AWMPFD	ED	MPE	MPS	AWMSI	PSCoV
					2000				
Urban fabric	730.50	1.23	1479.76	1.40	11.10	151.36	0.14	1.31	105.90
Scattered urban fabric	1.57	1.58	118.52	1.25	5.88	4104.82	63.50	1.62	77.87
Sparse urban fabric	763.35	1.22	1576.97	1.39	6.19	141.22	0.13	1.25	132.30
Olives	196.44	1.29	863.09	1.35	7.11	298.77	0.51	1.35	121.30
Annual crops associated with olives	100.94	1.37	938.57	1.33	35.48	10.19	433.82	1.39	120.28
Modern vineyards	85.63	1.29	636.50	1.32	41.26	455.65	1.17	1.34	101.99
Traditional vineyards	141.37	1.31	644.78	1.35	1.85	379.29	0.71	1.39	71.29
Orchards	158.96	1.25	705.57	1.33	3.44	333.07	0.63	1.25	63.69
Tree lines	363.86	2.56	2249.26	1.55	5.88	4104.82	63.50	2.97	183.25
Hedges	336.97	2.92	2524.45	1.59	22.31	564.19	0.30	3.96	140.58
Riparian vegetation	46.22	4.67	1739.15	1.59	23.62	2575.59	2.16	7.16	131.11
Forest	21.89	2.20	456.00	1.37	1.33	1546.26	4.57	2.21	78.36
Maquis	1.00	1.46	85.10	1.21	3.66	4253.01	99.50	1.27	83.54
Greenhouses(where present)	119.40	1.31	814.07	1.33	2.66	371.53	0.84	1.37	141.81
Beaches, dunes, sands	6.98	8.85	828.70	1.58	3.40	11876.01	14.33	8.85	188.99
Arable land	12.20	1.83	10802.51	1.35	117.59	1654.75	8.49	2.86	244.12
					2008				
Urban fabric	204.53	1.29	1664.08	1.35	29.17	254.29	0.49	1.68	478.25
Scattered urban fabric	1.52	1.66	309.30	1.26	4.61	3895.80	66.00	1.78	99.47
Sparse urban fabric	435.91	1.30	2333.39	1.38	17.21	196.02	0.23	1.36	119.04
Olives	199.97	1.40	1071.59	1.37	11.92	322.47	0.50	1.47	202.24
Annual crops associated with olives	106.59	1.44	1790.74	1.35	18.07	456.05	0.94	1.51	103.69
Modern vineyards	95.54	1.31	706.45	1.32	40.18	428.80	1.05	1.32	105.07
Traditional vineyards	224.23	1.31	806.19	1.36	3.03	292.83	0.45	1.31	99.28
Orchards	178.52	1.32	791.80	1.35	2.36	332.22	0.56	1.36	74.50
Tree lines	336.51	2.50	2240.32	1.56	22.25	482.56	0.30	3.48	68.98
Hedges	384.93	2.43	2875.81	1.53	24.44	419.75	0.26	2.78	156.18
Riparian vegetation	98.13	3.30	4357.52	1.55	22.12	1187.91	1.02	4.86	173.41
Forest	86.07	2.08	982.77	1.42	5.83	730.99	1.16	2.36	143.93
Maquis	40.02	1.96	9354.54	1.39	3.38	953.38	2.50	2.69	145.97
Greenhouses(where present)	94.57	1.33	663.87	1.32	4.13	423.56	1.06	1.31	131.87
Beaches, dunes, sands	26.45	3.41	913.48	1.50	3.76	2546.80	3.78	4.96	117.14
Arable land	45.30	5.24	2206.24	1.32	64.08	770.33	3.20	1.64	148.41
					% change				
Urban fabric	-72.00	4.47	12.46	-3.57	162.70	68.01	257.17	27.94	351.60
Scattered urban fabric	-3.78	4.82	160.97	0.38	-21.67	-5.09	3.93	9.59	27.74
Sparse urban fabric	-42.89	6.19	47.97	-0.79	177.98	38.80	75.11	9.18	-10.02
Olives	1.79	9.02	24.16	1.37	67.70	7.93	-1.76	9.10	66.74
Annual crops associated with olives	5.60	5.00	90.79	1.44	-49.07	4374.13	-99.78	8.91	-13.79
Modern vineyards	11.57	1.18	10.99	0.14	-2.60	-5.89	-10.37	-1.39	3.01
Traditional vineyards	58.61	-0.30	25.03	0.48	63.98	-22.80	-36.95	-6.17	39.27
Orchards	12.30	5.27	12.22	1.52	-31.40	-0.26	-10.96	8.73	16.96
Tree lines	-7.52	-2.10	-0.40	0.78	278.40	-88.24	-99.53	16.98	-62.35
Hedges	14.23	-16.77	13.92	-3.63	9.57	-25.60	-12.46	-29.78	11.10
Riparian vegetation	112.32	-29.28	150.55	-2.15	-6.32	-53.88	-52.90	-32.08	32.26
Forest	293.23	-5.78	115.52	3.31	338.95	-52.73	-74.57	6.81	83.67
Maquis	3882.58	33.97	10892.41	14.59	-7.49	-77.58	-97.49	111.16	74.72
Greenhouses(where present)	-20.80	1.72	-18.45	-1.03	55.25	14.01	26.27	-4.83	-7.00
Beaches, dunes, sands	279.00	-61.49	10.23	-5.02	10.62	-78.56	-73.61	-43.97	-38.02
Arable land	271.44	186.36	-79.58	-2.47	-45.51	-53.45	-62.28	-42.80	-39.20

