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A socioeconomic profile of vulnerable land to desertification in Italy

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HIGHLIGHTS

- Based on indicators, a socioeconomic profile of vulnerable land to desertification was developed for Italy.
- Four groups of indicators discriminating between vulnerable and non-vulnerable areas were identified.
- A contrasting profile was found for vulnerable lands in northern and southern Italy with policy implications.
- Results pointed out the changing geography of vulnerable land and socioeconomic contexts at the local scale.

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ABSTRACT

Climate changes, soil vulnerability, loss in biodiversity, and growing human pressure are threatening Mediterranean-type ecosystems which are increasingly considered as a desertification hotspot. In this region, land vulnerability to desertification strongly depends on the interplay between natural and anthropogenic factors. The present study proposes a multivariate exploratory analysis of the relationship between the spatial distribution of land vulnerability to desertification and the socioeconomic contexts found in three geographical divisions of Italy (north, center and south) based on statistical indicators. A total of 111 indicators describing different themes (demography, human settlements, labor market and human capital, rural development, income and wealth) were used to discriminate vulnerable from non-vulnerable areas. The resulting socioeconomic profile of vulnerable areas in northern and southern Italy diverged significantly, the importance of demographic and economic indicators being higher in southern Italy than in northern Italy. On the contrary, human settlement indicators were found more important to discriminate vulnerable and non-vulnerable areas in northern Italy, suggesting a role for peri-urbanization in shaping the future vulnerable areas. An in-depth knowledge of the socioeconomic characteristics of vulnerable land may contribute to scenarios' modeling and the development of more effective policies to combat desertification.

1. Introduction

Accelerated ecosystem transformations at the global scale have been identified as one of the major environmental problems in the last century (Millennium Ecosystem Assessment, 2005). Severe land degradation processes, possibly leading to irreversible phenomena of desertification, are impacting developed regions and emerging economies where climate aridity, poor soil quality, and restricted vegetation cover are constraints to agricultural production, natural vegetation, and human well-beings (Mouat and Hutchinson, 1996; Middleton and Thomas, 1997; Conacher and Sala, 1998; Geist, 2005) raising increasing concern at the continental and country level (Steffen, 2004). Desertification, however, cannot be convincingly explained as a phenomenon depending on changes in biophysical factors only, since it rarely occurs without human activities influenced by global, regional, and local socioeconomic drivers (Safriel and Adeel, 2008).

The concept of 'desertification' has experienced a constant evolution since the 1980s (Gisladottir and Stocking, 2005). This concept has led through a transition towards definitions centered on the interaction between human factors and the ecosystem, to achieve a focus that embraces all phenomena of "land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities", as clearly stated by United Nations Convention to Combat Drought and Desertification (UNCCD).

Land vulnerability to desertification depends on the interplay between natural (e.g. climate aridity, drought, soil degradation, poor vegetation cover) and human-derived factors (e.g. overgrazing, forest fires, landscape fragmentation, soil pollution, urbanization). The role of anthropogenic factors as key drivers of land degradation has been increasingly studied depending on the natural resource endowments (Wilson and Juntti, 2005). Underdevelopment, rural poverty and increasing human pressure in ecologically fragile areas have been hypothesized to be decisive to exacerbate the environmental conditions

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Table 1
The list of socioeconomic indicators used in the present study.

