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Linking traditional tree-crop landscapes and agro-biodiversity in Central Italy using a database of typical and traditional products: a multiple risk assessment through a data mining analysis

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Abstract

Understanding the latent relationship between rural landscape and biodiversity conservation is of key importance when aiming to preserve food security, ecosystem services and the quality of the environment. Crop intensification negatively impacted the biodiversity of rural areas and was followed by the adoption of mono-cultural production models. The conservation of traditional agricultural landscapes (TALs) based on traditional land management approaches, ensures the conservation of the ecosystem's complexity and high levels of biodiversity. In Europe, Mediterranean TALs are threatened by a combination of anthropogenic and natural factors. The need to preserve TALs is widely recognized despite the lack of comprehensive information and collective policy strategies. On the other hand, inventories are available for endangered cultivars, typical products and traditional agricultural practices. This study focuses on the relationship between traditional agricultural landscapes and the use of local varieties/typical products. The analysis will: (i) define, map and characterize the tree-crop based traditional landscapes in one of the Mediterranean regions (Latium, central Italy) through a land-use change detection analysis (1960-2000) and (ii) identify the most endangered TALs based on environmental risk factors, on autochthonous agro-biodiversity at risk of varietal erosion and on traditional products that risk to disappear. Results prove that the most endangered rural landscapes are the ones located on fringe and marginal lands due to climate aridity and soil erosion. The identification of the endangered TALs contributes to constructing more effective strategies for the preservation of agro-biodiversity and natural ecosystem functionality.

Keywords: Biodiversity erosion, Traditional agricultural practices, Cultural landscapes, Local varieties, Environmental risk.

Introduction

Rural landscapes are common in large areas all over Europe (EUROSTAT, 2014). It has been acknowledged that traditional agriculture has a positive impact on environmental resources, i.e. soil, atmosphere, biodiversity and landscape (Abbona et al., 2007). Traditional agriculture is highly adaptable to long-established practices that require low amounts of external inputs and ensure habitat conservation, thanks to sustainable land management approaches based on the use of local agro-biodiversity (Alvarez et al., 2010, Cullotta and Barbera 2011 and Halada et al., 2011). Traditional agricultural landscapes (TALs) have a positive impact on climate change mitigation, biodiversity preservation and ecosystem services provision (Abbona et al., 2007, Antrop, 2005 and Farina, 2000). Nonetheless, measures for the conservation of traditional agro-forest systems are far from being found both at a national and transnational level, and from being integrated in land planning/management approaches (Barbera and Biasi, 2011).

A number of agricultural landscape types have been classified in Europe and many of them are considered TALs (Agnoletti, 2013, Barbera and Cullotta, 2012, Meeus et al., 1995 and Zimmermann, 2006). Exploratory mapping methodologies for TALs have been proposed (Barbera et al., 2014, Cullotta and Barbera, 2011 and Štefunková et al., 2013), nonetheless a comprehensive knowledge of their distribution, consistency, function and status is not available in Europe. The multifunctional role of TALs - sometimes considered as important cultural landscapes - is nowadays extensively, but partially, documented (Antrop, 2005, Bignal and McCracken, 2000, Dieterich and van der Straaten, 2004, Farina, 2000 and Harrop, 2007). A widely accepted definition describes TALs as productive, stable and slowly-developing landscapes (Antrop, 2005), possibly with high resilience (Dezio et al., 2014). At the same time, it has been demonstrated that many TALs are experiencing rapid transformations under various environmental pressures such as urban expansion or land abandonment, climate change, agronomic innovation or crop intensification (Kumaraswamy and Kunte, 2013, MacDonalds, 2000, and Van Eetvelde and Antrop, 2004). The cultural landscapes under UNESCO's protection, which are stable and safeguarded through specific management actions (Gullino and Larcher, 2013), and the landscapes situated in protected areas (Agnoletti, 2013) are both equally endangered by socioeconomic transformations (Cavallo and Marino, 2012 and Geri et al., 2010), by the employment of improved cultivars for standardized productions and by high-input agronomic techniques (Godone et al., 2014). Unfortunately, an inventory of the most threatened TALs is still missing, despite its potential importance for sustainable land management.

The preservation of multifunctional TALs clearly depends on the economic viability of traditional agricultural practices (TAPs) and on the use of autochthonous genotypes from which typical products (TPs) are derived. TAPs design traditional sustainable landscapes characterized by high environmental diversity (Halada et al., 2011, Harrop, 2007 and Štefunková et al., 2013). Traditional land management not only constitutes the historical memory of local agricultural systems, but also represents highly sustainable agronomical models based on landraces with low-input requirements (Abbona et al., 2007 and Altieri and Nicholls, 2002). Despite their value, inventories of traditional agricultural knowledge are also missing. However, as tribute of their multiple functions, the grapevine training system (the so called *alberello*) adopted in the island of Pantelleria (Sicily, Italy) for the production of one of the most appreciated sweet Mediterranean wines, has been recently included in the Unesco's list as the first agronomical practice recognized as intangible heritage (www.unesco.it).

The consistency of the autochthonous cultivated biodiversity, a key element of TAPs and TALs, maintained thanks to local traditions and practices, is better documented. As opposed to modern intensive agricultural landscapes, TALs are based on practices of important biological and cultural values. Different measures have been adopted in the most recent Common Agricultural Policy in Europe (CAP Reform 2000- 2013) in order to preserve agro-biodiversity including (i) listing endangered cultivars, (ii) proposing specific monitoring and conservation programmes and (iii) adopting national plans for the conservation of cultivated biodiversity (INEA, 2012). In Italy a National Strategy for Biodiversity conservation was developed (2010) focusing on promoting the conservation and sustainable use of agricultural biodiversity, restoring ecosystem services within the agricultural environment and adopting integrated strategies to contrast the abandonment of marginal agriculture (MATT, 2010 and Marino, 2013). The value of local landraces lies in the derived typical and traditional agricultural products strongly related to their territories. Some of them are certified as quality products according to the European classification standards (CE 510/2006) that account for Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) products; others are simply listed as traditional products. Various inventories of typical and traditional products are available on a national, regional or local level and they are sometimes classified based on spatial distributions and risks of disappearance. On the other hand, information concerning the associated landscapes is lacking or poorly developed.