Table 5. Landscape metrics (excluding class area, see Table 2) by land-use class and year in the peri-urban area.

Class	Peri-urban area								
	PD	MSI	MPAR	AWMPFD	ED	MPE	MPS	AWMSI	PSCoV
					2000				
Urban fabric	124.16	1.61	2666.04	1.38	73.42	437.89	0.81	1.86	246.54
Scattered urban fabric	21.78	1.96	564.14	1.36	10.29	1538.05	6.09	2.26	119.97
Sparse urban fabric	421.88	1.35	1533.11	1.40	9.39	203.18	0.24	1.68	276.92
Olives	217.03	1.49	1644.70	1.39	34.63	319.38	0.46	1.75	209.62
Annual crops associated with olives	232.78	1.49	1030.48	1.40	24.38	328.62	0.43	1.70	116.90
Modern vineyards	75.32	1.49	880.48	1.33	88.54	490.00	1.33	1.60	252.49
Traditional vineyards	311.50	1.43	1227.21	1.40	12.21	272.32	0.32	1.53	112.63
Orchards	209.57	1.24	958.09	1.34	1.27	274.99	0.48	1.27	89.55
Tree lines	401.09	2.86	2679.01	1.59	14.04	491.95	0.25	3.45	128.72
Hedges	368.43	2.36	2114.17	1.54	38.45	428.82	0.27	2.86	112.14
Riparian vegetation	124.18	3.24	3897.13	1.54	12.76	978.05	0.81	3.82	113.70
Forest	48.00	2.63	1009.11	1.43	35.57	1179.44	2.08	3.05	206.35
Maquis	100.16	1.68	659.68	1.40	1.33	610.59	1.00	1.98	65.42
Beaches, dunes, sands	204.95	3.29	3735.40	1.49	0.79	581.55	0.49	2.81	154.88
Arable land	53.17	2.00	13369.92	1.39	143.34	802.94	1.88	2.73	410.15
					2008				
Urban fabric	148.74	1.56	4723.08	1.39	85.21	405.03	0.67	1.86	198.63
Scattered urban fabric	63.48	1.96	334.71	1.32	10.58	1943.39	11.09	2.07	824.01
Sparse urban fabric	456.70	1.38	1570.02	1.40	12.83	204.01	0.22	1.48	143.29
Olives	237.66	1.50	1924.95	1.39	31.69	310.49	0.42	1.68	174.09
Annual crops associated with olives	246.64	1.47	1187.35	1.39	30.95	309.02	0.41	1.61	141.21
Modern vineyards	76.08	1.44	1094.21	1.33	71.40	465.98	1.31	1.57	235.57
Traditional vineyards	387.36	1.37	1113.66	1.40	12.92	236.13	0.26	1.41	75.29
Orchards	248.20	1.43	1116.84	1.37	3.11	285.43	0.40	1.41	111.56
Tree lines	454.73	2.56	2534.95	1.57	27.45	409.93	0.22	3.04	120.49
Hedges	550.48	2.21	4920.34	1.55	33.46	328.74	0.18	2.76	129.15
Riparian vegetation	124.30	3.33	1643.83	1.55	12.30	1027.13	0.80	3.78	95.52
Forest	103.80	2.17	1518.91	1.43	46.88	675.56	0.96	2.50	193.05
Maquis	151.75	1.49	923.40	1.37	1.86	399.27	0.66	1.58	82.12
Beaches, dunes, sands	128.46	3.10	1568.34	1.52	1.25	918.51	0.78	3.04	47.29
Arable land	158.56	1.56	966.37	1.35	25.68	970.20	5.92	1.64	165.69
					% change				
Urban fabric	19.79	-2.78	77.16	0.65	16.07	-7.50	-16.81	-0.40	-19.43
Scattered urban fabric	191.48	-0.18	-40.67	-2.63	2.80	26.35	82.13	-7.98	586.83
Sparse urban fabric	8.25	2.64	2.41	-0.29	36.65	0.41	-7.61	-12.23	-48.26
Olives	9.51	0.53	17.04	0.11	-8.49	-2.78	-8.73	-4.08	-16.95
Annual crops associated with olives	5.96	-1.20	15.22	-0.42	26.96	-5.97	-5.71	-4.83	20.79
Modern vineyards	1.01	-3.29	24.27	-0.34	-19.36	-4.90	-1.02	-2.11	-6.70
Traditional vineyards	24.35	-4.14	-9.25	-0.13	5.80	-13.29	-19.58	-7.79	-33.15
Orchards	18.43	15.31	16.57	1.92	144.66	3.80	-15.53	10.55	24.57
Tree lines	13.37	-10.65	-5.38	-1.34	95.53	-16.67	-11.68	-12.12	-6.39
Hedges	49.41	-6.43	132.73	0.99	-12.98	-23.34	-32.97	-3.43	15.16
Riparian vegetation	0.09	2.88	-57.82	0.17	-3.58	5.02	-0.06	-1.27	-15.98
Forest	116.28	-17.50	50.52	0.20	31.79	-42.72	-53.77	-18.25	-6.44
Maquis	51.50	-11.02	39.98	-1.60	40.53	-34.61	-33.96	-20.31	25.54
Beaches, dunes, sands	-37.32	-5.61	-58.01	1.78	58.21	57.94	59.52	8.10	-69.46
Arable land	198.22	-22.07	-92.77	-2.57	-82.09	20.83	214.47	-40.14	-59.60

