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Linking trajectories of land change, land degradation processes and ecosystem services

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ABSTRACT

Land Degradation (LD) is a complex phenomenon resulting in a progressive reduction in the capacity of providing ecosystem services (ES). Landscape transformations promoting an unsustainable use of land often reveal latent processes of LD. An evaluation carried out in respect to the different ecosystem services is nowadays regarded as the most appropriate approach for assessing the effects of LD. The aim of this study is to develop an evaluation framework for identifying the linkages between land changes, LD processes and ES and suggesting Sustainable Land Management (SLM) options suited to reverse (or mitigate) LD impact. A SWOT analysis was carried out with the aim to identify internal and external factors that are favorable (or unfavorable) to achieve the proposed SLM actions. The study areas are the Fortore valley and the Valpadana, in Italy. The main trajectory identified for the Fortore valley is related to land abandonment due to population aging and the progressive emigration started in the 1950s. The most relevant LD processes are soil erosion and geomorphological instability, affecting regulating services such as natural hazard and erosion control. SLM options should consider interventions to contrast geomorphological instability, the promotion of climate smart agriculture and of typical products, and an efficient water resources management. The main trajectories identified for Valpadana are related to urban expansion and farmland abandonment and, as a consequence, land take due to anthropogenic pressure and woodland expansion as the main LD process. The reduction of food production was identified as the most relevant provisioning service affected. SLM should envisage best practices finalized to water saving and soil consumption reduction: efficient irrigation solutions, climate smart agriculture and zero sealing practices. This study highlights the diagnostic value of the suggested approach where LD processes are elicited from land change trajectories determining specific impacts on ES and providing operational support for the implementation of SLM options.

1. Introduction

Land Degradation (LD) is one of the major forms of environmental degradation all over the world. It is a complex process involving multiple causal factors, among which climate variability, soil quality and land management play a significant role (Reynolds and Stafford, 2002). LD is a process which entails a reduction in the capacity of providing ecosystem goods and services by cropland, rangeland, and woodlands: it becomes irreversible when reaching the last stage of desertification. The European Parliament (EC, 2002) identified eight degradation processes to which soils in the EU are confronted with: erosion, organic matter decline, contamination, salinisation, compaction, soil biodiversity loss, sealing, landslides and flooding. More processes related not only to soils but to landscape at large, such as loss of local culture, rural traditions, typical agricultural products and biodiversity, should also be taken into consideration.

Land use and land cover (LULC) changes have been identified as key drivers of global change with major impacts on ecosystems, climate and the human sphere (Foley et al., 2005). Landscape transformations represent the visible result of human interaction with land (Conacher and Sala, 1998). Land changes, intended as land use, population dynamics and ecosystem variations, can be

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analyzed and interpreted in terms of "trajectories" as typified, for instance, by the European Environment Agency (EEA) in the system for "Land and Ecosystem Accounts" (Gómez and Páramo, 2005).

Land changes often reveal latent LD processes, e.g. when associated with unsustainable use of land (Geist and Lambin, 2006; Hill et al., 2008; Schellnhuber et al., 1997). For example, the LD processes which are more directly associated to urban expansion, are land take and soil sealing, often occurring on fertile agricultural areas. In the case of deforestation, the related LD processes involved could be biodiversity loss and carbon stock capacity reduction. A better understanding of land trajectories associated with LD contributes to the assessment of past changes and to run short-term scenario analysis with reliable prediction rules.

As highlighted in the background document for the 2nd UNCCD Scientific Conference, Ecosystem Services (ES) are the base for the assessment of measurable outcomes of LD. An evaluation conducted in respect to the different ES is nowadays regarded as the most appropriate framework for assessing the environmental effects of LD (Helfenstein and Kienast, 2014; Nkonya et al., 2011). A variety of ES have been recognized and classified (MEA, 2005). The relationship between ES, LULC trajectories and ecological setting has been fully investigated with the aim to identify the provision and spatial distribution of ES and to evaluate environmental costs and benefits of different land planning decisions (e.g. De Fries et al., 2004; Feng et al., 2012; Mendoza-Gonzalez et al., 2012; Nahuelhual et al., 2014; Schirpke et al., 2013). Given the difficulty to take into consideration the wide range of ES (supporting, provisioning, regulating and cultural) in a territory, the identification of the main trajectories of land change and related LD processes provides a framework to focus on the key ES affected (Barral and Maceira, 2012).

The aim of this study is to develop an evaluation framework for identifying the linkages between land change, LD processes and ES. The procedure relates the trajectories of land change to LD processes which in turn can affect ES provision, suggesting Sustainable Land Management (SLM) options suited to reverse (or mitigate) LD impact. Despite the importance attributed to land use planning in contrasting unsustainable land cover changes, often ES provision is not taken into consideration (Cowling et al., 2008). The procedure presented in this paper incorporates the analysis of ES in the identification of the most appropriate SLM solutions evaluating changes in LULC, the environmental sensitivity to LD and population dynamics.

The procedure was developed at local scale in two areas in Italy traditionally used for agricultural purposes, which differ substantially in terms of environmental heterogeneity, rural development and land cover dynamics: the Fortore valley in southern Italy and the Valpadana, a portion of the Po plain, in northern Italy. The development of the procedure al local level can help to shed light on important issues and to a better understanding of the local context, priorities and values (Potschin and Haines-Young, 2013), also in relation to ES and sustainability (Turner et al., 2007). While the national scale meets the needs for monitoring and forecasting to support broad management strategies, it is at the regional/local scale that environmental policies and management would be best implemented and applied (Wilson, 2009).

As typically observed in Italy, as well as in other European areas, the period analyzed, of about 50 years, is characterized by the rapid industrialization, urbanization and agricultural intensification of the lowland areas (Antrop, 2000; European Environment Agency, 2006; Lambin and Geist, 2006; Serra et al., 2014) and the abandonment of hilly and mountainous areas (Ferrara et al., 2014; MacDonald et al., 2000) with considerable changes in the local economic structure (Cowell, 2010).