Italy has been one of the first European countries to develop national and regional laws with the aim of preserving biodiversity. In particular, the Latium region was one of the first regions to adopt strategies for autochthonous biodiversity conservation since 2000 (Porfiri et al., 2008). In the Latium region, which includes the city of Rome, the cultivation of olives (*Olea europeae*), grapevines (*Vitis vinifera*) and wheat (*Triticum* spp) was carried out by the Etruschi before the Romans (since VII, VI century b.C). The Romans developed many agricultural practices that became the subject of agronomical treaties (Cortonesi, 2005). In the Middle Ages, all over the Latium region, the tree crop–cultivations were confined in church and monastery gardens, or around urban centres symbolizing primitive forms of peri-urban agriculture (Ronchi et al., 2014). The landscape of mixed olives, grapevines, fruit species and vegetables rapidly grew during the XII and XV century due to the proximity to Rome (Cortonesi, 2005). Since the XVI century, tree crop-based landscapes have expanded all over the region and have maintained their traditional structure until the beginning of the agriculture's industrialization process during the half of the last century (Biasi et al., 2012 (a)). Crop intensification negatively impacted the landscape leading to the expansion of homogeneous, highly specialized crops and damaging traditional agriculture and multipurpose traditional cultivars. Furthermore, Rome's urban expansion led to the fragmentation of natural and agricultural landscapes and to the loss of priority habitats. These events confirm the importance of conservation strategies (Colantoni et al., 2015 and Frondoni et al., 2011).

Given the tight relationship between TALs, TAPs and TPs and given the absence of a complete inventory of TALs and of information on typical/traditional agricultural products and local agro-biodiversity, the aim of this study is to identify and map TALs in Latium, a Mediterranean region characterized by rich agro-biodiversity, diversified physiographic characteristics and human pressures, through land-use change detection (1960-2000) analysis. An approach aimed at identifying the most relevant environmental risk factors that negatively impact autochthonous agro-biodiversity and traditional products at risk of erosion was developed in accordance with the most recent trends in biodiversity conservation strategies. In fact, the importance of mapping biodiversity richness and threats has recently been emphasised (Shapcott et al., 2015 and Tulloch et al., 2015). Mapping is crucial to address conservation decisions and to identify areas with conservation priority. Other authors have demonstrated that an indicator-based approach (Lomba et al., 2014) may be crucial to discriminate within a given category, like in the case of the agricultural areas of high natural value. Finally, recent research work (Walz, 2015) highlighted the importance of using official statistical data when deriving proper indicators for landscape analysis.

Despite the existence of inventories in which biodiversity is scored for the genetic erosion threat, an effective strategy for a sustainable biodiversity safeguard should consider the spatial link between biodiversity and related landscapes (Biasi and Brunori, 2015 and Brunori et al., 2015). For the purpose of this study tree crops were considered, in the TALs identification process, as relevant and traditional crops in the area of study and, more generally, in the Italian agricultural tradition.

Materials and methods

Study area

This study was carried out in one of Italy’s twenty administrative regions (Latium, central Italy). The region’s land is administered by five provinces (Viterbo, Rieti, Rome, Latina, and Frosinone) and 378 municipalities (Fig. 1) for a total surface area of 17,065 km^2. The Latium region is characterised by a complex topography ranging from 0 to nearly 2,200 m above sea level, with different climatic zones along the elevation gradient, from a dry area along the coast with 600-650 mm average annual rainfall, to a humid zone in the Apennine zone with more than 1,000 mm annual rainfall and a transitional zone between the two, including lowlands and hilly areas far from the sea. Irregular and intense rainfalls are common and mean annual temperatures range from ca. 10°C in the mountains to 20°C in the lowlands. In the last fifty years, the study area experienced massive land cover changes due to the expansion of Rome and of other four major towns. Tourism development (mainly around the coastal rim), forest fires, intensification of agriculture in lowland and hilly areas, and the abandonment of agricultural terraces inland contributed to determine the most recent changes/alterations in Latium's landscape (Salvati et al., 2014).

Logical framework

The methodology proposed in this paper intends to explore the relationship (Fig. 2) between traditional agricultural landscapes (TALs), traditional agricultural practices (TAPs) based on the use of local varieties and traditional products (TPs). In particular, we assumed that the spatial distribution of TPs and the related cultivated biodiversity can be used to identify TALs and to classify them as 'resilient' (active typical and traditional products; conserved local varieties) or 'vulnerable' (endangered typical and traditional products; endangered landraces) landscapes. We also assumed that TAL vulnerability increases with environmental risk. Two types of data have been processed, i.e. geophysical and biological data. Official national/regional database and statistics have been used to gather geophysical data for the 1960 – 2000 period.

Data on local agro-biodiversity (landraces) and the related typical and traditional productions has been gathered from national/regional databases and proper indexes have been calculated. The data source for Latium's landraces is an official database based on a methodology that allows inscription after the verification of the following proprieties: real presence of the landrace, identity of the germplasm evaluated through the description of morphological traits, and autochthony (Costanza et al., 2012 and Porfiri et al., 2008).

TAL mapping

The map of tree crop-based TALs in the Latium region was designed using previously developed approaches (Biasi et al., 2012 (a) and Cullotta and Barbera, 2011) that identify land-use persistence. In particular, a change detection analysis (1960-2000) was carried out using two compatible digital maps: a Land Cover Map (LCM), generated by the National Research Council and the Italian Touring Club in the early 1960s (LCM60), and a map produced by Latium's regional authority in the early 2000s (LCM00). The LCM60 was produced integrating topographic maps with cadastral maps at a nominal scale of 1.200,000 producing a hierarchy of 22 land-use classes. The

LCM00 was produced at a nominal scale of 1:100,000, with a legend of 76 classes in accordance with the CORINE Land Cover nomenclature (http://www.eea.europa.eu/publications/COR0-landcover). In this case, the official three levels scheme of the nomenclature was extended to a fourth level in order to encompass the specificity of regional land-uses. In order to make the two legends comparable, land-use/land cover nomenclature was reclassified in 12 classes to harmonize thematic content and to eliminate the inconsistencies in the hierarchical classification (Biasi et al., 2012 (a)). After the homogenization of the legend nomenclature, the LCM60 and the LCM00 were overlapped and elaborated for land-use persistence. For the purpose of this study, the following uses of land were tested for temporal persistence: (i) vineyards, (ii) olive groves, (iii) fruit orchards and (iv) consociated tree-crops. The map produced meets the following criteria: (a) the persistent patches of each selected land-use classes were assembled when reciprocal distance was lower than 1 km; b) the minimum mapping unit of the persistent patches was 5 km^2. The spatial distribution of the persistent patches - intended as candidate TALs (Cullotta and Barbera, 2011) - was then referred to the landscape systems as delimited by the Agrarian Region concept (Barbera et al., 2014), i.e. spatial domains represented by municipalities aggregated according to homogeneous crop specialization, climate-soil characteristics and socioeconomic structure (Biasi et al., 2012 (a)). Areas with persistent use of land over time, i.e. the potential traditional agricultural areas, were validated through the photo-interpretation of recent aerial photographs (2012) tested for the presence of the traditional structural traits (i.e., eco-mosaic complexity, patches dimension and shape) following the methodology reported in Barbera et al. (2014).