Acronym	Name	Dimension	Source	Year
Demography and territorial characteristics				
I1	% urban areas	Human settlements	Corine Land Cover	2000
I2	% dispersed urban settlements on total urban areas	Human settlements	Corine Land Cover	2000
I3	% population residing in compact urban centers	Human settlements	Census of population	2001
I4	Total municipality footprint (km^{-2})	Human settlements	Censuses of population, agriculture and industry	2001
I5	% non-occupied houses	Human settlements	Census of population	2001
I6	Average house size (m^2) per inhabitant	Human settlements	Census of population	2001
P1	Average family size	Population structure	Census of population	2001
P2	Population > 80 years/births	Population structure	Census of population, population register	2001
P3	% population > 75 years	Population structure	Census of population	2001
P4	Elderly index	Population structure	Census of population	2001
P5	Dependency ratio	Population structure	Census of population	2001
P6	Number of resident foreign people per 100 inhabitants	Population structure	Census of population	2001
P7	Masculinity ratio	Population structure	Census of population	2001
Labor and human capital				
L1	Activity rate	Job market	Census of population	2001
L2	Occupancy rate	Job market	Census of population	2001
L3	Unemployment rate	Job market	Census of population	2001
L4	Unemployment rate of young people (<35 years)	Job market	Census of population	2001
L5	Female activity rate	Job market	Census of population	2001
L6	Female occupancy rate	Job market	Census of population	2001
L7	Female unemployment rate	Job market	Census of population	2001
L8	Unemployment rate of young women (<35 years)	Job market	Census of population	2001
L9	% employees on total workers	Job market	Census of Industry and Services	2001
L10	% women workers on total workers	Job market	Census of Industry and Services	2001
L11	% consultants on total workers	Job market	Census of Industry and Services	2001
L12	% temporary workers on total workers	Job market	Census of Industry and Services	2001
L13	% voluntaries on total workers	Job market	Census of Industry and Services	2001
L14	% temporary workers on consultants	Job market	Census of Industry and Services	2001
F1	% population with tertiary education	Educational level	Census of population	2001
F2	% population graduated in high-school	Educational level	Census of population	2001
F3	% population with secondary education	Educational level	Census of population	2001
F4	% population with primary education	Educational level	Census of population	2001
F5	% literate population without formal education degree	Educational level	Census of population	2001
F6	% illiterate population	Educational level	Census of population	2001
Economic specialization and competitiveness				
S1	Average number of workers per industrial local unit	Productive structure	Census of Industry and Services	2001
S2	Density of workers per municipality surface area (km^2)	Productive structure	Census of Industry and Services	2001
S3	% workers in the agricultural and forestry sectors	Productive structure	Census of Industry and Services	2001
S4	% workers in fishing and complementary activities	Productive structure	Census of Industry and Services	2001
S5	% workers in mining industry	Productive structure	Census of Industry and Services	2001
S6	% workers in manufacturing industry	Productive structure	Census of Industry and Services	2001
S7	% workers in energy production and distribution industry	Productive structure	Census of Industry and Services	2001
S8	% workers in construction industry	Productive structure	Census of Industry and Services	2001
S9	% workers in commerce sector	Productive structure	Census of Industry and Services	2001
S10	% workers in hotel and restaurant services	Productive structure	Census of Industry and Services	2001
S11	% workers in transportation and logistics services	Productive structure	Census of Industry and Services	2001
S12	% workers in financial, insurance and banking services	Productive structure	Census of Industry and Services	2001
S13	% workers in informatic jobs, renting and real estate services	Productive structure	Census of Industry and Services	2001
S14	% workers in the public sector	Productive structure	Census of Industry and Services	2001
S15	% workers in education services	Productive structure	Census of Industry and Services	2001
S16	% workers in health sector	Productive structure	Census of Industry and Services	2001
S17	% workers in other social services	Productive structure	Census of Industry and Services	2001
T1	Number of beds in hotels and campings/resident population	Tourism specialization	Census of Industry and Services	2001
T2	Average number of beds per hotel	Tourism specialization	Census of Industry and Services	2001
T3	Hotel occupancy level (five-years average)	Tourism specialization	ISTAT (2006)	2001
T4	Camping occupancy level (five-years average)	Tourism specialization	ISTAT (2006)	2001
T5	Agri-tourism occupancy level (five-years average)	Tourism specialization	ISTAT (2006)	2001
T6	Number of beds in agri-tourism accomodation/beds in hotel	Tourism specialization	ISTAT (2006)	2001
T7	Resident population/total number of stores	Tourism specialization	ISTAT (2006)	2000
Quality of life				
Q1	% subscriptions on state radio-television channels	Living standards	Banca d'Italia and Istituto Tagliacarne	1999
Q2	Number of cars/inhabitants	Living standards	Banca d'Italia and Istituto Tagliacarne	1999
Q3	Number of deposits/banks	Living standards	Banca d'Italia and Istituto Tagliacarne	1999
Q4	Number of deposits/inhabitants	Living standards	Banca d'Italia and Istituto Tagliacarne	1999
Q5	Value of bank deposits/banks (euros)	Living standards	Banca d'Italia and Istituto Tagliacarne	1999
Q6	Average value of bank deposits (euros)	Living standards	Banca d'Italia and Istituto Tagliacarne	1999
Q7	Value of bank deposits/inhabitants (euros)	Living standards	Banca d'Italia and Istituto Tagliacarne	1999
Q8	Per capita income tax amount (euros)	Living standards	Istituto Tagliacarne	1998
Q9	Per capita real estate tax amount (euros)	Living standards	Istituto Tagliacarne	1998
Q10	Per capita municipal solid waste tax amount (euros)	Living standards	Istituto Tagliacarne	1998
Q11	Disposable income (euros)/inhabitants	Living standards	Istituto Tagliacarne	2000
Q12	Consumption (euros)/inhabitants	Living standards	Istituto Tagliacarne	2000