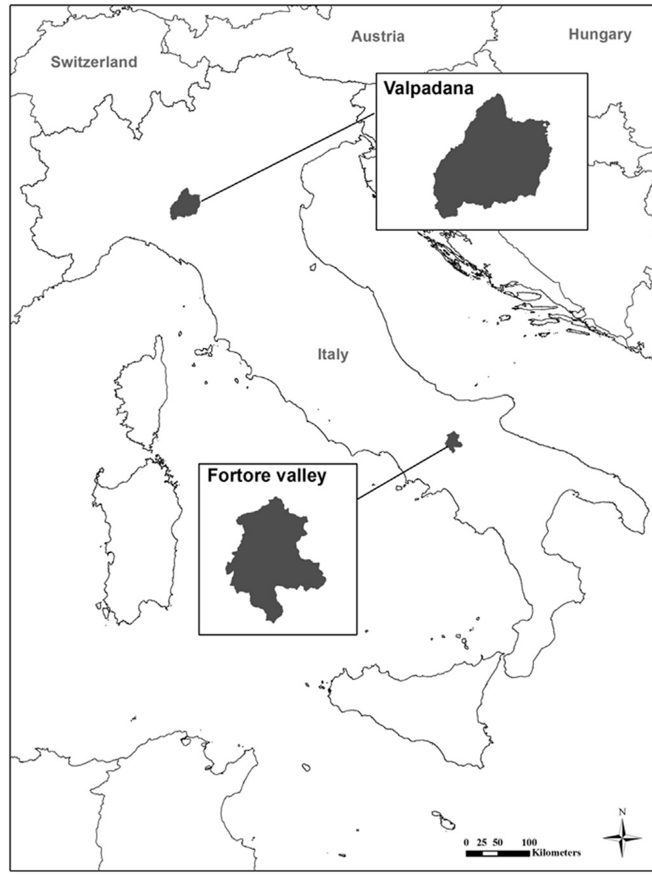

Fig. 1. Location of the study areas (the Valpadana and the Fortore valley).

2. Study areas

2.1. Fortore valley

The Fortore valley is located in southern Italy (Fig. 1), and extends around 472 km^2. The area is mainly mountainous (55%) and hilly (39%), covering between 400 and 900 m above sea level. Being part of the Apennine mountain range of southern Italy, the valley experienced a progressive depopulation in the last decades. The flysch substratum makes the area particularly sensitive to the risk of soil erosion. Nearly 1600 landslides have been surveyed in the study area (http://www.sinanet.isprambiente.it/progettoiffi). Land is primarily used for cropping (82%), especially wheat. Natural and semi-natural areas cover 17% of the study area and the artificial surfaces occupy only 1% of the valley.

2.2. Valpadana

The study area is situated in the provinces of Parma and Piacenza, in the Emilia Romagna region, northern Italy (Fig. 1), covering a surface of around 1423 km^2. The area is mainly characterized by the alluvial plain of the Po River, which is sensitive to both rapid urban expansion and agricultural development. The hilly landscape of the Apennine mountain range represents a part of the study area and is mostly occupied by natural and semi-natural areas. The land cover is dominated by agricultural areas (73%), mainly wheat, but also maize and meadows. The natural and semi-natural areas cover about 18%. Artificial areas, which cover almost 7%, are primarily located in the flat district.

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3. Methods

3.1. Land change trajectories

The procedure to identify the main land change trajectories in the two study areas entails the following steps: (i) LULC change analysis, (ii) evaluation of the environmental sensitivity to LD and (iii) in-depth analysis of population dynamics. The data processed and used are summarized in Table 1.

3.1.1. LULC change analysis

The LULC maps of the Fortore valley were derived from the map generated by the Italian National Research Council and the Italian Touring Club in the early 1960s (nominal scale 1:200,000) and from the map of Corine Land Cover dated 2006 (nominal scale 1:100,000) generated by the European Environment Agency. Regarding the Valpadana study area the LULC maps were derived from the thematic layers produced for the years 1954 and 2008 by the Emilia Romagna Regional Cartographic Service (nominal scale 1:25,000).

In order to make the legends comparable and to harmonize their thematic content, the LULC maps were reclassified into eight categories (artificial surfaces, arable land, permanent crop, meadows and crop mosaic, forests, scrublands, grassland and water bodies). All maps were rasterized with a grid resolution of 50 m. The LULC change analysis were performed using the IDRISI TAIGA® (Eastman, 2009) Land Change Modeler (LCM), comparing the 1954 and 2008 datasets of the Valpadana and the 1960 and 2006 datasets of the Fortore valley.

3.1.2. Environmental sensitivity to land degradation

Taken as one of the most used methodologies to assess sensitivity of land to degradation in the Mediterranean region (Costantini et al., 2009; Santini et al., 2010; Symeonakis et al., 2007), the ESA (Environmentally Sensitive Areas) approach was adopted in the present study. The ESA approach derives a composite index of land sensitivity (ESAI) from the geometric mean of the scores obtained on four quality indicators of climate, soil, vegetation and land management according to Basso et al. (2000). Each thematic indicator score is the geometric mean of the different scores assigned to a number of environmental variables.

The Climate Quality Index (CQI) is computed using the average annual precipitation, the average annual index of aridity and the aspect. The Soil Quality Index (SQI) is obtained combining parent material, soil depth, texture and slope. The Vegetation Quality Index (VQI) is obtained composing four variables: vegetation cover, fire risk, protection offered by vegetation against soil erosion, and degree of resistance to drought shown by vegetation. The management quality index (MQI) takes into account population density, population growth rate and land use intensity.