Table 6. Results of the Principal Component Analysis: component loadings by landscape metrics (bold indicates relevant loadings > |0.5|).

Metric	**Inland-hilly district**				**Coastal district**				**Peri-urban district**			
	2000		*2008*		*2000*		*2008*		*2000*		*2008*	
	PC 1	PC 2	PC 1	PC2	PC 1	PC 2	PC 1	PC 2	PC 1	PC 2	PC 1	PC 2
Cum. variance (%)	*38.9*	*72.5*	*41.5*	*72.2*	*26.1*	*50.9*	*35.2*	*60.3*	*38.4*	*68.9*	*39.2*	*69.1*
CA	**0.89**	-0.16	**0.95**	0.18	**0.84**	0.25	**0.69**	-0.32	**0.96**	0.04	**0.67**	0.20
PD	**-0.83**	-0.15	**-0.66**	0.16	-0.05	0.23	**-0.72**	-0.04	**-0.67**	0.18	**-0.66**	0.25
MSI	-0.15	**-0.97**	-0.26	**-0.93**	-0.09	**-0.97**	0.50	**-0.82**	-0.18	**-0.94**	-0.43	**-0.86**
MPAR	0.44	-0.40	0.45	0.38	**0.94**	0.16	-0.15	-0.47	**0.66**	-0.35	**-0.53**	0.12
AWMPFD	**-0.56**	**-0.79**	**-0.56**	**-0.80**	-0.24	**-0.70**	-0.44	**-0.73**	-0.49	**-0.74**	**-0.84**	-0.49
ED	**0.84**	-0.14	**0.80**	0.17	-0.35	0.29	0.29	-0.49	**0.89**	0.02	0.18	0.40
MPE	**0.64**	**-0.51**	**0.67**	**-0.62**	0.03	**-0.84**	**0.74**	0.08	0.36	**-0.66**	**0.55**	**-0.83**
MPS	0.27	**-0.58**	**0.83**	-0.21	-0.38	0.27	0.70	0.42	0.45	-0.25	**0.78**	-0.51
AWMSI	-0.04	**-0.98**	-0.19	**-0.94**	-0.24	**-0.92**	0.01	**-0.73**	-0.05	**-0.97**	-0.48	**-0.81**
PSCoV	**0.84**	0.20	**0.65**	-0.13	**0.73**	0.48	-0.13	-0.06	**0.80**	0.07	**0.82**	-0.36