TP mapping

The spatial distribution of the typical and traditional tree-crop products in the Latium region was derived from the data extracted from different databases and organized on a municipal scale computing for density (number of TPs per municipality) and vulnerability (active production at risk of disappearance). The databases used were (i) the Atlas of the typical and traditional productions realized by the Italian Ministry of Agricultural, Food and Forestry Policies (Rosati, 2013) and (ii) the official ARSIAL (Regional Agency for Development and Innovation of Agriculture in Latium, Italy) catalogue (www.arsial.it, accessed July 2014). According to the ARSIAL catalogue, all typical products can be classified as (i) certified foods products (protected designation of origin, PDO), (ii) protected geographical indication (PGI), (iii) traditional specialities guaranteed (TSG) and (iv) traditional products or else they can be classified in accordance to the Italian law (Law no. 173/98 and Ministerial Decree 350/99) whose techniques of processing and preserving have been consolidated for more than 25 years. These are also classified according to the production status, i.e. active or at risk.

Local agro-biodiversity mapping

A map of the autochthonous tree crop agrobiodiversity has also been produced for the study area using data from the ARSIAL database (see above) in which local regional varieties are classified for their distribution and status (risk of erosion: low, medium or high). In particular, variety frequency and variety richness maps have been produced based on the relationship between individual frequency of landraces, spatial distribution and risk of genetic erosion following the evaluation parameters proposed in the literature (Costanza et al.,, 2012). Data were elaborated in order to regionalize three cultivar erosion indexes calculated for each municipality as follow: (i) density of cultivars per km^2; (ii) density of cultivars per species number; (iii) an index of cultivar loss ranging from 0 (no loss) to 3 (maximum loss risk) based on the Regional Agency for Agricultural Development database (www.arsial.it, accessed July 2014).

Evaluating TAL environmental vulnerability

Following the overlapping of maps of land use persistence and TP's density, a risk assessment for TALs was made considering a set of environmental risk indicators and ancillary socio-demographic variables representing the complexity of the territorial context as described below.

Soil sealing

Anthropogenic pressure is a relevant environmental risk factor in southern Europe, because it is directly related to demographic dynamics, economic development, social changes, and urban sprawl leading to landscape fragmentation, and indirectly causing soil pollution risk from diffused and point sources (Salvati and Zitti, 2005). In particular, tourism concentration, population growth and urban expansion represent the main drivers of Land Degradation in highly anthropogenic landscapes; this is mainly due to the increasing negative impact connected to the consequent increase in soil sealing. Five variables were calculated on a municipal scale (or a lower scale, e.g. building block, when available) and included population density (POP) and growth (GRW), the proportion of built-up areas (URB), the concentration of population in compact urban centers (SET) and tourism density (TOU). All the variables were derived from the National Censuses of Population, Buildings and Industry carried out by the Italian National Statistics Institute (ISTAT) and from the CORINE land cover maps provided by the Italian National High Institute for Environmental Research and Protection (ISPRA).

Soil salinization

Soil salinization is the process through which water-soluble salts (sodium, magnesium, calcium, chloride, sulphate, carbonate and bicarbonate) accumulate in the soil reducing its fertility. Salt in soils decrease the soil's osmotic potential so that plants find it difficult to absorb water from it. This can also have a direct effect as it is toxic for plants. Salinization can occur naturally (primary salinization) or as a consequence of unsustainable management practices (Van-Camp et al., 2004). Given the limited and localized field data quantifying these processes, proxies are generally used to define the areas exposed to salinization risk (Costantini et al., 2009). In this work four variables were used, including the surface areas exposed to primary salinization (determined by a spatial intersection between the Geological Map of Italy at the 1:500,000 scale and the distance from the sea coast) (SAL), the percentage surface area of farms practicing groundwater irrigation (GRO) and equipped with obsolete irrigation systems (IRR) on the total agricultural surface area. The Shannon index applied to irrigated farm data was also used to estimate the diversity of irrigation sources used by Italian farms (DIV). The last three variables were calculated on a municipal scale based on data provided by the National Census of Agriculture carried out by ISTAT.

Soil erosion

Soil erosion is considered as a striking process of land degradation and its natural rate usually increases with unsustainable human activities and climate change (Verheijena et al., 2009). As soil formation is a very slow process, high soil losses can have serious effects, both on- and off-site. Due to the lack of homogeneous field measures covering the entire country of Italy, we used a set of twelve variables considered as proxies for the process of soil erosion mainly due to the impact of water on soil. These are related to four themes: soil properties, natural vegetation and crop cover, anthropogenic pressure and soil protection measures (Kosmas et al., 2003).

Soil properties include depth (DEP), texture (TEX), parental material (PAR), and the agricultural soils' potential (maximum) water capacity (AWC). The maps produced by the Italian National Centre of Pedological Cartography were considered as the representative data source. Additional information was gathered from the European Soil Map produced by the Joint Research Centre (JRC). The variables referring to the last three themes were derived from the CORINE land cover map, the map of soil erosion risk produced by the JRC, and the National Censuses of Agriculture and Population. They include an indicator of potential risk erosion estimating the annual soil loss (ERO) using the USLE methodology (Salvati et al., 2009), a drought resistance indicator (DRE), the rate of vegetation cover (VEG), and two additional indicators quantifying fire risk (FRE) and the vegetation protection against soil erosion (EPR). The last four indicators were obtained by reclassifying the CORINE land cover map through the MEDALUS procedure. According to Kosmas et al. (2003), a weight was attributed to each land cover category in order to obtain the territory's classification based on the different levels of its vegetation's sensitivity and of the landscape's characteristics. Variables quantifying forest fires as a percentage of burnt surface area on the total forested surface area (BUR), overgrazing (GRA) as the ratio of an indicator of livestock pressure to the available grassland surface area (Salvati et al., 2007), and the percentage of surface areas under environmental protection (PRO) were lastly calculated on a municipal scale.