The final ESAI score ranges from 1 (which corresponds to the lowest land sensitivity to degradation) to 2, the highest sensitivity to degradation. The ESAI score is classified in the following classes of land sensitivity: unaffected by land degradation ($ESAI < 1.225$), fragile areas ($1.225 < ESAI < 1.375$) and critical areas ($ESAI > 1.375$). For a detailed description of the ESA model and variables used see Salvati and Bajocco (2011).

In this study we calculated the percentage of land classified at different sensitivity levels (non-affected, fragile, critical) from 1960 to 2010 in the two study areas. Each thematic map (representing the four quality indicators) and the final ESAI maps were converted to raster layers having a resolution of 1000 m per pixel. We enriched the analysis by considering a change layer of land sensitivity to degradation as calculated in a previous study (Salvati et al., 2014a). This was achieved by computing in each elementary unit the percent score variation in the composite ESA Index (ESAI) over the last fifty years using the formula:

$$[(ESAI_{2010} - ESAI_{1960})/ESAI_{1960}]^{*}100$$

3.1.3. Population dynamics

Resident population data were collected for the years 1951 and 2011, and refer to each of the municipalities of the two study areas. Data were derived from the national census of population and households carried out by the Italian National Institute of Statistics (ISTAT).

3.2. Linking land change trajectories, land degradation processes and ecosystem services

The adopted scheme defines which LD processes are relevant for the trajectories of land change identified in the two study areas, an estimation of the main ES involved and candidate SLM options (Table 2). A SWOT (strengths, weakness, opportunities, and threats) analysis was carried out in order to identify the

Table 1
List of data and variables used in the evaluation framework.

Theme	Data	Variable	Scale	Data source
Fortore valley LULC (1960)	Land use map		1:200,000	Italian National Research Council, Italian Touring Club
Fortore valley LULC (2006)	Corine Land Cover map		1:100,000	European Environment Agency
Valpadana LULC (1954–2008)	Land use maps		1:25,000	Emilia Romagna Regional Cartographic Service
ESAI (1960–2010)	Soil quality	Soil texture	1:250,000	European Soil Database (Joint Research Centre)
		Soil depth	1:250,000	
		Parent material	1:250,000	
		Slope angle	1:25,000	
	Climate quality	Annual mean rainfall rate	1:500,000	Agro-meteorological
		Aridity index	1:500,000	Database (Ministry of Agriculture)
		Aspect	1:25,000	Aster Digital Elevation Model
	Vegetation quality	Fire risk	1:100,000	European Environment Agency
		Erosion protection	1:100,000	
		Drought resistance	1:100,000	
		Vegetation cover	1:100,000	
	Land management	Population density	1:400,000	Italian National Institute of Statistics
		Demographic variation	1:400,000	
		Land use intensity	1:100,000	European Environment Agency
Population data (1951–2011)	National census of population and households	Resident population	1:400,000	Italian National Institute of Statistics

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Table 2
The evaluation framework: from land change trajectories to land degradation processes. Implications for ecosystem services and sustainable land management options.

Land change trajectories	Land degradation processes	Ecosystem services	SLM options
Artificial land expansion	Land take	Provisioning	Mitigation of causes
Farmland abandonment	Soil sealing	Regulating	Adaption
Afforestation	Protracted soil aridity	Cultural	Restoration
Re-naturalization	Soil erosion	Supporting	Compensation
Internal conversions of agricultural land	Organic matter decline		Inaction
Expansion of agriculture	Hydrological instability and flooding		
Others	Soil salinization		
	Soil compaction		
	Point and diffused soil contamination		
	Biodiversity loss		
	Loss of cultural landscapes Others		

internal and external factors that are favorable (or unfavorable) to achieve the proposed SLM actions.

At the same time, the present study incorporates short-term climate scenarios as a key variable in the study of ES loss driven by LD. As a matter of fact, climate change will play a key role in the next future given its influence on land use sustainability, for instance in terms of crop yields and water use efficiency (MEA, 2005; Fraser et al., 2011). We used average values of (minimum and maximum) temperature and precipitation estimated over the period 2021-2050 in the framework of the Italian national project Agroscenari. An increase in both minimum and maximum temperature by 1.5–2 °C is predicted for both study areas (Tomozeiu et al., 2014) and a reduction of total precipitation except for the Po valley which shows an increase in autumn and spring averages (Tomei et al., 2010; Villani et al., 2011). Climate scenarios were considered as important external factors in land change. This is especially true when considering land use planning in contrasting and possibly adjusting to future climate variability.

4. Results

4.1. LULC change analysis

The landscape of the Fortore valley is rather stable (Fig. 2a) with almost 82% of the territory unchanged between 1960 and 2006. The natural areas increased of about 13.8% at the expense of agricultural areas, especially where the slopes are steeper, whereas agricultural areas increased of about 2.7% at the expense of natural areas. Urban expansion was moderate (about 0.6%). The most relevant LULC change between 1954 and 2008 in Valpadana (Fig. 2b) involved agricultural areas which were converted to artificial surfaces (about 5.6%), natural areas (about 5.6%) (through both artificial reforestation and natural processes of forest re-colonization on abandoned meadows and crop mosaic), and to water bodies (about 0.6%).