Figure 1. Upper panel: (left) the position of Latium region in Italy; (right) the location of the three study areas in Latium (1: inland-hilly district 'CDO Est! Est! Est! Classic area', 2: coastal district 'CDO Cerveteri' and 3: peri-urban district 'CDO Castelli Romani'); lower panel: selected pictures illustrating the dominant landscape in the three study areas (left: area1; middle: area2; right: area3).

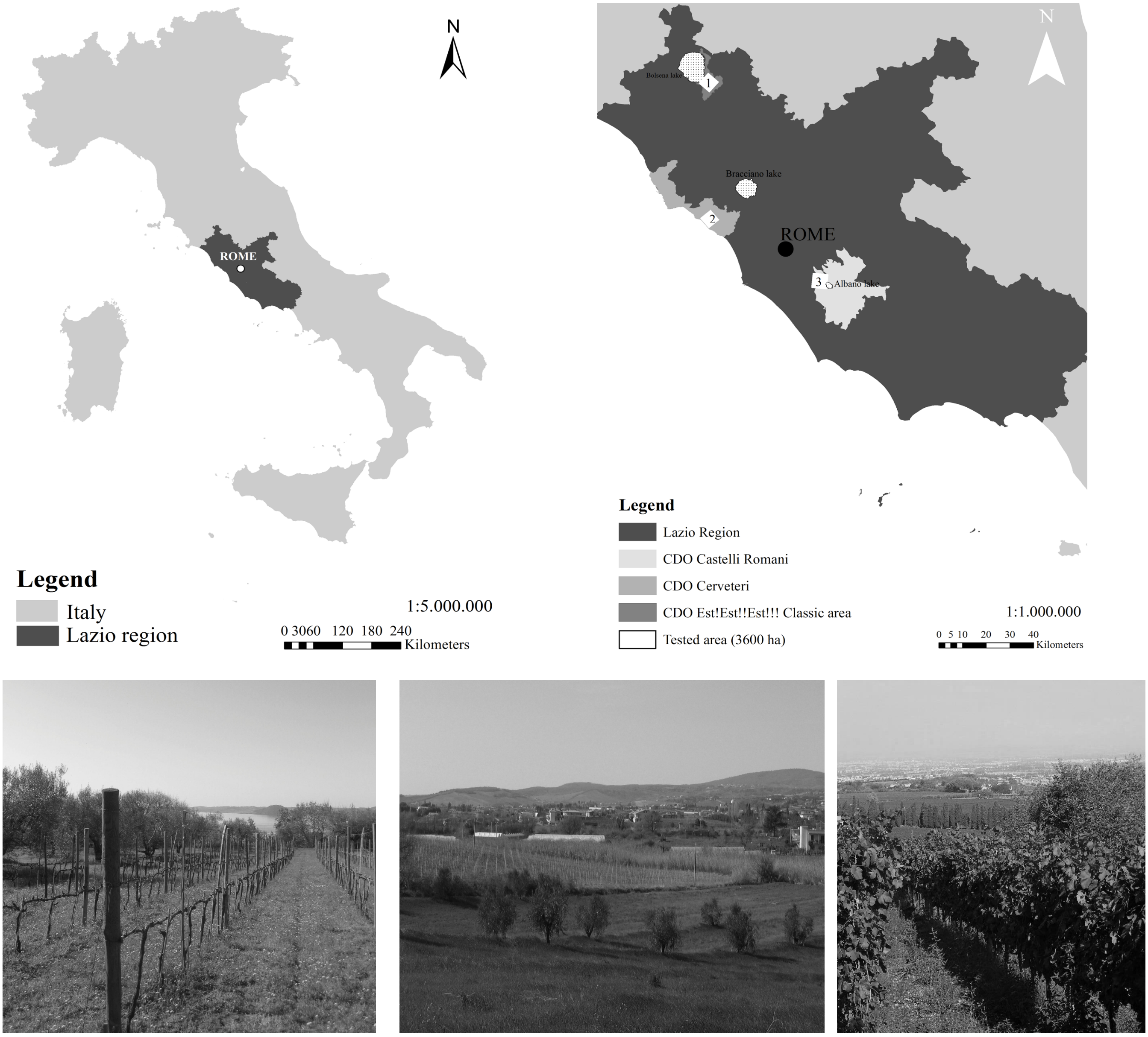

Figure 2. Spatial distribution of land-use classes in the three study areas at the beginning of the study period (2000).

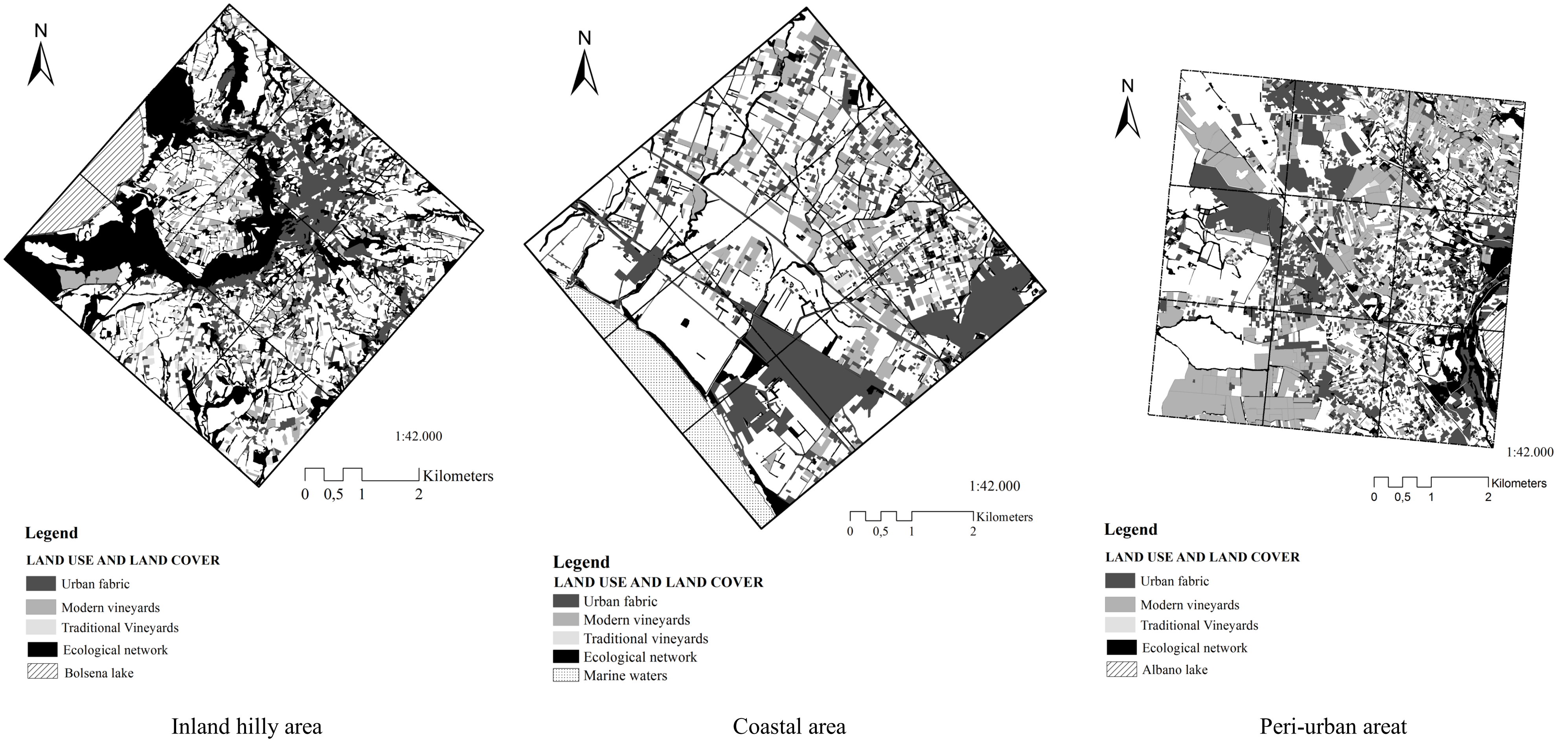

Figure 3. Scores of the investigated landscape metrics along principal components 1 and 2 for the inland hilly area (arrow indicates changes between 2000 and 2008).