Soil compaction and agricultural intensification

Environmental hazards due to agriculture are mainly caused by the often market-induced unsustainable management of the land (Shortle and Abler, 1999). On the one hand, where the natural resources are relatively abundant and technology is easily available, a progressive crop intensifications can be observed with the associated risk of soil resource overexploitation. On the other hand, when depopulation and economic marginalization take place, the consequent abandonment of land may contribute to the further deterioration of the landscape and of the environment's quality in general. We have selected five variables as proxies for agricultural intensification and farm marginalization: crop intensity (INT), land rented for cultivation (AFF), farmer ageing (AGE), land abandonment (LOS), and an index of soil compaction risk (COM) due to heavy mechanization. Crop intensity was estimated as the ratio of the intensively cultivated area (arable crop and orchards) to the total agricultural area (AUA, Agricultural Used Area). The land rented for cultivation was computed as the ratio of the rented agricultural surface to the AUA (Salvati et al., 2007). Contrarily to farmers who own their land, farmers renting it lack in long-term perspectives and prefer to arrange crop production with the aim of maximizing immediate profits. Farmer ageing was calculated as the ratio of agricultural workers older than fifty-five to the total number of agricultural workers. Young farmers show, on average, higher entrepreneurial and educational achievements, as well as more attention to environmental matters, than older farmers. Land abandonment was estimated by computing the rate of change of the cultivated land surface between 1990 and 2000 (Khanal and Watanabe, 2006). Finally, an index of soil compaction risk was calculated based on the density of agricultural machines available in each farm and classified by type and size according to data provided by the National Census of Agriculture (Salvati and Zitti, 2005). All variables were calculated on a municipal scale.

Supplementary indicators

Climate and soil characteristics are the most important factors affecting the landscape's vulnerability to degradation (Rubio and Bochet, 1998). The following variables were considered: (i) climate aridity index (IAR), (ii) maximum Available Water Capacity of the soil (AWC), and (iii) erosion rate of the soil (ERO). IAR was calculated as the ratio between average annual rainfall and reference evapotranspiration (Salvati et al., 2005). It was derived from weather stations evenly distributed throughout the regional territory. The average annual precipitations for the period 1951–2000 were calculated using data of daily precipitations from the 185 national meteorological network's stations . The average annual reference evapotranspiration rate was calculated using the Penman-Montieth formula (Venezian Scarascia et al., 2006), based on the daily values of meteorological variables recorded during the period 1951–2000 at about 30 gauging stations. To obtain a regional distribution and the spatial coverage of the two meteorological variables over the two study periods (1951–1970 and 1981–2000) kriging and co-kriging (with elevation, latitude, and distance to the sea as ancillary variables) procedures were applied, to precipitation and reference evapotranspiration respectively (Salvati et al., 2005). IAR mean values were obtained in the form of raster maps by GIS tools in each study period. Zonal statistical procedures were applied to obtain an estimation of IAR mean value in each municipality of Latium. Data on Available Water Capacity of the soil were taken from an Italian database of soil characteristics, built-up on more than 18,000 original soil samples, as well as on soil databases such as the eco-pedological and geological maps of Italy and additional sources such as Digital Elevation Models and land use maps (Salvati et al., 2005). The point values of AWC were interpolated to an 8 km longitude-latitude grid resulting in a raster map. A zonal statistic procedure was applied to obtain an estimate of the AWC median value in each municipality of Latium. Finally, the erosion rate (ERO) was estimated by applying the USLE model (Salvati et al., 2005), based on the Italian map of soil erosion, produced by JRC on behalf of the Italian Ministry for the Environment. A zonal statistic procedure was used to obtain an estimate of the ERO median value in each municipality of Latium.

The impact of land-use changes was assessed as a result of practices such as intensification of agriculture, farm abandonment, as well as variation in woodland surface (e.g. Brouwer et al., 1991). Agriculture intensification (INT) was measured through the simple index described by Salvati and Zitti (2005), which is the ratio between the surface of most intensified crop (i.e., perennial crop and arable land) and the total cultivated surface. The variation of the surface of cultivated land over time (LOS), referred to a time horizon of ten years, was regarded as a proxy of land abandonment. Finally, the ratio between woodland cover and cultivated land surface (WOO) was taken as a proxy of rural land cover change (Salvati et al., 2008). All the variables were computed on a municipal scale based on the national agriculture census data as described above.

The influence of land-use change on land degradation was finally assessed as a result of practices such as intensification of agriculture, farm abandonment and variation of the woodland surface (Brouwer et al., 1991). Agriculture intensification (INT) was measured through the simple index described by Salvati and Zitti (2008), i.e. the ratio of the most intensified crop area (i.e., perennial crop and arable land) to the total cultivated area. Changes in cultivated land area over time (LOS), referred to a time horizon of ten years, were regarded as a proxy of land abandonment. Finally, the ratio between woodland and cultivated land area (WOO) was taken as a proxy of rural land cover change (Salvati et al., 2008). Variables were computed on a municipal scale based on the national agriculture census data as described above.

Statistical analysis

Non parametric Spearman rank correlations were carried out to assess the relationship existing between TALs and the other environmental, agronomic and socioeconomic variables testing at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

A Principal Component Analysis (PCA) was developed on the full data matrix to identify latent factors representing changes in the local territorial/environmental context and tree crop landscape. As the PCA was based on the correlation matrix, the number of significant components (m) was chosen by retaining the components with eigenvalue >1. Based on the loadings of the principal components, variables have been discriminated into different groups.

Results

Analysis of stable tree crop landscape distribution

The TALs' map was produced for the study area and illustrated in Figure 3. The spatial distribution of the stable tree crop landscape was overlapped with the map of Agricultural Regions of Latium. The persistence of some selected land uses are concentrated in specific agricultural districts; in particular vineyards, almost exclusively from the coastal hills of Colli Albani, and fruit orchards, concentrated in the agricultural district of Cimini hills (northern Latium) and in the plain of Terracina and Fondi (southern Latium). The olive groves and the consociated tree-crops are scattered on hilly areas, especially in the west and south-west side. Land-use persistence was relatively scarce along the coast, except for the most southern part, possibly as a result of intense coastal urbanization over the study period.