4.2. Changes in the level of land degradation

From 1960 to 2010 the Fortore valley experienced moderate changes in land sensitivity to land degradation (Fig. 3 and Table 3) remaining relatively stable during the study period: 74.7% of the percent score variation of the ESAI ranges between −5% and 5% (Table 4). The area shows a slight increase of the land classified as

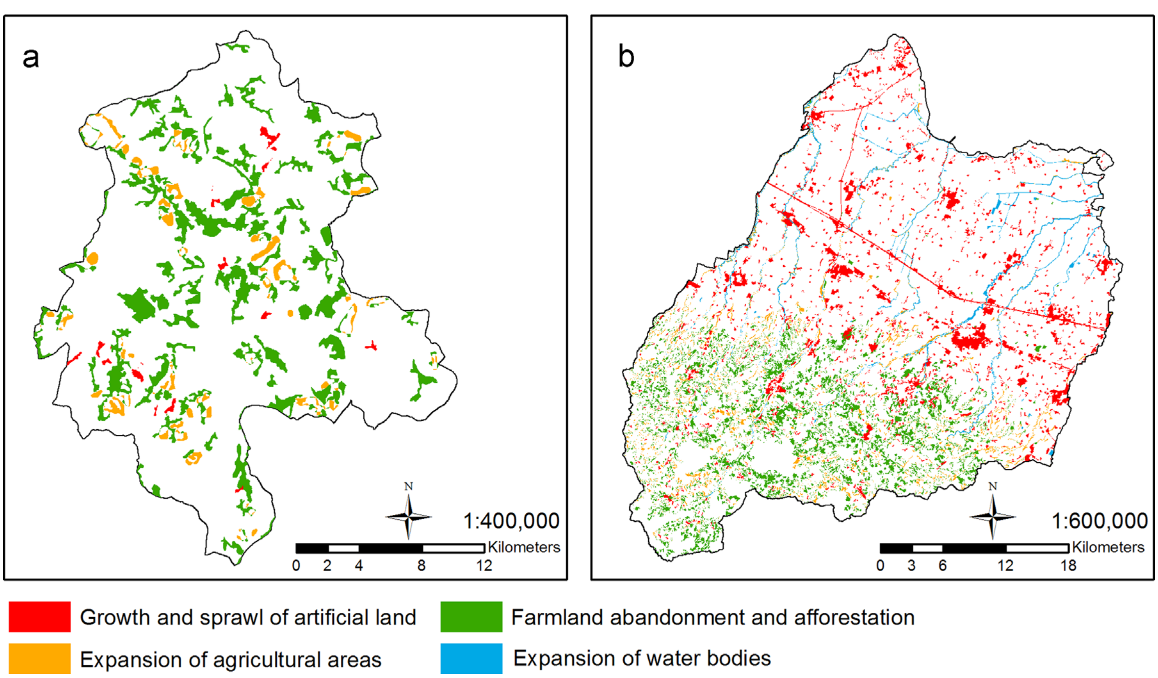

Fig. 2. LULC changes of (a) the Fortore valley (1960–2006) and (b) the Valpadana (1954–2008).

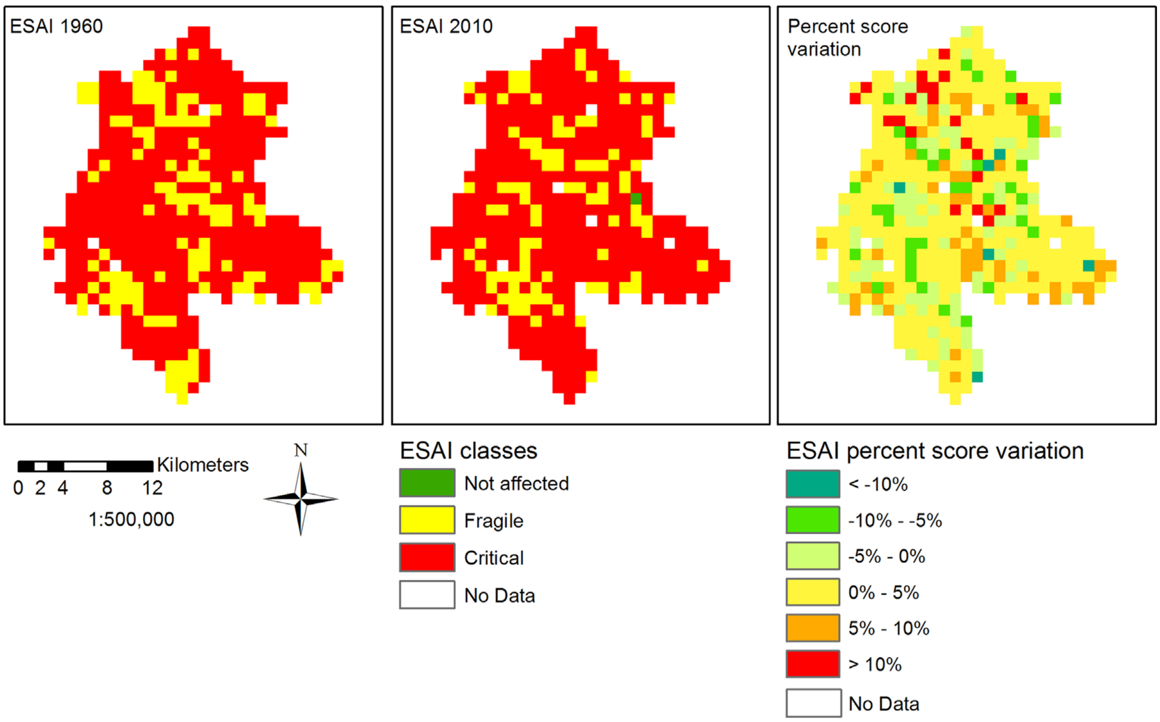

Fig. 3. Classes of sensitivity to degradation of the Fortore valley by year (a: 1960; b: 2010) and (c) the percent score variation.

Table 3
Classification of the study areas (percent surface area) by year based on the ESA classification.

Class	Fortore valley			Valpadana		
	1960	2010	Change (%)	1960	2010	Change (%)
Not affected	0.0	0.2	0.2	1.4	3.4	2.0
Fragile	24.8	19.4	−5.4	72.2	52.1	−20.1
Critical	75.2	80.4	5.2	26.4	44.5	18.1

Table 4
Distribution of changes in land sensitivity to degradation (assessed through the ESAI) in the study areas between 1960 and 2010.