Table 1 (*continued*)

Acronym	Name	Dimension	Source	Year
Quality of life				
Q13	Total value added per municipality (euros)	Living standards	CENSIS	2003
D1	Crime intensity index	Crime and society	ISTAT (2006)	2000
D2	Crime severity index	Crime and society	ISTAT (2006)	2000
D3	Number of crimes per 1000 inhabitants	Crime and society	ISTAT (2006)	2000
D4	Work accidents per 100 inhabitants	Crime and society	ISTAT (2006)	2002
Rural development and water management				
SR-A1	Rented agricultural surface area/total agricultural surface area	Land tenure	Census of agriculture	2000
SR-A2	% agricultural land owned by the state	Land tenure	Census of agriculture	2000
SR-A3	Average farm size (hectares)	Land tenure	Census of agriculture	2000
SR-A4	Total agricultural land/total municipal surface area (%)	Land tenure	Census of agriculture	2000
SR-A5	Agricultural utilized area/total agricultural land (%)	Land tenure	Census of agriculture	2000
SR-P1	% agricultural utilized area under environmental protection	Landscape	Census of agriculture	2000
SR-P2	Arable land/agricultural utilized area (%)	Landscape	Census of agriculture	2000
SR-P3	Perennial crop/agricultural utilized area (%)	Landscape	Census of agriculture	2000
SR-P4	Pastures and meadows/agricultural utilized area (%)	Landscape	Census of agriculture	2000
SR-P5	Farm size diversity (Shannon index)	Landscape	Census of agriculture	2000
SR-P6	% woodland surface area in total farm surface	Landscape	Census of agriculture	2000
SR-P7	% change in agricultural utilized area (1990–2000)	Landscape	Census of agriculture	2000
SR-P8	Agricultural landscape diversity (Shannon index)	Landscape	Census of agriculture	2000
SR-M1	Number of agricultural machines per farm	Production intensity	Census of agriculture	2000
SR-M2	Irrigated land/total agricultural utilized area (%)	Production intensity	Census of agriculture	2000
SR-M3	Agricultural utilized area per worker in agriculture	Production intensity	Census of agriculture	2000
SR-M4	Agricultural intensity index	Production intensity	Census of agriculture	2000
SR-Q1	Agricultural utilized area under organic farming (%)	Quality and innovation	Census of agriculture	2000
SR-Q2	Area cultivated with DOC designation of origin grapevines (%)	Quality and innovation	Census of agriculture	2000
SR-Q3	Area cultivated with DOCG designation of origin grapevines (%)	Quality and innovation	Census of agriculture	2000
SR-Q4	Livestock organic farms/total farms (%)	Quality and innovation	Census of agriculture	2000
SR-Q5	Agricultural utilized area under good agronomic practices (%)	Quality and innovation	Census of agriculture	2000
SR-Q6	Agricultural utilized area under sustainability certification (%)	Quality and innovation	Census of agriculture	2000
SR-Q7	Number of cattle/agricultural utilized area	Quality and innovation	Census of agriculture	2000
SR-Q8	Agricultural utilized area applying sustainable irrigation (%)	Quality and innovation	Census of agriculture	2000
SR-Q9	Index of economic marginalization of farms	Quality and innovation	Census of agriculture	2000
SR-L1	% employees in the primary sector	Human capital	Census of agriculture	2000
SR-L2	% farmholders > 55 years	Human capital	Census of agriculture	2000
SR-L3	% farmholders on total workers in the primary sectors	Human capital	Census of agriculture	2000
SR-L4	% farmholders with technical (agronomy) education	Human capital	Census of agriculture	2000
SR-L5	Farmholder's activity diversification index	Human capital	Census of agriculture	2000
A1	Per capita distributed water	Water management	Census of water resources	1999
A2	Water dispersion index	Water management	Census of water resources	1999
A3	Consumed water/inhabitants	Water management	Census of water resources	1999
A4	Proportion of water distributed to civil uses	Water management	Census of water resources	1999
A5	Number of reservoirs/100 inhabitants	Water management	Census of water resources	1999
A6	Reservoir capacity/100 inhabitants	Water management	Census of water resources	1999

possibly leading to desertification (Blaikie and Brookfield, 2000; Boyce, 1994; Barbier, 2000; Reynolds and Stafford-Smith, 2002; Boardman et al., 2003; Iosifides and Politidis, 2005; Romm, 2011).