The spatial distribution of typical agricultural products

Traditional and certified products are recognized in the Latium region. In particular, as far as the certified productions are concerned, most of them are productions derived from grape transformation and 2 for olive oil (data not shown); 9 products are derived from chestnut (*Castanea sativa*) transformation, 6 from *Olea europaea*, 2 from *Ficus carica* and 2 from *Prunus avium*. Minor products derive from *Corylus avellana*, *Prunus cerasus*, *Pyrus communis*. The TPs map (Fig. 4) from fruit trees and vines shows a widespread distribution all over the region, although exhibiting a peculiar spatial profile compared with the regional agricultural base. Interestingly, the active traditional productions were found independent from the land-use persistence concentration. TP density was coherent with the distribution of land-use persistence and reflects the fragmentation of land-use persistence. Finally, the spatial distribution of endangered production may discriminate the TAL risk of erosion, as demonstrated in the following section.

Crop varieties' erosion indexes

The main endangered tree crop species are listed in Table 1. The three selected indicators (Fig. 5) show a quite distinct spatial distribution. The density of local varieties (Fig. 5a) is higher in the rural areas surrounding the municipality of Rome with traditional cropping systems and a millenary human-nature interaction. The average number of local varieties per cultivated species (Fig. 5b) is higher around Rome and in the traditional cropland of Frosinone. The index of local cultivar loss (Fig. 5c) is higher in Viterbo and Rome with a lower proportion of tree crop stable landscape (see paragraph 3.1).

Environmental vulnerability and the socioeconomic context

The spatial distribution of the selected processes of soil and landscape degradation (Online Resource 1) is a key component to understanding the specific impact on the agricultural production. Each degradation process shows a defined spatial distribution based on specific drivers and territorial characteristics. While soil salinization was typically associated to coastal areas and soil sealing was mainly concentrated in suburban areas, soil erosion and compaction showed a more variable spatial distribution being associated to rural areas with specific characteristics for slope, cropping system, mechanization, crop intensity, irrigation and land-use patterns. Over time, the environmentally sensitive area index showed worse environmental conditions especially in the rural areas around Rome due to the combined effect of increased human pressures and local climate shifts towards aridity and warming.

Statistical analysis

A correlation analysis was carried out between the proportion of TALs and selected environmental, agronomic and socioeconomic variables characterizing the territorial context of each municipality in the study area (Online Resource 2). Vineyard is the use of land with the highest number of correlations with the selected predictors. The percentage of stable vineyards increases with the Climate Quality Index and the land Management Quality Index observed in 2010, indicating vineyards as the most exposed crop to climate aridity (or other climate-driven risks) and human pressure, reverting the correlation pattern observed in the past (not significant correlations found in 1960). A higher proportion of stable vineyards was found in the municipalities with intense soil sealing, suggesting that vineyards are more vulnerable to urbanization-driven land-use changes than in the past. These results are also validated by the positive correlation with population density and growth over time. As far as olive groves are concerned, the only significant correlation found in the Latium region is with soil erosion, indicating that stable olive groves are concentrated in areas with a high risk of soil erosion. The proportion of fruit trees is positively correlated with the risk of crop varieties' erosion while consociated tree crop is a landscape element negatively associated with the density of crop varieties on a municipal scale. These results provide a framework to identify specific degradation processes for each examined crop in the study area.

A Principal Component Analysis was finally run on the same data matrix in order to summarize the possible relationship between the variables (Table 2). The two main components extracted explained more than 31% of the total variance. This appears as a reliable result due to the high number of input variables. The first component represents a typical elevation gradient being associated to climate and land-use characteristics coupled with higher human pressure and environmental sensitivity. Stable vineyards are moderately associated to this component. The number of varieties per crop is positively associated to component 2 together with population density and the climate aridity index. This suggest that varieties' erosion risk may be affected by human settlement dynamics and variations in local climate regime.

Discussion

The agricultural landscape and environment transformation

Despite the agricultural industrialization processes and the subsequent landscape simplification and homologation that has occurred since the second half of the last century (Cullotta and Barbera, 2011), central Italy is still rich in landscape diversity that is also highly representative of the Italian physiographic variability due to the high diversity of natural and rural environment along the elevation gradient. Latium is characterized by a widespread but residual, distribution of stable and traditional land-uses contributing to landscape sustainability with traditional agriculture (Antro, 2005 and Farina, 2000). Many factors have driven the Italian agricultural landscape transformation (Cavallo and Marino, 2012), mainly social-economic pressures acting within given physical environments. Landscape transformations have sometimes occurred following the application of European agricultural policies. In fact, a Common Agricultural Policy (CAP) initially oriented to the promotion of the market and of products has determined agricultural intensification, specialization, disappearance of the traditional Mediterranean mixed crop, natural habitat fragmentation and loss in ecological connectivity (Biasi and Botti, 2011 and Godone et al., 2014). Some tree crops expanded rapidly and others started to erode. The grapevine surface area in the Latium region decreased (ISTAT, 2011) by 46% in the period between 2000-2010, together with fruit orchards (-7%) and citrus orchards (-36%), whereas the olive cultivation, remaining rather stable, changed in its physiognomy disappearing in marginal areas and becoming a more industrial crop in lowland (Biasi and Rugini, 2009). Nonetheless many historical landscapes have survived in the region at local scale even close to Rome (Agnoletti, 2012 and Frondoni et al., 2011). The new CAP policy (2014-2020) will strongly affect the future landscape. Transformations will be combined with the promotion of preservation strategies for the natural areas, the multifunctional agriculture, the spaces of ecological interest like forest remnants, riparian vegetation, tree rows, natural hedges and other habitats linked to the agricultural systems (Lefebvre et al., 2014). The Rural Development's Programme will stimulate farmers to be actively engaged in the protection of biodiversity (Marino, 2013).

As noted in other Mediterranean areas (Garcia Latorre et al., 2001 and Iosifides and Politidis, 2005), worse environmental conditions affecting landscape sensitivity were observed in Latium over the study period. The analysis of environmental and territorial drivers endangering rural landscapes suggests that factors correlated to climate change, soil degradation and increased human pressure play a key role in determining high levels of environmental sensitivity for stable tree crop landscapes reflected in crop varieties' erosion with consequent deep biological diversity loss and loss of gene pool. In fact, landraces are "varieties with a high capacity of tolerating biotic and abiotic stress, resulting in an high yield stability, an intermediate yield level under a low input agricultural system" (Zeven, 1998). The traditional use of local genetic resources, i.e. planting, growing, transformation and consumption, at the base of a traditional way of life and a traditional socioeconomic structure, represents sustainable productive models based on low outside-farm inputs employment (Alvarez et al., 2010).