Percent score variation (%)	Fortore valley	Valpadana
< −10	1.3	2.8
−10–5	8.0	4.0
−5 to 0	16.2	22.7
0–5	58.5	30.2
5–10	11.4	24.6
> 10	4.5	15.8

highly sensitive to degradation; it also has the largest surface land classified as “critical” in both time periods (Table 3).

The Valpadana shows the highest increase in land sensitivity (18.1%) as illustrated in Table 3 and a marked percent score variation in the ESAI (Table 4). The Valpadana is becoming increasingly sensitive to land degradation and a slight increase was also observed for the ‘non-affected’ class (Table 3), concentrated in the hilly-mountainous areas (Fig. 4).

4.3. Population dynamics

In the Fortore valley the resident population decreased in all municipalities with the overall density declining from 82 to 51 inhabitants/km^2 between 1951 and 2011 (Fig. 5). This is consistent with the depopulation process of Apennine marginal lands after World War II (Barbati et al., 2013; Falcucci et al., 2007; Smiraglia et al., 2007). Land abandonment and out-migration determine isolation of local communities and marginalization of rural populations, contributing to population aging and to a loss of knowledge and traditions related to land management.

The Valpadana shows a slight decrease in the population density (from 112 to 108 inhabitants/km^2) between 1951 and 2011. The population density at the municipal scale shows a more complex dynamic: a decrease in the hilly-mountainous zone and an increase in the municipalities located on flat areas (Fig. 6). Population increase takes the form of a compact and dense urban expansion around the main urban centers (Parma and Piacenza) and of a more dispersed urbanization along transport axes and in more remote districts (Fig. 2b) (Salvati et al., 2013; Smiraglia et al., 2015).

4.4. The output of the evaluation framework

Based on the results of the land change analysis (LULC changes, land sensitivity to degradation and population dynamics), the evaluation framework allowed to identify and interpret the main trajectories of change occurred in the two areas. It also made clearer the LD processes involved and, in turn, the main ES affected.

4.4.1. Fortore valley

The population dynamics show a depopulation process due to emigration which started in the early-1950s (Bonamici et al., 2012, 2013). Despite this process the landscape of the Fortore valley seems quite persistent in terms of changes in LULC and level of LD: some of the possible reasons are discussed hereinafter.

The depopulation process has been accompanied by changes in traditional demographic and social structures, as observed in other studies in southern Italy (Salvati, 2012; Forino et al., 2015). The consequences in terms of land tenure and farming systems have been the fragmentation of the large farm holdings and the downfall of family-run farms. However this did not lead to major

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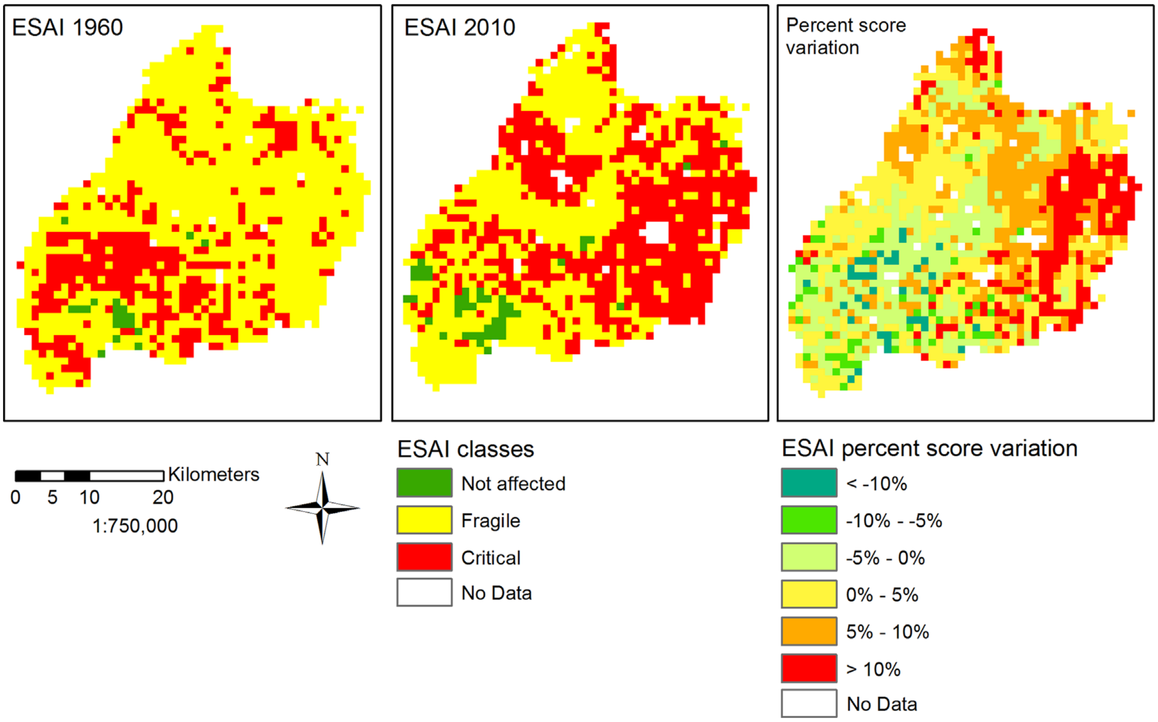

Fig. 4. Classes of sensitivity to degradation of the Valpadana by year (a: 1960; b: 2010) and (c) the percent score variation.

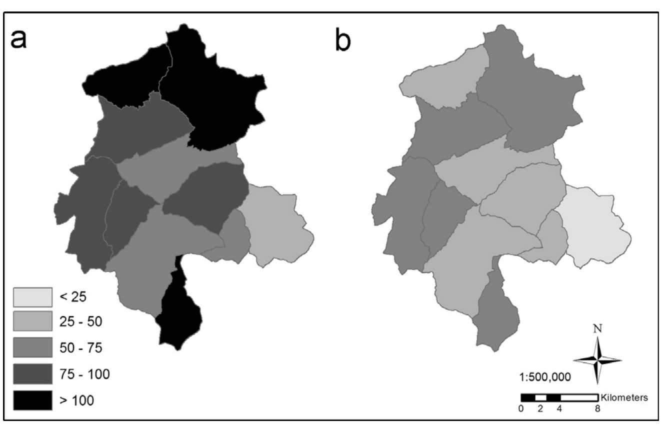

Fig. 5. The spatial distribution of population density (inhabitants/km^2) at the municipal scale in the Fortore valley (a: 1951; b: 2011).

