Exploring the role of land degradation on agricultural land use change dynamics

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HIGHLIGHTS

• Land degradation (LD) directly influences land-use changes (LUCs) in time and space.
• We investigated the role of LD on land abandonment (LA) and urban expansion (URB).
• We used Ecological Niche Factor Analysis (ENFA) to model the LD niche of LA and URB.
• LA is a complex process driven by both "pedological" and "anthropogenic" LD factors.
• URB is a continuous process mainly guided by one LD factor, namely "anthropogenic".

GRAPHICAL ABSTRACT

ABSTRACT

The role that land-use and socioeconomic factors exert on consolidating land degradation (LD) processes is a major research issue. However, intensity and type of the impact played by LD on such land use factors is still underexplored. The present study investigates the role of LD on land-use change (LUC) trajectories of land abandonment (LA) and urban expansion (URB) in the three geographical repartitions (North, Centre, South) of Italy between 1990 and 2012, by means of the Environmental Niche Factor Analysis (ENFA). ENFA is a multivariate approach originally introduced in the analysis of animal ecology allowing to compute habitat suitability (HS) models without requiring presence/absence data. Four environmental quality indices about climate (CQI), soil (SQI), vegetation (VQI) and land management (MQI) have been analyzed for the years 1990 and 2000 and related to the trajectories of LA and URB, respectively, for the time periods 1990–2000 and 2000–2012. Empirical results have indicated that different driving forces are linked to LA and URB, and that for each trajectory, the role of some forces may change over time. Evidence shows that soil quality and low human pressure represent the main drivers of LA. By contrast, as for URB, high human pressure represented the main driving factor throughout the country, both during 1990–2000 and 2000–2012. The HS maps show the probability arrangement of LA and URB in the three geographical repartitions. Starting from this work, further research is increasingly required to implement prediction models of future LA and URB trajectories according to the current land quality status.

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Keywords: Italy, Environmental quality indicators, Land abandonment, Niche modelling, Urban expansion

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1. Introduction

Land degradation (LD) is a global process involving multiple causal factors which entails an overall reduction in the capacity of providing ecosystem goods and services by cropland, rangeland, and woodlands. Such process becomes irreversible when reaching the last stage of desertification (Montanarella, 2007). In the Mediterranean Basin, climate and land-use play a significant role in the LD process. The joint effect of global warming, soil deterioration, loss of natural vegetation, human pressure and unsustainable land-use management is responsible for large scale LD phenomena not only in semi-natural areas, but also in agricultural and peri-urban areas (Salvati et al., 2014a). LD is often viewed in relation to certain ecosystem services that are expected or desired to be provided within particular socioeconomic and land-use systems (Stringer, 2017).

After World War II, land-use changes (LUCs) experienced rapid modifications due to the acceleration of processes such as land abandonment, agricultural intensification and uncontrolled expansion of urban areas (Lambin and Geist, 2006). Land-use changes (LUCs) have been identified as key drivers of global change with major impacts on ecosystems, climate and the human sphere (Foley et al., 2005). Land changes, intended as joint land-use modifications, population dynamics and ecosystem variations, can be analyzed and interpreted in terms of “trajectories”, according to the European Environment Agency (Gómez and Páramo, 2005). LUC trajectories and LD are often associated, e.g. urban expansion trajectory is directly associated with land take and soil sealing LD processes (Smiraglia et al., 2016).

In the last decades, the dominant LUC trajectories observed in the northern Mediterranean Basin are (i) a decreasing human pressure in marginal areas due to land abandonment and (ii) the expansion of urban areas, especially along the sea coasts and in inland plains (Millington et al., 2007; Bajocco et al., 2012).

Land abandonment (LA) consists in a progressive decline of cropland associated with rural-to-urban internal migrations. This is one of the major land cover and land-use changes in Europe since the 19th century, especially in mountainous areas and semiarid environments (Poyatos et al., 2003). As a consequence, unmanaged vegetation has substantially increased, making the environmental mosaic more homogeneous, decreasing the productive capacity of land, reducing the protection function of soils, increasing soil erosion risk, altering the water use balance and increasing the biomass available (Scherr and McNeely, 2008; Serra et al., 2014; Romero-Díaz et al., 2017). These impacts affect not only the abandoned area and its local population but also society as a whole, which feels the negative impact in the production of goods and services by agricultural land (Mottet et al., 2006; Plieninger et al., 2014).