Factors contributing to environmental sensitivity in Latium include climate aridity and poor soil characteristics, as well as the concentration of economic activities as a result of urban growth and intensive agriculture. In the mountain districts, the crisis of traditional agriculture systems associated with land abandonment by rural populations and consequent deterioration of soil especially in sloping areas — also due to more intense rainfall determining soil erosion — may represent critical drivers of environmental degradation with implications for agronomic biodiversity erosion (MacDonald et al., 2000 and Puigdefabregas and Mendizabal, 1998). However, in such areas ecological factors could mitigate landscape and soil degradation, e.g. the increase of woodland cover and the decrease in human pressure and agricultural intensification (Bouma et al., 1998).

In addition to the many efforts made to integrate biodiversity conservation within CAP priorities (Piorr and Müller, 2009), other international strategies for sustainable development highlight the importance of traditional agricultural landscapes. The European Landscape Convention (2000) promotes the knowledge of environmental heterogeneity in terms of landscape diversity (agricultural landscapes included), and the 3rd target of the EU 2020 Biodiversity

Strategy (http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm) focuses on the contribution of agriculture to biodiversity throughout the promotion of traditional farming.

The autochthonous agro-biodiversity

The current tree crop production in Italy is based on a limited number of "major fruits" with few improved cultivars needing technological inputs. However, in Italy there is an increasing interest for the promotion of traditional fruit tree varieties, both autochthonous or of foreign origin, mainly for apples (*Malus communis*), pears (*Pyrus communis*), prunus (*Prunus domestica)* and table grapevines (*Vitis vinifera*) (Tibiletti and Tibiletti, 2010). According to a recent definition of landrace, i.e. a variety that lacks "formal" genetic improvement, highly adapted to the innate environment and "associated with traditional use, knowledge, habits, dialects and celebration of the people who developed and continue to growth it" (Lorenzetti and Negri, 2009), they are not necessarily maintained under traditional farming but because of traditions related to food (Marino, 2013).

Beside "major fruits", many "minor fruits" are promoted for cultivation, like pomegranate (*Punica granatum*), carob (*Ceratonia siliqua*), mulberry (*Morus* spp), arbutus (*Arbutus unedo*), medlar (*Mespilus germanica*), azarole (*Crataegus azarolos*), bergamot (*Citrus bergamia*), cedar (*Citrus medica*), chinot (*Citrus myrtifolia*), quince (*Cydonia communis*), fig (*Ficus carica*) or prickly pears (*Opuntia ficus-indica*) (Tibiletti and Tibiletti, 2010). Finally, some wild species, i.e. forest fruits, have been domesticated and promoted for wider production like *Prunus cerasifera*, *Fragaria vesca* , *Rubu*s spp, *Vaccinum myrtillus*, *Ribes* spp owing to their high nutraceutical significance or utility for the animal biodiversity support.

Traditional crops and agricultural systems acquire importance for many reasons, other than for the preservation of cultural values. One of the major benefits of traditional agricultural systems is that they can act as *in-situ* conservation spaces. At a local level, i.e. in the study area (Latium region) 193 landraces (out of 2365 landraces) are listed in the official database for *in-situ* conservation, most of them belonging to fruit trees (73%) and to a lesser extent to cereals and grain legumes (12%) and vegetable (9%) (Paccino et al., 2013). Nonetheless the real consistency of the local varieties is difficult to assess because of synonyms.

Ex-situ and *in-situ* conservations are complementary strategies for the safeguard of agrobiodiversity, both in terms of autochthonous cultivar and of ancestral species of crop. Owing to its peculiarity, *in-situ* conservation has more recently gained importance because several functions have been attributed to this procedure like the preservation of selective pressure factors, the maintenance of habitat diversity, and when *in-situ* conservation is carried out on farm, the safeguard of typical and traditional uses and economic income, as well as of cultural values.

Traditional agricultural systems are strategic spaces to maintain the selection pressure on the local varieties in the pristine environment, therefore preserving and providing a gene pool crucial for the genetic improvement of commercial varieties. In fact, the limited genetic base of the major cultivars for the fruit species is in contrast with the high density of local ecotypes within the different major and minor species that have been selected in a highly heterogeneous territory. A total of 12.000 accessions are maintained *ex-situ* among the different collection public or private in Italy. At the Italian National Center of Fruit Germplasm (CNGF, 2001) on 5159 fruit accessions of 24 fruit species (39 of which are botanical species or interspecific hybrids) 1801 are Italian local varieties (Engel et al., 2014). For instance only for stone and pome fruits the autochthonous germplasm has been utilized in the period 1980-2008 for the constitution of 123 new varieties (Della Strada and Fideghelli, 2011).

The characterization of local genetic resources is crucial to improve the quality of the plant material, for instance for the phytosanitary status, higher quality of the production and increased competitiveness of typical products (Bacchetta and Di Giovanni, 2013) against marked homologation and increased competitiveness of the farms.

The interest in inventory, conservation and reintroduction of local varieties is based on traits like unique flavors, high adaptability to the environment, high storage life, reduced production costs. At the moment their use may have an economic importance for local economies against globalized productions. On the other hand, conservation strategies for “minor fruit species” have just begun and are still based on the employment of local germplasm as ornamental trees in gardens and parks, including the urban ones, or in multifunctional didactic farms, hotspots of biodiversity or niche productions (Galluzzi et al., 2010).

Finally, the management of local grapevine cultivars in the most treated environments like coastal land or other marginal productive areas may lead to a sustainable use of the territory. In fact, relict crops of marginal productive areas represent interesting systems characterized by an heterogeneous eco-mosaic that ensure local biodiversity with high rusticity and adaptation features. Furthermore, they may represent productive systems preserving other natural resources, i.e. water, soil, landscape. The re-functionalization of these productive spaces could provide a valuable tool for the “on farm conservation” of local varieties together with the preservation of their landscape of high environmental and cultural meaning (Biasi et al. 2012 (b)).

The traditional productions

Typical productions are considered as valuable local assets. Mediterranean countries account for the higher density of geographical indications in Europe (Kizos and Vakufaris, 2011). Many of these productions derive from small farms in marginal territories so that maintaining them at the core of their production process can result in the preservation of traditional knowledge and of traditional sustainable landscapes, with great benefits in the most endangered contests (Tregear et al., 2007).