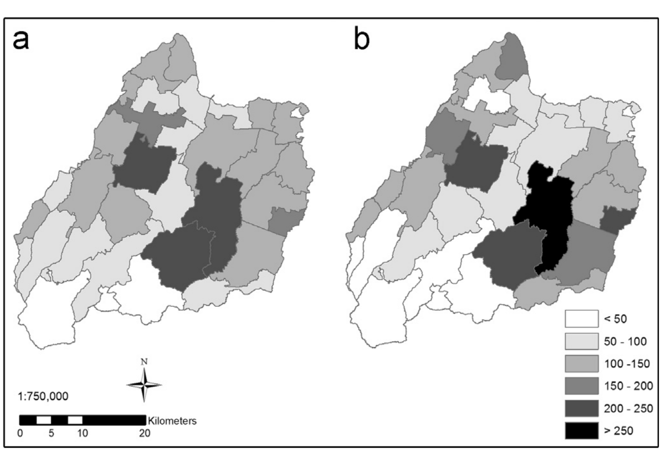

Fig. 6. The spatial distribution of population density (inhabitants/km^2) at the municipal scale in the Valpadana (a: 1951; b: 2011).

land cover changes, but rather to land abandonment which is indeed the main trajectory identified in the Fortore valley (Table 5). Land abandonment leads to more "loose" forms of land management practices. This can enhance the level of hydrogeological risk in a territory which is already prone to landsliding (Lesschen et al., 2008; Rey Benayas et al., 2007). Land abandonment often exposes soils to erosion, especially on steep terrain, undermining the long-term availability of land resources (Lestrelin and Giordano, 2007; Piccaretta et al., 2006; Pinto Correia, 1993).

Due to both land abandonment and a high risk of landslides, the most relevant LD processes involved are soil erosion and geomorphological instability, affecting regulating services such as natural hazard and erosion regulation (Table 5). In a previous study Buondonno et al. (1993) estimated the degree of soil erosion in the study area through the USLE (Universal Soil Loss Equation) model (Wischmeier and Smith, 1978). The results showed that 42% of the area is affected by high soil erosion (52–156 t/ha/year), 31% by very high soil erosion (229 t/ha/year) and 14% by severe soil erosion (437 t/ha/year).

4.4.2. *Valpadana*

The main trajectories identified in the area relate to urban expansion and to the abandonment of farmland (Table 6 and Fig. 2b). In terms of LD, the former trajectory is associated to soil sealing, a key degradation process in Europe as well as elsewhere in the world (Eckelmann et al., 2006; EC, 2012). This has several negative effects as far as ES are concerned including provisioning services, i.e. the capacity to generate agricultural products for human consumption, other non-food uses (fuel, fiber, etc.) and/or livestock feeding. From this perspective there is a negative effect of soil sealing in terms of reduction of the agricultural production capacity.

The latter trajectory leads to different impacts on ES, which are often controversial in their combined effect. On the one hand, land abandonment resulting in woodland creation produces positive effects in terms of ES such as biodiversity, carbon stock, water and soil regulation. However, woodland creation on agricultural

Table 5
The evaluation framework of the Fortore valley.

Land change trajectories	Land degradation processes	Ecosystem services	SLM options
Land abandonment	Soil erosion Geomorphological instability	Regulating: –*Natural hazard* –*Erosion regulating*	Contrast geomorphological instability Halt land abandonment Promotion of typical products Promotion of climate smart agriculture Efficient water resources management Dissemination actions

abandoned lands also entails a reduction (due to land take) in the production capacity of an area. In the study area woodland creation takes place on former agricultural soils determining a loss of agricultural production capacity.

To assess the effect of soil sealing and woodland expansion (solely in terms of provisioning services) on the capacity of the territory to produce food (for human consumption or livestock feeding) we followed the method proposed by Gardi et al. (2014) which assesses the loss of winter wheat production as a proxy for Potential Agricultural Production Capability (PAPC). The loss of PAPC (PAPC_LOSSES, in tons) is calculated taking into consideration the land take of agricultural areas for a given period (ALT, in ha) and the Average Winter Wheat Yields (AWWY) for that area (t/ha):

$$PAPC\_LOSSES = ALT * AWWY$$

Based on the results of the LULC change analysis performed in this study, the sealed area and the expansion of natural (woodland) areas over agricultural areas amount to about 8000 ha each. The AWWY in the Emilia Romagna region (where the Valpadana is located) was estimated at 68.5 t/ha in the plain and 44.9 in the hills and mountains (Gardi and Dall'Olio, 2012), where the two processes of soil sealing and woodland creation occurred. The loss of PAPC for the period 1954–2008 was calculated at about 900,000 t of wheat (Table 7).

5. Discussion

The sustainable use of land resources is a key element for minimizing LD and ensuring long-term environmental functions for the optimal delivery of goods and services meeting human needs.

The present study provides an evaluation framework which relates environmental and social land changes to LD processes and the provision of ES. The identification of the main trajectories of land change and the considerable LD processes allow to focus on the key ES affected and to develop appropriate SLM policies. The focus on the main changes and effects is a support for addressing specific policies, especially at the regional and local levels. This contributes to contextualize problems and solutions (Forino et al., 2015; Kelly et al., 2015; Wilson et al., 2015).

The results shed light on landscape transformations observed in two rural areas in Italy over a period of about 50 years, after the end of World War II. In the two areas land changes were driven by distinctive processes, and characterized by specific trajectories.