Urban expansion (URB) instead leads to the transformation of agricultural and natural ecosystems into artificial surfaces and is regarded as one of the severe processes of land change in Europe as well as elsewhere in the world (Eckelmann et al., 2006; Salvati et al., 2013). As cities expand, activities associated with urban growth generate ecological disturbances, mainly through soil sealing processes. Urban expansion compresses, moves, deposits, and contaminates soils, affecting environmental quality at progressively larger scales (Lavy et al., 2016). It may also lead to crop production decline, soil erosion, loss of organic carbon stock and water reserves, decrease in biological diversity (Ceccharelli et al., 2014). The environmental consequences of both LUC trajectories entail, on the one side, the gradual decrease in landscape diversity and complexity, and, on the other side, the increase of vulnerability to certain hazards such as forest fires, erosion, floods, and droughts (Serra et al., 2014; Smiraglia et al., 2015).

The role that human induced (land-use; socioeconomic) factors play on the occurrence of LD is a major research issue (Basso et al., 2000; Symeonakis et al., 2007; Bajocco et al., 2012). However the entity and type of the role played by LD on such factors is still underexplored and only partially known. Understanding the relationship among land-use changes (LUCs) and their driving factors is extremely important for enabling scientists, landscape managers and policy makers to design nature conservation strategies and develop informed and appropriate land-use policies with the aim of preserving some of the unique characteristics of both natural and anthropogenic landscapes (Zasada et al., 2017). There is a need for scientific research that advances our understanding of the main environmental features that lead to such main LUC trajectories. We especially need better comprehension of the impact of land quality status on land-use management and transformations (Colazo and Buschiazzo, 2015; van Hall et al., 2017).

Under the assumption that LD is not static over time, the working hypothesis of this study is that LD, determining the quality level of an area, directly influences LUC trajectories, and that the spatio-temporal distribution of areas with different degrees of land quality affects human pressure, land-use management, and ecosystem variations at large (Khatari and Tyagi, 2015; Salvati et al., 2014b). Based on these premises, the aim of this work is to investigate the role of LD on the LUC trajectories of land abandonment (LA) and urban expansion (URB) occurred in agricultural areas, by means of Environmental Niche Factor Analysis (ENFA). The analysis benefited from a selection of environmental quality indices specifically assessing climate (CQI), soil (SQI), vegetation (VQI) and land management (MQI) made available for two time points (1990 and 2000) and related to the trajectories of LA and URB separately for the time periods 1990–2000 and 2000–2012.

2. Study area

Italy is located in southern Europe extending about 300,000 km². The country area is composed of about 23% of flat zones, 42% of hilly areas, and 35% of mountainous districts. Both the amount of precipitation and the proportion of semi-natural land tend to increase along the elevation gradient. Italy is characterized by two major ranges of mountains (the Alps and the Apennines), extensive hilly zones, river valleys, and a coastline of about 7600 km. Land cover is characterized predominantly by agricultural areas (52%) and secondary by natural and semi-natural areas (42%), most of which are forests (25%). Artificial areas, which cover almost 5%, are prevalently located along the coasts and in the wide plains.

The country is divided into three geographical belts (North, Centre, South) which show important regional disparities in socioeconomic development, natural resource availability and land quality (Salvati and Bajocco, 2011). This subdivision was derived from the Italian Institute of Statistics (ISTAT) which groups the 21 NUTS-2 administrative regions of Italy in three geographical macro-regions on the base of administrative and socioeconomic criteria as follows:

- Northern Italy: Piemonte, Valle d’Aosta, Liguria, Lombardia, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Emilia-Romagna;
- Central Italy: Toscana, Umbria, Marche, Lazio;
- Southern Italy: Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia, Sardegna.

3. Data

3.1. Land use change trajectories

The land cover maps used in this study were derived from the maps of CORINE Land Cover dated 1990, 2000 and 2012 (nominal scale 1:100,000) generated by the European Environment Agency. The standard CLC nomenclature includes 44 land cover classes. These are grouped in a three-level hierarchy. The five main (level-one) categories are: 1) artificial surfaces, 2) agricultural areas, 3) forests and seminatural areas, 4) wetlands, and 5) water bodies.