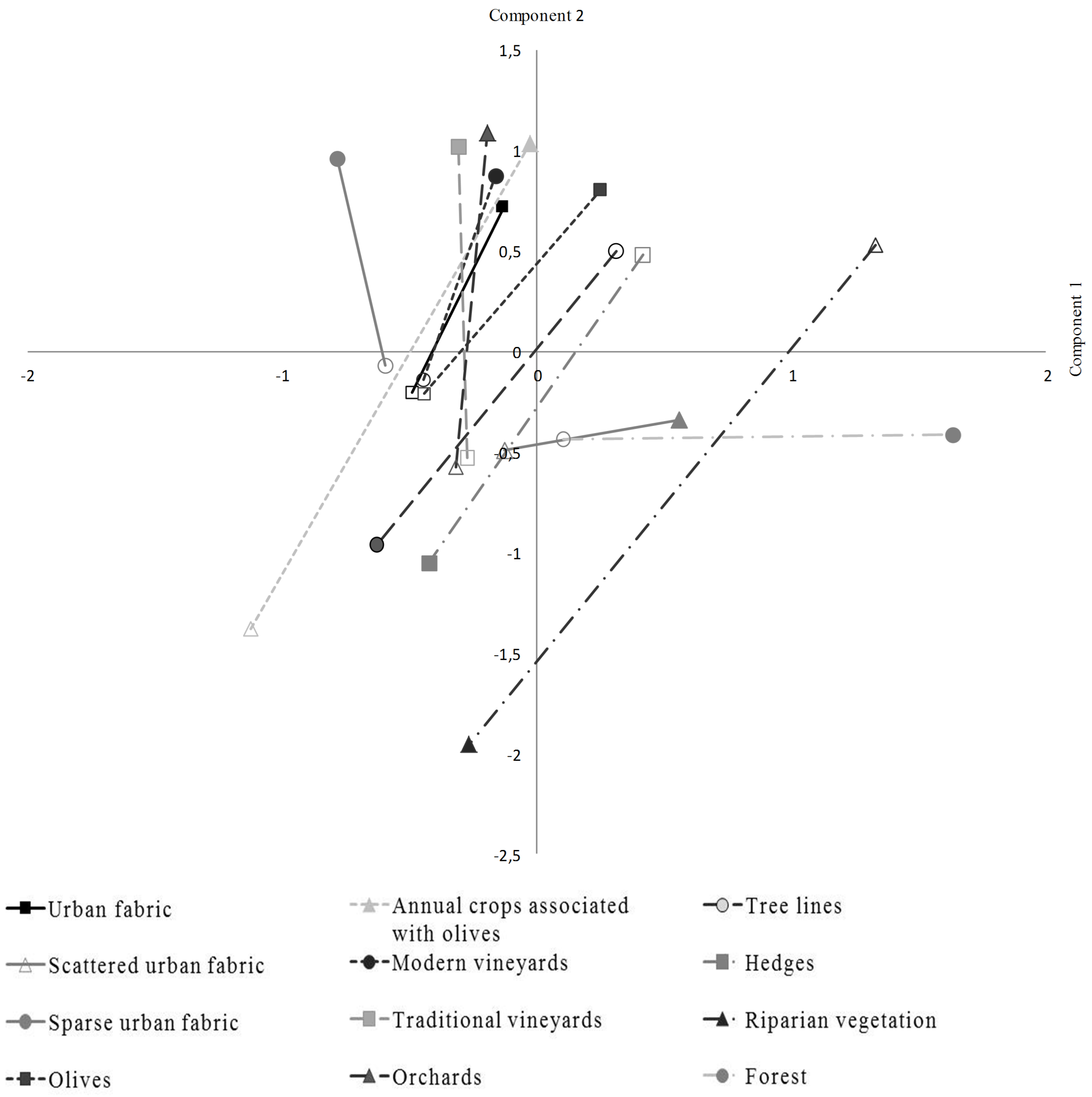

Figure 4. Scores of the investigated landscape metrics along principal components 1 and 2 for the coastal area (arrow indicates changes between 2000 and 2008).