Typical and traditional productions have an impact on land-use patterns. Even with no empirical evidence, it is reasonable to assert that this occurs because they are tightly linked to the physiography of the territory and specific sustainable land-use practices based on the use of landraces (Lamarque and Lambin, 2015). Our study shows that the most endangered typical and traditional productions are concentrated in areas where multiple environmental risk factors act together. The value added of promoting typical and traditional productions has been only rarely investigated in terms of environmental benefits (Kizos and Vakufaris, 2011 and Lamarque and Lambin, 2015). The distribution of traditional production at risk in our study area together with the spatial distribution of local variety at the base of the geographical indications proves that their valorization could result in the preservation of biodiversity and ecosystem diversity, cultural knowledge. This was indirectly demonstrated highlighting the tight linkage among traditional cultivations, landscape and biodiversity preservation (Bender, 2010) or among geographical indications, cultural biodiversity and local knowledge (Berard and Merchenay, 2006 and Tregear et al.,1998).

Given the fact that typical and traditional productions are certified for their origin but also for the environmental-friendly production process, as a consequence of the use of landraces and organic farming, the promotion of these productions turn out in the raise of a sustainable land-use, extensive land management, provision of multiple ecosystem services and, finally, in the conservation and valorization of traditional agricultural landscapes (Lamarque and Lambin, 2015). Finally, efforts for preserving landraces, typical productions and traditional landscapes may have major impact in sensible areas like the peri-urban ones.

The increasing interest for sustainable agriculture in the peri-urban space could justify the adoption of strategies for preserving local varieties, typical production and traditional agricultural systems in areas with high anthropogenic pressure and tourism. There is increasing interest for peri-urban farming all over in Europa (Lohrberg and Timpe, 2012) and in new planning strategies that take into account urban agriculture (Groening, 2014). In particular, Rome has been recently indicated as a suitable context where to apply a strategy of “food planning” aiming urban landscape resilience and therefore sustainable development, green infrastructure construction for biodiversity conservation, soil consumption reduction, cultural and natural capital valorization, promotion of social and economic equity (Marino and Cavallo, 2014) and sustainable tourism based on the fruition of the agricultural space all around the city center. In the Rome municipality in the last ten years the UAA (Utilized Agricultural Area) has increased by 17% (39% of the total city area), the number of farm has increased by 40%. These productions serve different agricultural models such as traditional or cooperative farming, common farming, social farming (Marino and Cavallo, 2014).

Conclusions

The proposed approach sheds light in the complexity of landscape change processes under environmental and socioeconomic transformations. A comprehensive knowledge of such processes may support sustainable land management decisions and land-use policy recognizing the role of traditional agricultural landscapes as strategic elements for the conservation of on-farm agro-biodiversity and related typical productions.

Based on our approach, resilient agricultural districts are eligible for *in situ* strategies addressing biodiversity and high-value landscape conservation.

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Figure legends

Figure 1 A map illustrating Latium region, the five provinces and the boundaries of local municipalities.

Figure 2 The relationship among the traditional agricultural landscape (TALs), traditional agricultural practices (TAPs) and traditional products (TPs).

Figure 3 The map of stable tree crops-based landscapes in Latium (1960-2000); water bodies are illustrated in blue.

Figure 4 The distribution of TPs in Latium: number of certified TPs from tree crops per municipality (a), active traditional productions (b), at risk of erosion (c).

Figure 5 Indexes of local tree crop varieties' erosion in Latium region: density of varieties per km^2 (a), average density of varieties per species (b), index of local variety loss (c).

Table 1 The main endangered tree crop species in Latium region for local germplasm erosion and the related risk level with the number of landraces implicated.

Tree crop species	**Risk of erosion Local Cultivars (n)**			
	High	Medium	Low	**Total**
Pear	7	2	0	**9**
Peach	4	0	0	**4**
Plum	1	4	0	**5**
Sour Cherry	1	0	0	**1**
Sweet Cherry	10	0	0	**10**
Apricot	5	1	0	**6**
Olive	7	5	1	**13**
Apple	32	1	0	**33**
Azarole	0	1	0	**1**
Hazelnut	3	0	0	**3**
Chestnut	0	1	0	**1**
Grapevine	10	15	7	**32**

Table 2
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Table 2 Results of Principal Component Analysis (bold indicates variables with loadings > |0.5|).

Theme	Variable	Factor 1	Factor 2
Stable landscape	Vineyards	-0.40	0.14
	Olive groves	-0.03	0.00
	Fruit orchards	-0.06	-0.16
	Mixed tree crop	0.07	0.17
Environmental risk	CQI_1960	**-0.53**	-0.49
	CQI_2010	**-0.64**	-0.17
	SQI	-0.10	-0.31
	VQI_1960	**-0.50**	-0.34
	VQI_2010	**-0.64**	-0.15
	MQI_1960	**-0.65**	0.47
	MQI_2010	**-0.85**	0.00
	ESAI_1961	**-0.82**	-0.08
	ESAI_2011	**-0.89**	-0.17
Soil degradation	Erosion	0.14	0.38
	Sealing	**-0.76**	0.43
	Salinization	-0.39	-0.07
	Compaction	0.08	0.20
Crop varieties	Varieties' density	0.04	0.06
	Varieties per crop	0.13	**0.54**
	Varieties' erosion	-0.38	-0.48
Socioeconomic drivers	DEN70	**-0.66**	**0.53**
	DEN00	**-0.76**	0.48
	VAR70	**-0.80**	0.08
	VAR00	-0.49	-0.29
	COI70	-0.25	0.41
	COI00	-0.43	0.45
	BOS70	0.19	0.10
	BOS00	0.42	0.11
	INT70	**-0.52**	-0.13
	INT00	**-0.62**	-0.25
	SAV70	0.03	-0.06
	SAV00	0.04	-0.13
	TUR71	-0.32	0.35
	TUR01	-0.36	0.36
	ESTR71	-0.19	0.11
	ESTR01	-0.15	0.10
Territory	AWC00	0.10	0.02
	IAR00	**0.62**	**0.53**
	Elevation	**0.61**	0.16
	Closeness to the sea	-0.42	0.00
	Municipal surface area	-0.27	0.05
	Explained variance %	**22.40**	**9.10**

Figure 1
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Figure 2
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Figure 3