The land cover transformations observed in the considered time period over Italy were assessed by means of the changes observed on the CLC classifications aggregated at the first hierarchical level. For this
study the following LUC trajectories observed over two time intervals (1990–2000 and 2000–2012) were analyzed (Figs. 1 and 2): (i) land abandonment (LA) and (ii) urban expansion (URB). LA included all LUCs from agricultural areas (CLC2) to natural land cover types, such as grasslands, shrublands and forests (CLC3). URB included all LUCs from Agricultural areas (CLC2) to artificial surfaces (CLC1). ArcGIS 9.2® was used for land classification and detection of LUC trajectories. All maps were rasterized with a grid resolution of 1000 m.

3.2. Environmental quality indices

The Environmentally Sensitive Area (ESA) framework (Basso et al., 2000) was used to estimate the environmental quality of Northern, Central and Southern regions of Italy in 1990 and 2000. This framework is able to integrate variables from different data sources about geology, topography, climate, land cover and anthropogenic pressure (Symeonakis et al., 2007), and to derive composite environmental quality indices (Table 1).

Climate quality (CQI) was described by the average annual rainfall rate, aridity index (sensu UNEP, 1992), and aspect (Basso et al., 2000). Such variables were obtained from the National Agrometeorological Database of the Italian Ministry of Agriculture in 1990 and 2000.

Vegetation quality (VQI) was assessed through four indicators: fire risk, protection offered by vegetation against soil erosion, drought resistance of vegetation, and plant cover (Basso et al., 2000). Such indicators were obtained from CLC maps of 1990 and 2000.

Land management (MQI) was assessed by analysing population density, demographic growth rate and intensification of agriculture (Otto et al., 2007). Population density and growth rate were measured at the municipal level in 1991 and 2001 according to the data from the Italian National Census of Population and Households. Agricultural intensification estimates were derived from the CLC maps of 1990 and 2000 according to Kosmas et al. (2003).

Soil data (SQI) were obtained from the soil quality map of DISMED project (Brandt, 2005), based on the European Soil Database (Joint Research Center, JRC). Considering the examined time span, these variables can be considered as static, as they change slowly or rarely over time (Basso et al., 2000).

According to the ESA framework, CQI, SQI, VQI and MQI were estimated separately as the geometric mean of the different scores of the variables associated to each of the four thematic indices. For a detailed description of the ESA model, see Salvati and Bajocco (2011).

4. Methods

First, we led a Principal Component Analysis (PCA) in order to explore the distribution of the LUC trajectories analyzed in the ordination space of the environmental quality indicators, and to see if, analysing Italy as a whole, there is any difference across the years and geographic repartitions. We examined separately LA and URB for the time periods 1990–2000 and 2000–2012.

Then, we analyzed Northern, Central and Southern districts separately, quantifying the environmental niche of the LUC trajectories of LA and URB with the using of the Ecological Niche Factor Analysis (ENFA; Hirzel et al., 2002). ENFA is an empirical model and, as such, it is not expected to provide any information about the underlying ecological/environmental mechanisms or to quantify the actual correlations between parameters and predicted responses (Dettki et al., 2003). Yet, it can be used to identify and rank the most important variables for the predicted responses. ENFA compares the distribution of independent environmental variables (i.e. the land quality indicators) for a presence dataset (i.e. the locations where the LUCs were observed), with the global distribution of the same variables in the entire study area. ENFA is a presence-only multivariate approach which does not require absence data of the species, such as e.g. logistic regression models do (Dettki et al., 2003). Unlike presence-absence models, it uses only the presence data because in environmental studies they represent a doubtless information, while the absence data could be a false registration. The use of presence-only data makes the ENFA analysis particularly robust to the quality of data (https://www2.unil.ch/biomapper/enfa.html).
LUCs can be modeled like a “species” with variable preferences for different resources (i.e. the background environmental conditions; De Angelis et al., 2012; Bajocco et al., 2016).

In this paper, we used the four environmental quality indicators (CQI, SQI, VQI, MQI) described above as predictor (background) variables in the ENFA, while the dependent (species) variables were the LUC trajectories of LA and URB, separately. The environmental quality indicators of 1990 were compared with the LUC trajectories of 1990–2000; the environmental quality indicators of 2000 were compared with the LUC trajectories of 2000–2012.