Mediterranean-type ecosystems are regarded as a desertification hotspot due to climate changes, soil vulnerability to degradation, increasing vegetation sensitivity to fires, loss in biodiversity and human pressure (Pueyo et al., 2006; Montanarella, 2007; Barbayiannis et al., 2011; Salvati and Bajocco, 2011). These processes are largely driven by changes in the socioeconomic context, such as accession to the European Community, and strongly impact the way the land is being used (Antrop, 2005). In past decades, especially the European Mediterranean areas have undergone widespread land-use transformations depending on urbanization, industrialization and agricultural mechanization on the one hand, and depopulation with economic marginalization and land abandonment of rural areas, sometimes accompanied by local processes of soil erosion, on the other hand (Conacher and Sala, 1998; Basso et al., 2000; Salvati and Zitti, 2008; Abu Hammad and Tumeizi, 2012).

For the disadvantaged rural regions of southern Europe, several authors explored the relationship existing among vulnerability of land to desertification, economic marginality, social inequality, and territorial disparities (Rubio and Bochet, 1998; Iosifides and Politidis, 2005; Wilson and Juntti, 2005; Salvati and Carlucci, 2011). Using an econometric approach set up at the district scale, Salvati et al. (2011) identified per-capita income, crop intensity, irrigation and elevation, as crucial indicators associated to the level of vulnerability to desertification in Italy. At the same time, they criticized mechanistic approaches *à la* EKC (the Environmental Kuznets Curve: Salvati, 2010), suggesting instead that a number of social and economic factors influence the level of land vulnerability in a non-linear way.

Land degradation has been considered a typical phenomenon associated to agro-pastoral landscapes that are undergoing late economic development (Basso et al., 2000; Marathianou et al., 2000; Helldén and Tottrup, 2008; Imeson, 2012). Sometimes this process has been interpreted as a downward spiral fuelled by a persistent socioeconomic imbalance between vulnerable, disadvantaged areas and the neighboring, competitive regions (Salvati and Zitti, 2008). The northern Mediterranean region thus represents an intriguing case study to explore the relationship between the spatial distribution of vulnerable land to desertification and different socioeconomic contexts at the local scale, including both dry but affluent areas with an industrial and service-oriented economy, and semi-arid disadvantaged areas with an agriculture-oriented economic structure (Salvati and Bajocco, 2011).

To identify the role of the anthropogenic factors involved in land degradation processes is a deserving issue with policy implications because of the increasing impact of both external drivers (e.g. climate changes) and internal forces (e.g. social, cultural and political changes, evolution of the economic structure, global financial crisis) on natural resources and landscapes (Sivakumar and N'diangui, 2007). Although recent studies have tried to answer this complex issue (Portnov and Safriel, 2004; Danfeng et al., 2006; Wang et al., 2006; Wessels, 2007;

Abu Hammad and Tumeizi, 2012), further investigation focusing on the local scale is needed. Basically, these studies have dealt with specific territorial contexts and the description of the socioeconomic conditions supposedly to influence land degradation was mainly based on a restricted number of indicators made available at the regional (or sub-regional) level. For the Mediterranean region, Rubio and Recatalà (2006) proposed a literature review centered on the socioeconomic drivers of land degradation and Salvati (2010) tried to classify the main factors underlying land degradation in two groups (proximate causes and indirect factors).

However, although the increasing interest on this topic, few empirical analyses have been carried out, until now, to explore the intimate relationship between land degradation processes and the socioeconomic local context. The present study proposes an exploratory analysis of the relationship between the spatial distribution and level of land vulnerability to desertification and the different socioeconomic local contexts found in Italy. The novelty of this research, which is based on a large dataset compiled from different statistical sources, lies in the local scale analysis covering the whole national territory; a total of 8100 municipalities have been examined under the assumption that municipality data may provide a reliable *proxy* description of the local socioeconomic context. The study was based on a 'holistic' multi-dimensional approach (111 socioeconomic indicators have been considered here by covering five themes subdivided into 13 research dimensions) supported by descriptive and inferential statistical analysis with the aim at identifying the indicators that better discriminate Italian land in vulnerable and non-vulnerable areas. This approach allows defining multiple socioeconomic profiles of the vulnerable lands in Italy according to the geographical gradients supposed to have an influence on land degradation processes. Finally, it was discussed how an *in-depth* knowledge of the socioeconomic characteristics of vulnerable land may contribute to scenarios' modeling and integrated policies targeting specific anthropogenic processes in ecologically-fragile areas.