Table 7
Losses of PAPC in Valpadana between 1954 and 2008.

	ha	Average winter wheat yields (t/ha)	Yield loss (t)
Soil sealing	8001	68.5	548,069
Woodland creation	7979	44.9	358,257
Total	15,980		906,326

Among these, abandonment of the traditional agricultural mosaic in the hilly-mountainous areas, and urban expansion (both compact and dispersed) in flat areas, are the most representative ones.

The outcomes of the land change analysis are one of the inputs in a SWOT analysis addressing policy issues as well as specific SLM actions to be implemented.

5.1. Fortore valley

As shown in the SWOT analysis (Table 8) the Fortore valley has a high agricultural potential. This is due for instance to local cultivars of wheat which are highly productive as well as cultivars enjoying a wide range of hydrological and thermal flexibility, more adaptable in the perspective of climate changes. Furthermore, given the known capacity of natural land and resources to provide provisioning, regulating and cultural services (Nahuelhual et al., 2014; Paletto et al., 2015; Vanacker et al., 2014), the presence of natural areas and cultural landscapes in the Fortore valley is an important strength of the territory.

The main weaknesses are land abandonment and geomorphological instability, together with depopulation and aging. The reduced degree of land protection assured by farmers' activities is a negative element for land stability and soil conservation (MacDonald et al., 2000; Perini et al. 2014). Efforts to provide farmers with new skills and technologies about innovative and sustainable methods of cultivation or other activities in the rural areas are insufficient. This is also due to an aging population which has a limited adaptive capacity to changes (Adger, 2000; Wilson et al., 2015).

Agricultural reorganization and the promotion of wheat cultivars adaptable to climate change could represent an opportunity to develop new markets and a mean to protect local agro-biodiversity. A good management of natural and agricultural areas is important for reducing the loss of ES and the decline of natural and cultural landscapes. The protection of such landscapes is also important for the development of tourism and the promotion of

Table 6
The evaluation framework of the Valpadana.

Land change trajectories	Land degradation processes	Ecosystem services	SLM options
Farmland abandonment Urban expansion	Land take Soil sealing	Provisioning: –*Food production: loss of agricultural yield*	Soil consumption reduction Efficient irrigation systems Less water demanding crops Sustainable mechanization Landscape conservation

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Table 8
The SWOT analysis of the Fortore valley.

Internal	Positive	Negative
	Strengths	Weakness
	Agricultural potential	Land abandonment
	Environmental flexibility of local wheat cultivars	Geomorphological instability Depopulation and ageing population
	High value of natural and cultural landscapes	Lack of farmers "refresher" trainings
External	Opportunities	Threats
	Future temperature increase compatible with some local cultivars	Temperature increase Precipitation decrease
	Agricultural reorganization and modernization	Increase of water demand
	Development of markets	Loss of agricultural productivity
	Development of new tourism and related products	

local products as a source of income and for increasing the economic viability of marginalized agricultural areas (Briedenhann and Wickens, 2004; Sharpley, 2002).

The main threats are represented by climate change (increase in temperature and decrease in precipitations) and namely the consequences in terms of increase of water demand as well as loss of agricultural productivity.

The possible SLM options (Table 5) should take into consideration a set of best practices aimed at halting land abandonment through climate-smart agriculture, the strengthening of farming communities as custodians of agro-biodiversity and land protection, and the promotion of typical products and agricultural diversity, in order to increase the wealth of local communities. In fact, it has been acknowledged that the SLM of traditional agriculture has a positive impact on environmental resources in terms of low-input requirements, climate change mitigation, biodiversity preservation and ES provision (Abbona et al., 2007; Antrop, 2005; Halada et al., 2011).

Water savings will be guaranteed by the use of cropping systems better adapted to climate change and by careful management of water resources (i.e. more efficient irrigation systems, storage of rainwater). The candidate SLM strategy should includes not only actions to prevent abandonment but also actions to manage abandoned land, e.g. measures to safeguard land stability and to contrast soil erosion. An environmental awareness campaign through dissemination actions and involvement of local population, farmers and local authorities should be realized. Financial support to the farmers wishing to renew or introduce technologies related to sustainable methods of cultivation should be envisaged.

The revaluing of sustainable environmental management practices and traditional skills and knowledge can be fundamental in the preservation of land, reducing environmental risks and maintaining natural resources, local identities and heritage (Pinto Correia, 1993; MacDonald et al., 2000; Kelly et al., 2015). Overall, the territory of the Fortore Valley needs maintenance.

5.2. Valpadana

Table 9 shows the results of the SWOT analysis. Climate change scenarios (Tomei et al., 2010; Villani et al., 2011) suggest that water demand should not increase drastically in the Valpadana district. This is due to increased precipitation in spring and autumn that could mitigate the impact of the parallel increase in temperature and evapotranspiration during summer. This condition would allow maintaining the current level of productivity with little need for adaptation to changes while supporting the quality of local products.

The main weaknesses are urban growth (both compact and dispersed) and land abandonment (in the hilly districts). These processes, especially in the case of soils which are structurally prone to compaction, have a negative effect on soil degradation. Furthermore, the concentration of precipitations in spring and autumn and the possible occurrence of intense rains could affect soil erosion and, together with land take, could cause negative effects on the overall agricultural productivity.

The possible SLM options (Table 6) should consider best practices finalized to soil consumption reduction. For example this can be achieved by promoting the use of "brownfields" (EC, 2012; Shadler et al., 2011, 2012). This is especially relevant considering that urbanization processes, and namely the sprawling expansion, frequently occurs on the most fertile soils (Ceccarelli et al., 2014) impacting on the agricultural production capacity of a territory. More efficient irrigation systems and the introduction of less water demanding crops should be envisaged in the perspective of climate changes. The quality of soils should be safeguarded by forms of sustainable mechanization in order to prevent soil compaction.