ENFA summarizes all environmental predictors into a few uncorrelated factors retaining most of the system's variance and having ecological meaning (Hirzel et al., 2002; Brotons et al., 2004). The first factor is the one retaining the majority of information and it is termed “marginality” (Dolédec et al., 2000; Hirzel et al., 2002). It quantifies the distance between the average conditions of the available (background) habitat and the average conditions of the habitat occupied by the species. The marginality coefficients (m) range from −1 to +1. For each analyzed environmental variable, the higher the absolute value of a coefficient, the larger (negative or positive) the difference between the habitat used by the species and the habitat available in background. The global marginality index (M) usually ranges between 0 and 1, with large values indicating that LUC trajectories occur preferentially in marginal environmental conditions in relation to the background (Basille et al., 2008). In terms of land use change dynamics, the marginality factor indicates if the LUC analyzed mainly occurs in marginal (i.e. not frequent) conditions with respect to the global distribution of the background environmental conditions (i.e. the tails of the distribution), or if it occurs in areas with mean environmental conditions.

The subsequent factors explain the “specialization” and express how the variance of environmental variables at LUCs locations differs from the global variance. The global specialization index varies from 1 to infinite; values progressively >1 mean an increasing level of specialization. Accordingly, the inverse of specialization, the tolerance (T), varies from

### Table 1

<table>
<thead>
<tr>
<th>Theme</th>
<th>Variable</th>
<th>Scale</th>
<th>Unit of measure</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil quality</td>
<td>Soil texture</td>
<td>1:250,000</td>
<td>Sensitivity class</td>
<td>Ministry of Agriculture, European soil database</td>
</tr>
<tr>
<td></td>
<td>Soil depth</td>
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<td>mm</td>
<td>Ministry of Agriculture, European soil database</td>
</tr>
<tr>
<td></td>
<td>Parent material</td>
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<td></td>
<td>Rock fragments</td>
<td>1:250,000</td>
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<tr>
<td></td>
<td>Drainage</td>
<td>1:250,000</td>
<td>Sensitivity class</td>
<td>Ministry of Agriculture, European soil database</td>
</tr>
<tr>
<td></td>
<td>Slope angle</td>
<td>1:25,000</td>
<td>%</td>
<td>Ministry of Environment</td>
</tr>
<tr>
<td>Climate quality</td>
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<td>mm</td>
<td>Meteorological statistics</td>
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<td>Aridity index</td>
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<td>Sensitivity class</td>
<td>Corine Land Cover maps</td>
</tr>
<tr>
<td></td>
<td>Erosion protection</td>
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<tr>
<td></td>
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<tr>
<td>Land management</td>
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<td>People km²</td>
<td>Census of Population</td>
</tr>
<tr>
<td></td>
<td>Population growth rate</td>
<td>1:400,000</td>
<td>%</td>
<td>Census of Population</td>
</tr>
<tr>
<td></td>
<td>Agricultural intensity</td>
<td>1:100,000</td>
<td>Sensitivity class</td>
<td>Corine Land Cover maps</td>
</tr>
</tbody>
</table>

Fig. 2. Distribution of the URB trajectory in 1990–2000 (left) and 2000–2012 (right) across Italy.
0 to 1. A tolerance value close to 1 denotes a wide niche and a low degree of specialization. In terms of land use change dynamics, the specialization indicates if the LUC analyzed preferentially occurs in areas with a wide range of the background environmental conditions (i.e. the amplitude/narrowness of the curve of distribution), or if it mainly occurs in areas with a narrow range of the background environmental conditions.

The LUC trajectories distribution on the environmental factors ordination space allows to compute a habitat suitability (HS) index according to the values of any set of environmental variables and thus to draw the HS map. The weights assigned to each factor are computed from the eigenvalues and represent the amount of information explained. HSI scores are on a standard scale between 0 and 1, where 0 indicates unsuitable habitat and 1 indicates optimum conditions and optimum quality and availability of resources. For details see Hirzel et al. (2002) and Calenge and Basille (2008).

For the sake of consistency, all variables were downscaled to a pixel resolution of 1000 m according to the grain of the variables with coarsest resolution (i.e. SQI). Next, for analysing the LA trajectory, the environmental characteristics of all landscape cells that changed from agriculture to natural and semi-natural areas during 1990–2000 and 2000–2012 (used habitat) were compared with the environmental characteristics of all cells that were labeled as agriculture in 1990 and 2000, respectively (background). Likewise, for analysing the URB trajectory, all cells that changed from agriculture into artificial areas during 1990–2000 and 2000–2012 were compared with all cells labeled as agriculture in 1990 and 2000, respectively. For each of the LUC trajectories occurred in 2000–2012, the HS map was also derived and classified into four categories using 0.25 as threshold for the HS index. The classes range from 1 (low suitability) to 4 (high suitability). Class 0 corresponds to areas where no LA or URB trajectory occurred.