2. Methodology

2.1. Study area

Italy is a European Mediterranean country extending for more than 301,330 km^2. Italy's surface land is composed of nearly 23% lowlands, 42% uplands, and 35% mountains (Salvati and Bajocco, 2011). The partition into three geographical divisions (North, Center, and South) reflects the socioeconomic divide still observed in the country together with important differences in landscapes, soils and the climatic regime. Northern Italy, characterized by a generally wet and continental climate, is one of the most developed regions in Europe, occupies the whole Po valley and is separated from Europe by Alps. Central Italy, separated from northern Italy by the Apennines is a polarized region in urban and rural areas with traditional landscapes located in the internal mountainous zone. On the contrary, Southern Italy, including the main islands of Sicily and Sardinia, is one of the most disadvantaged and driest regions in Europe (Costantini et al., 2009) with an economic structure centered on low- and medium-income agriculture and traditional tertiary activities (including constructions, commerce, and the public sector). Italy shows disparities in population density, rural settlements and urban forms, income distribution, and natural resource availability possibly influencing the spatial distribution of vulnerable land to desertification (Salvati and Zitti, 2008).

2.2. Assessing land vulnerability to desertification

Based on UNCCD definition of 'desertification', land degradation is intended here as a temporary or permanent decline in the productive capacity of the land that can be referred to a loss of biomass, a reduction in actual (or potential) productivity, a change in vegetation cover or a loss in soil fertility (Salvati, 2010). The concept of 'land vulnerability to desertification', intended as the degree to which a land system undergoes changes due to natural forces, human intervention or a combination of both, was operationalized with special reference to the Mediterranean region (Salvati and Bajocco, 2011). Land vulnerability to desertification was selected as the key variable of this study because it represents a comprehensible concept for stakeholders and a traditional policy target in southern Europe (Salvati and Zitti, 2008).

According to this rationale, Italy was classified into vulnerable and non-vulnerable land to desertification following the Environmental Sensitive Area (ESA) scheme (Basso et al., 2000). This methodology, developed in the framework of the MEDALUS and DESERTLINKS projects funded by the European Commission, has been considered as a standard procedure to assess the level of land vulnerability to desertification using simplified quantitative tools (Kosmas et al., 2003). The ESA framework was applied to case studies in Mediterranean Europe, northern Africa and the middle East (see Ferrara et al., 2012 for a review). The capability of the ESA procedure to identify vulnerable land to desertification was verified on the field

Table 2
Surface area, number of municipalities, resident population and density in each land vulnerability ESAI class and geographical division of Italy.

Vulnerability class	North	Center	South	Italy
Municipalities (%)				
Low	33.4	23.7	4.9	23.2
Medium	58.0	63.9	70.4	62.6
High	8.6	12.4	24.7	14.2
Total number	4540	1003	2557	8100
Surface area (%)				
Low	38.9	21.8	4.0	21.3
Medium	53.9	68.3	71.1	63.7
High	7.3	9.9	24.9	15.0
Total (km^2)	119,919	58,352	123,060	301,331
Population distribution (%)				
Low	11.3	6.3	1.2	6.7
Medium	63.9	54.2	58.5	60.1
High	24.9	39.5	40.3	33.2
Total inhabitants	25,571,115	10,906,626	20,515,736	56,993,477
Population density (inhabitants/km^2)				
Low	62	54	49	59
Medium	253	148	137	178
High	729	745	270	419
Average (inhabit./km^2)	213	187	167	189