Furthermore, land use policies for hilly areas should be addressed toward landscape conservation. The abandonment of traditional cropping systems typical of the Apennine district has negative implications for land stability and soil conservation (Perini et al., 2014). By contrast, farmers' activities related to agroforest systems ensure land protection on the same hilly areas.

5.3. A summary: common and different traits of the two sites

Fig. 7 attempts to compare the two study areas from the perspective of trajectories, LD processes, ES and relevant SML options.

While the trajectories of land abandonment and depopulation apply to both areas (although with reference to the sole hilly districts in the Valpadana site), urban expansion is specific to lowlands of the Valpadana area. Although soil erosion and

Table 9
The SWOT analysis of the Valpadana.

	Positive	Negative
Internal	Strengths	Weakness
	High productivity of the animal husbandry sector	Urban expansion in the lowlands
	Presence of products certified as Protected Designation of Origin (PDO)	Agricultural abandonment in the hills and mountains
	Ability to adapt the crop irrigation systems in the perspective of climate change	Soils sensibility to compaction
	Ability to maintain the level of productivity in the perspective of climate change	
External	Opportunities	Threats
	Development of low-impact technologies to reduce energy input and soil degradation (e.g. soil compaction)	Precipitation concentration during spring and autumn
	Limited effect of climate changes on water demand	Decrease of agricultural productivity due to growing water demand and land take

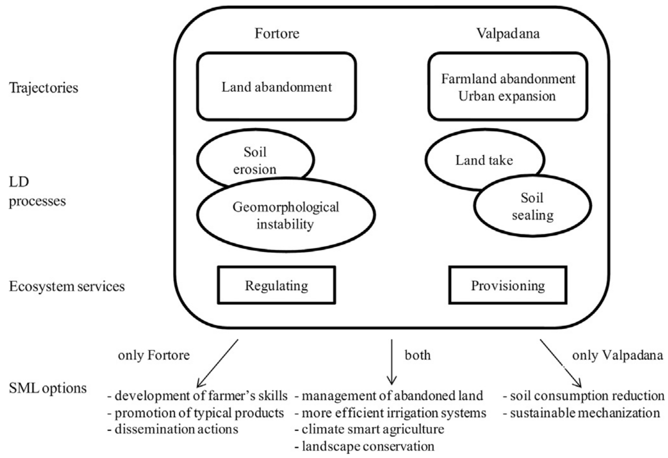

Fig.7. The main highlights of the Fortore valley and the Valpadana: common and different traits.

geomorphological instability are LD processes which are common to the two areas, the effects in the Fortore valley in terms of the respective regulating services are clearly recognized. One the other hand the Valpadana area is affected by land take and soil sealing, with a remarkable impact in terms of provisioning services (and namely in the sense of reduction of agricultural productivity, both in quantitative and qualitative terms).

The SWOT analysis for the two areas contributes to further evaluate internal strengths and opportunities. This is especially important when searching for possible SLM options in face of climate change and other global trends. When considering internal strengths, it appears evident that while natural and cultural landscapes are a specific asset of the Fortore valley, the agricultural potential as well as the ability to maintain and adapt current levels of productivity in face of climate change are common trait of the two areas. This translates into similar opportunities such as the development of forms of climate smart agriculture to reduce water consumption, energy input, and soil degradation.

SLM actions can be thought of which are applicable for the two areas (e.g. management of abandoned land, more efficient irrigation systems, landscape conservation) but may also diverge depending on their peculiarities. In the case of the Valpadana the emphasis is on soil consumption reduction and sustainable mechanization, while in the Fortore Valley it is on strengthening the traditional agricultural practices at large and on promoting a territorial branding made of typical products and new forms of related tourism.

6. Conclusions

Since World War II, the decline of cultivation and agro-forest practices in the more marginal, often hilly and mountainous areas and the intensive exploitation of the more accessible regions have had a strong impact on environmental and socioeconomic transformations of Italian landscapes. Problems related to the unsustainable use of land resources, rural–urban migration, farm marginalization and regional disparities contributed to a progressive degradation of land (Pinto Correia, 1993; Iosifides and Politidis, 2005; Salvati et al., 2014b). The lack of development perspectives and SLM policies triggered more intense LD processes.

Also the Annex IV of the UNCCD highlights critical conditions occurring in the northern Mediterranean region. This is the case of traditional agricultural systems with associated land abandonment and deterioration of soil and water conservation structures. With the "Zero Net Land Degradation" (ZNLD) strategy, the UNCCD promotes the rehabilitation of degraded land as a means of adaptation to climate change. In this perspective, national and local governments should plan strategies, development policies and context-specific policy designs that can be sustainable in the long term.

The thorough understanding of these intricate processes requires an in-depth investigation of the underlying factors by integrating quantitative methodologies and narrative approaches. The estimation of ES provision under changing landscapes can support strategies for a sustainable use of land resources, effective protection of the natural environment and development of marginal areas. In this view, it seems necessary to evaluate the land use efficiency of a given location. This implies the identification of the main changes occurred, the most relevant ES affected, the relationship with living organisms and the impacts that may arise as a result of unsustainable land uses.

The present study suggests a diagnostic approach where LD processes are elicited from land change trajectories and linked to specific losses in terms of ES. The approach can be linked to the assessment of specific ES and finally helps identifying SLM options. The local scale adopted provides the context in which problems can be recognized and appropriate choices can be made. The two study areas are example of changes occurred in hilly-mountainous and flat areas driven by processes widely studied in Europe as well as elsewhere in the world (Geist and Lambin, 2006; EC 2012). Although results cannot be generalized given the uniqueness of the test areas selected, the procedure can be easily applied to other contexts.

Finally, the approach represents a basis for the evaluation of ES in turn addressing the quest for the identification of measurable outcomes of LD as pointed out by the UNCCD, among others.

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