ENFA is released in the BIOMAPPER package, freely available at http://www.unil.ch/biomapper/.

5. Results

During 1990–2000 the LA trajectory occupied about 686 km², while URB occurred in about 793 km². Conversely, nearly 2551 km² and 2124 km² respectively experienced LA and URB during 2000–2012. The PCA run on the available data matrix showed that the trajectories of land abandonment and urban expansion act differently according to the initial land quality status of the Italian agricultural areas; however, each trajectory maintains its characteristic behavior through times. In detail, as for the LA trajectories in 1990–2000 and 2000–2012, PCA biplots show that the first two axes explain, respectively, 76.9% and 72.2% (Fig. 3) of the total variance, and that VQI represents the most important indicator in both time periods. In addition, both biplots show that, according to the 95% ellipses, the observations in Southern Italy follow a distinctive statistical distribution compared with observations from both Central and Northern Italy. By contrast, as for the URB trajectories in 1990–2000 and 2000–2012, PCA biplots show that the first two axes explain, respectively, 65.8% and 67.5% (Fig. 4) of the total variance, and that MQI represents the most important indicator in both time periods. According to the 95% ellipses, the observations in northern, central and southern Italy do not follow a distinctive statistical distribution, with the ellipse of southern Italy including the other two districts.

Looking separately at the three geographical macro-regions, the ENFA results confirm that different driving factors are linked to LA and URB, but, for each trajectory, the role of some factors changes through times. The coefficients of all environmental variables on the marginality factors of the two LUC trajectories are shown in Table 2.

In northern and central Italy, during 1990–2000 (Table 2), LA mainly occurred in low quality soils, with respect to the mean LD status of 1990; furthermore, while in northern Italy also the scarce anthropogenic presence affected such LUC trajectory (MQI m = −0.599), in central Italy the bad climate conditions additionally influenced the process of LA (CQI m = −0.609). By contrast, in 2000–2012 (Table 2), with respect to the mean LD status of 2000, low human pressure resulted as the main driving factor in both northern and central Italy, despite the good climate (CQI m = −0.645) and vegetation cover conditions (VQI m = −0.543), respectively. Notably, LA in 1990–2000 in northern Italy had a high global marginality value (M = 0.857), meaning that in those years land abandonment was strongly guided by the environmental quality status and mainly occurred in background conditions largely different from the mean. As for Southern Italy, LA in 1990–2000 resulted mainly driven by the low human impact, while in 2000–2012, also the bad soil quality assumed a major role (SQI m =

![Fig. 3. Ordination biplots based on PCA applied to the environmental quality indicators (1990) of the observations where the LA trajectory occurred (a: 1990 vs 1990–2000; b: 2000 vs 2000–2012). Numbers in brackets are the percentage of variance associated with each PC-axis. The 95% ellipses refer to the observations in North (blue), Centre (red) and South (black) Italy. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)](http://www.unil.ch/biomapper/)
As for URB, human pressure was the main driving factor throughout Italy, both during 1990–2000 and 2000–2012, determining extremely high values of the marginality coefficients. Only in northern Italy, and only during the time period 1990–2000, with respect to the LD status of 1990, LD-prone vegetation cover also influenced the urban expansion over agricultural lands (VQI m = 0.526).

Finally, the HS maps for the LA (Fig. 5) and URB (Fig. 6) trajectories in 2000–2012 show that, as for Northern Italy, the central part of this macro-region, where the largest Italian plain is located (Po valley), presents the largest area of lowest probability of land abandonment and highest probability of urban expansion at the expenses of agricultural lands. As for central and southern Italy, the least LA-prone areas are located along the sea coasts; while the most LA-prone areas are in the inner mountainous zones. By contrast, the URB trajectory does not follow distinctive patterns, but clusters of URB-prone areas are dispersed across plains and valleys of the two macro-regions.