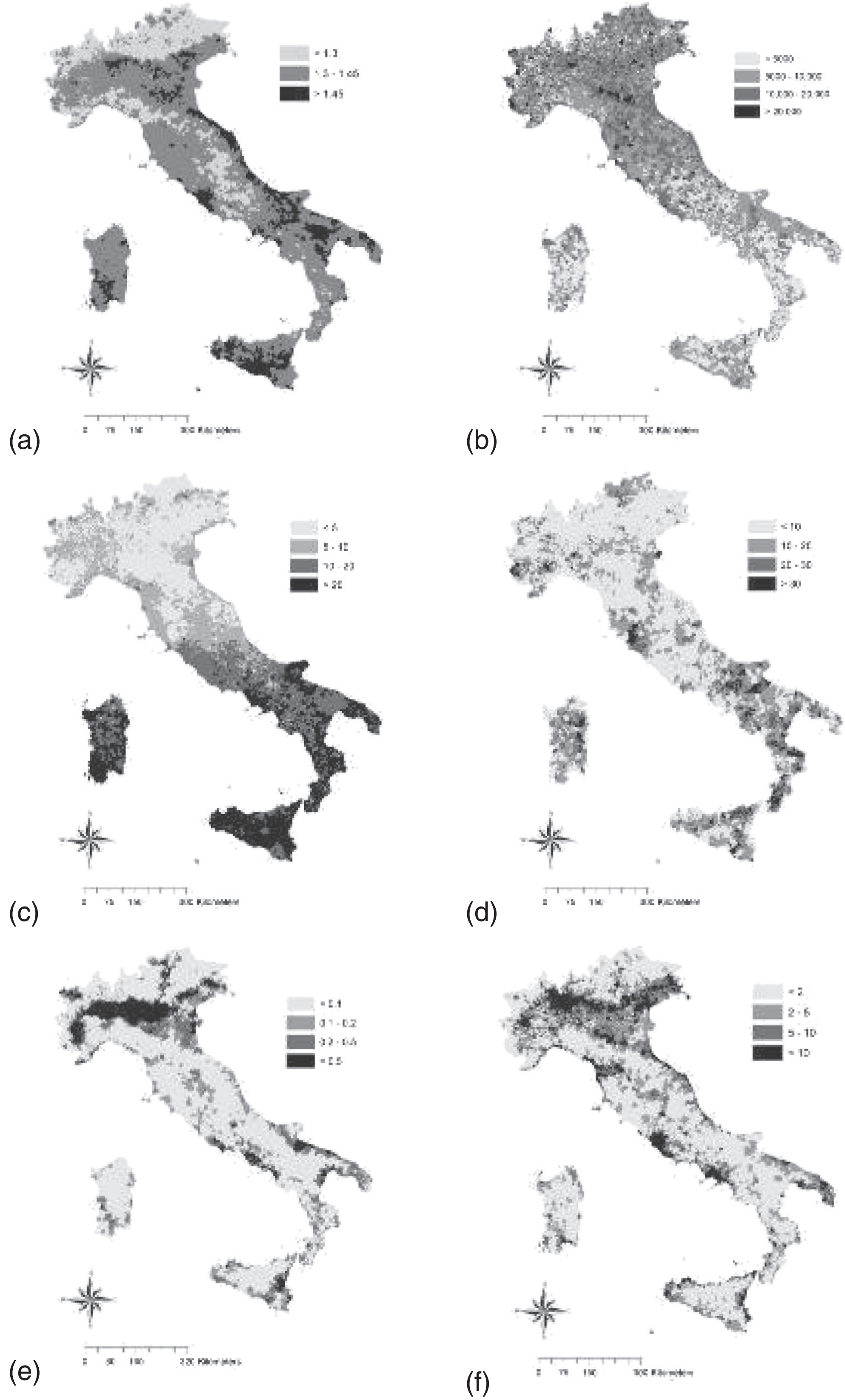

Fig. 1. Selected variables describing land vulnerability to desertification in Italy and the socioeconomic context: (a) municipality classification according to the ESAI score; (b) per-capita income (euros), (c) percent rate of unemployment, (d) share of workers in agriculture, (e) share of irrigated land to the total cultivated land, (f) percentage of urban areas.

through the use of independent indicators of land degradation in several study areas (Basso et al., 2000; Kosmas et al., 2003; Lavado Contador et al., 2009).

According to the ESA scheme, the selected variables evaluate land quality as a combination of (possibly unsustainable) land management together with predisposing environmental factors. Four dimensions (climate quality, soil quality, vegetation quality and land-use) have been considered as the most important factors related to land degradation processes (Salvati and Bajocco, 2011). The ESA scheme integrates fourteen biophysical variables into a GIS environment to provide a composite index of land vulnerability called the ESAI. The considered variables include (i) average annual rainfall rate, aridity index, and aspect as proxies for climate quality, (ii) soil depth and texture, slope, and the nature of the parent material as proxies for soil quality, (iii) the degree of vegetation cover, fire risk, protection offered by vegetation against soil erosion, and the degree of resistance to drought shown by vegetation as proxies for vegetation quality and, finally (iv) population density, annual population growth rate and an indicator of land-use intensity (Ferrara et al., 2012). All variables refer to 2000 or 2001 and have been derived at the lowest available spatial resolution from official sources including meteorological statistics, population and agricultural censuses, Corine Land Cover maps, and a soil quality map provided by the European Joint Research Centre (see Salvati and Bajocco, 2011 for in depth description of data sources and variables).