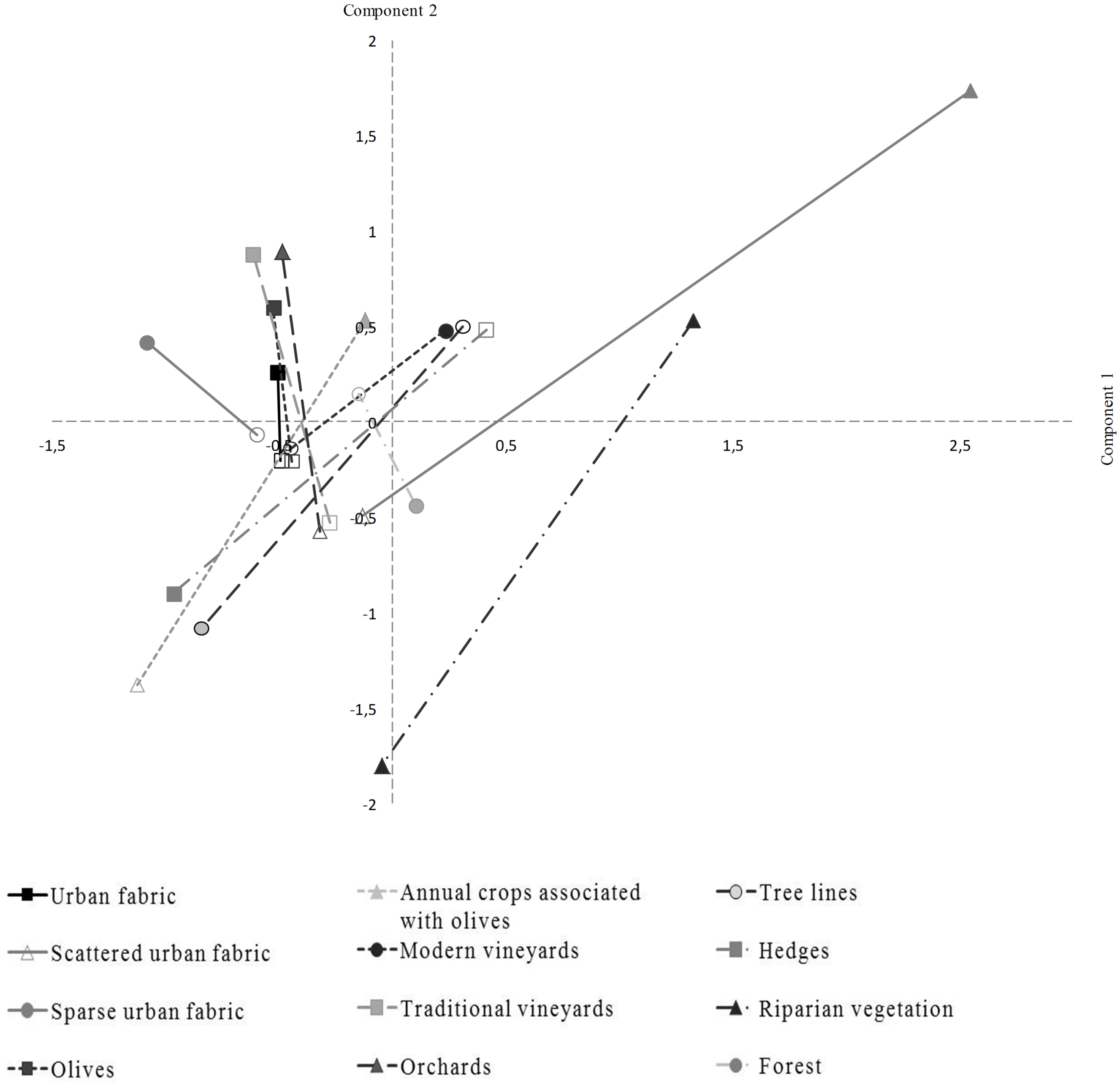

Figure 5. Scores of the investigated landscape metrics along principal components 1 and 2 for the peri-urban area (arrow indicates changes between 2000 and 2008).