6. Discussion

Assessing territorial disparities in socioeconomic phenomena is a key issue in regional studies and takes advantage of the use of multi-domain frameworks and decision support systems (Salvati et al., 2014a). The working hypothesis of this study is that not only the land use dynamics (as already largely studied) could impact on the land degradation status, but that, backwards, also the current land quality status of a territory may somehow affect its management in terms of land use. It would be a sort of spiral process (i.e. the land use influences land quality, which in turn impacts on land use trajectories, and so on) and in this

<table>
<thead>
<tr>
<th>Marginality coefficients (m)</th>
<th>Land abandonment</th>
<th>Urban expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CQI</td>
<td>0.218</td>
<td>–0.218</td>
</tr>
<tr>
<td>VQI</td>
<td>0.609</td>
<td>0.388</td>
</tr>
<tr>
<td>SQI</td>
<td>0.447</td>
<td>0.24</td>
</tr>
<tr>
<td>MQI</td>
<td>–0.645</td>
<td>–0.4</td>
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<tr>
<td>Global marginality (M)</td>
<td>0.857</td>
<td>0.389</td>
</tr>
<tr>
<td>Tolerance (T)</td>
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<td>0.729</td>
</tr>
<tr>
<td>CQI</td>
<td>–0.087</td>
<td>–0.303</td>
</tr>
<tr>
<td>VQI</td>
<td>–0.445</td>
<td>–0.293</td>
</tr>
<tr>
<td>SQI</td>
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<td>–0.25</td>
</tr>
<tr>
<td>MQI</td>
<td>0.831</td>
<td>0.72</td>
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<tr>
<td>Global marginality</td>
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<td>0.262</td>
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<tr>
<td>Tolerance</td>
<td>0.931</td>
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</table>
study, we want to investigate this aspect, i.e. if the quality level of a territory can affect its land use change trajectories. We performed an exploratory analysis of environmental indicators with the aim of investigating spatial and temporal differences in agricultural land abandonment and urban expansion trajectories in Italy over a period of about 20 years. The results of our study indicate that latitude and LD patterns have determined complex spatial configuration and dynamics of land-use in Italy, and that looking at the LUC trajectories in Italy as a whole hides the intrinsic variability of the three geographic repartitions associated to different dynamics and territorial characteristics, which furthermore evolve through time.

In this sense, PCA run on the environmental conditions of land abandonment shows that in both periods analyzed, vegetation cover quality represents the main component explaining the LA distribution throughout Italy, with a slight difference in the behavior of southern Italy with respect to North and Centre. As for urban expansion, the land management in terms of human pressure plays the main role in describing URB across Italy, both in 1990–2000 and in 2000–2012, without any remarkable differences between the three districts. To the contrary, looking at the three repartitions separately highlighted how the same LUC trajectories vary through time and space, contradicting the PCA results.

In detail, the importance of the variables derived from ENFA clearly showed that the major drivers of agricultural abandonment differed among regions, distinguishing northern, central and southern Italy. ENFA results identify two major causes of agricultural abandonment in Italy: low quality soils and the reduced human pressure, the latter factor being more evident in the time period 2000–2012. According to these evidences, the habitat suitability map of LA in 2000–2012 showed that the abandoned agricultural pixels (LA) resulted preferentially distributed in the inner hilly-mountainous areas of Italy (Fig. 5), mainly characterized by low human presence and low soil quality and where a process of depopulation, typical of mountain districts in Italy, started in the early-1950s (Falcucci et al., 2007). As a consequence, a reduced degree of land protection assured by farmers might lead to negative implications for environmental quality, e.g. triggering hydrogeological risk and soil erosion (Smiraglia et al., 2016).

By contrast, the agricultural urbanization trajectory seems characterized by less spatial and temporal variability with respect to land abandonment, and ENFA results confirm what the PCA highlighted. In detail, the main environmental driver for urban expansion into agriculture resulted mainly linked with high human pressure in all the three geographic repartitions and in both periods analyzed. The habitat suitability map (Fig. 6) shows that the most URB-prone areas are preferentially distributed across the large Po valley in the North, and the Apennine’s embedded flat areas in central and southern Italy; this is probably due to the fact that the urban expansion frequently occurs on well-endowed areas characterized by easy accessibility, infrastructure development, industrialization and tourism concentration (Ferrara et al., 2014). Such results demonstrate that the urbanization process is mainly determined by socioeconomic choices, and that the anthropogenic component, in general, is the sole factor influencing urban expansion in space and time (Wilson et al., 2016).
By comparing the two LUC trajectories, LA and URB, considering the agricultural background, it is interesting to notice that the factors leading to the different final uses are contrasting: low human pressure on the one side, high human pressure, on the other side.

Furthermore, land abandonment resulted as the most complex LUC trajectory, with a much higher spatial and temporal variability than urbanization. This could be explained by the fact that cultivated land abandonment and urban expansion trajectories according to the one side, high human pressure, on the other side.