The ESA score system was applied separately to each variable in order to estimate their contribution to the level of land vulnerability to desertification (Basso et al., 2000; Salvati and Zitti, 2008; Lavado Contador et al., 2009). Scores were based on the estimated degree of correlation between the mentioned variables and independent field indicators of land degradation measured in several pilot areas in southern Europe (Kosmas et al., 2003). Intermediate and final maps have been produced using the ArcGIS software (ESRI Inc., Redwoods, USA) after the various layers were rasterized, registered, and referenced to the elementary 1 km^2 spatial unit. The unit's size has been selected according to Basso et al. (2000). Following Salvati and Bajocco (2011), the ESAI score ranges from 1 (the lowest vulnerability to desertification) to 2 (the highest vulnerability to desertification). Italian land was classified into three levels of vulnerability (low: ESAI < 1.30, intermediate: 1.3 < ESAI < 1.45 and high: ESAI > 1.45) according to the score assigned to each investigated spatial unit; the classification system is similar to what is proposed by Basso et al. (2000) and Salvati and Bajocco (2011).

2.3. Socioeconomic indicators

The variables used in the present study (see Table 1 for a list) have been made available from data provided by national statistical sources (primarily from the Italian National Statistical Institute, Istat) and mainly referring to 2000 or 2001. A total of 111 indicators have been calculated from the collected variables for each Italian municipality and classified within five themes (Demographic and territorial characteristics, Labor market and human capital, Economic specialization and competitiveness, Quality of life, Rural development) in turn subdivided into 13 research dimensions (see Table 1). The selection of variables and data sources, the procedure for the construction of indicators, and the identification of the thematic dimensions adequate to describe the socioeconomic context possibly influencing land degradation at the local scale have been set up according to the suggestions provided in Trisorio (2005). Although the indicators selected in this study cannot be considered as an exhaustive description of the socioeconomic context, they provide a broad qualification of the economic structure and social characteristics at the local scale. All selected indicators are easily and freely available from statistical sources; the restricted availability of other variables at the municipal scale prevented us to include them in the analysis; moreover, the dataset developed in the present study includes indicators at the most recent date when they were available in a comparable way at the desired geographical scale. Finally, the selected socioeconomic indicators were chosen not to be redundant with the biophysical variables used in the computation of the ESAI.

The final data matrix contained 111 socioeconomic indicators, four supplementary variables made available in each of the 8100 Italian municipalities (the average ESAI score, total resident population, average elevation, and latitude based on a dummy classifying land as belonging to northern-central Italy or to southern Italy) and one additional zoning variable (e.g. a code illustrating the administrative region of each municipality). Supplementary variables were used in an exploratory analysis aimed at describing the geographical distribution of land vulnerability to desertification according to specific gradients (latitude, elevation and population density). An average ESAI score has been assigned to each municipality by using the 'zonal statistics' tool provided with ArcGIS software (ESRI Inc., Redwoods, USA) after the overlap between the ESAI raster file and the shapefile describing the municipalities' boundaries. The 'zonal statistics' procedure computes a surface-weighted average of the raster values (i.e. recorded on each elementary pixel) belonging to each spatial unit.

2.4. Statistical analysis

Descriptive statistics of land surface area, number of municipalities, population size and density classified at different levels of vulnerability