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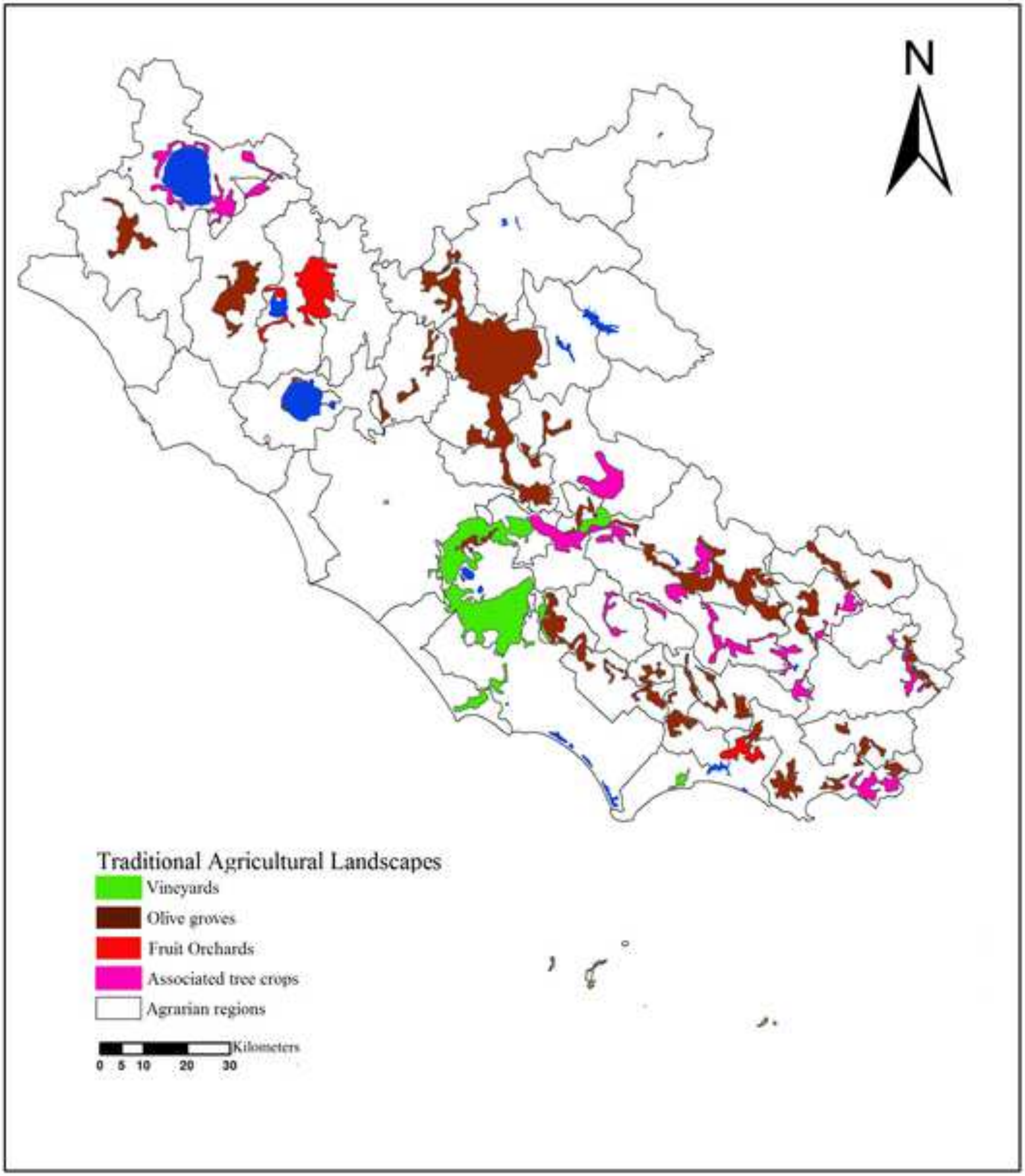

Figure 4
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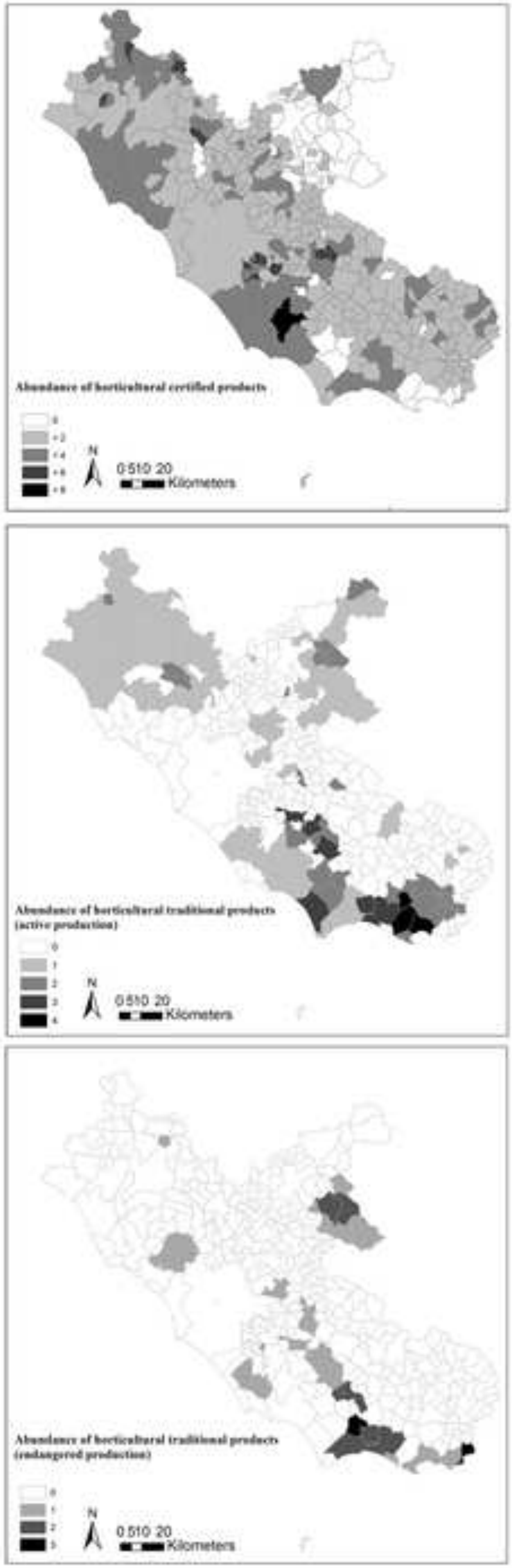

Figure 5

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