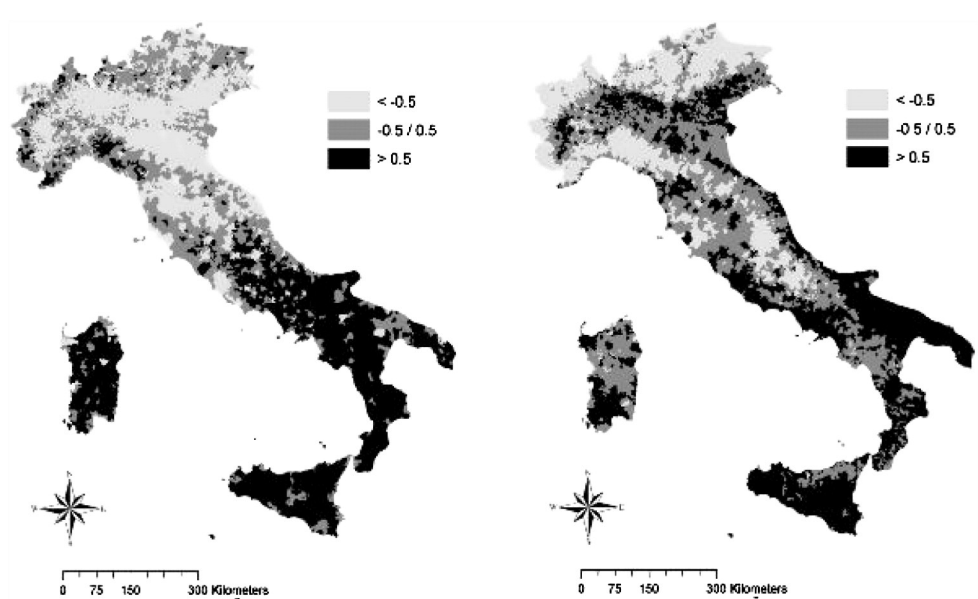

Fig. 2. PCA factor scores of the Italian municipalities on axis 1 (left) and axis 2 (right).

to desertification in Italy have been calculated using three geographical divisions (northern, central, and southern Italy). The average value of each socioeconomic indicator has been calculated for each geographical division by the three ESAI land vulnerability classes as reported in Section 2.2. Selected variables were mapped at the municipal scale to provide a picture of the socioeconomic conditions in Italy. They were selected to illustrate different geographical gradients including (i) the economic north–south divide traditionally observed in Italy after World War II, (ii) the socioeconomic polarization in coastal and inland areas, (iii) the elevation gradient and (iv) the urban–rural gradient. A Principal Components Analysis (PCA) was undertaken on the data matrix described in Section 2.3 to summarize the latent factors representing the local socioeconomic context in Italy (Salvati and Zitti, 2009). These latent factors extracted by PCA have been subsequently correlated to the level of land vulnerability to desertification observed in each municipality. As the PCA was based on the correlation matrix, the number of significant axes (m) was chosen by retaining the components with eigenvalue > 3. The Keiser–Meyer–Olkin (KMO) measure of sampling adequacy, which tests whether the partial correlations among variables are small, and Bartlett's test of sphericity, which tests whether the correlation matrix is an identity matrix, were used to assess the quality of PCA outputs. These tests evaluate the appropriateness of the factor model to analyze the original data. Based on the scores of the two most important factors, municipalities have been mapped into different groups (Salvati and Zitti, 2009). The coordinates of each municipality over the x–y factorial plane (Axis 1 and Axis 2) have been correlated to the four supplementary variables (see Table 1 and Section 2.3) available at the same spatial scale using a Spearman Rank Cograduation Test.

A Kruskal–Wallis non-parametric Analysis of Variance was carried out separately for each indicator in order to test if significant differences in the indicator's distribution exist between vulnerable and non-vulnerable areas in each Italian division. Based on Bonferroni's correction for multiple comparisons, significance was set up at $p < 0.001$. Statistical analyses have been carried out using STATISTICA package (Tulsa, Oklahoma).

3. Results

3.1. Descriptive statistics

By using the three ESAI classes and the geographical divisions described in Section 2.2, a detailed analysis of surface land and resident population in areas classified at different levels of vulnerability to desertification in Italy is reported in Table 2. The number of municipalities, the class area and resident population in the highest vulnerability category (ESAI > 1.45) increased rapidly moving from northern Italy to southern Italy. In southern Italy more than 40% of the total population inhabits land with the highest degree of vulnerability. At the national scale, population density increased strongly when moving from low-vulnerability to high-vulnerability land (passing from an average density of 60 inhabitants/km^2 observed in low-vulnerability areas to 420 inhabitants/km^2 in high-vulnerability areas). This pattern is evident in all the three geographical divisions examined in the present study.

The distribution of vulnerable land to desertification in Italy is mapped in Fig. 1 together with selected socioeconomic indicators. Indicators were chosen to represent different spatial gradients observed at the municipal scale, including (i) the economic north–south divide traditionally observed in Italy after World War II (and illustrated in Fig. 1 using variables such as per-capita income and the unemployment rate), (ii) the socioeconomic polarization in coastal and inland areas (illustrated by the spatial distribution of urban areas), (iii) the elevation gradient (illustrated by the percentage of irrigated land) and (iv) the urban–rural gradient (illustrated by the share of workers in the agricultural sector). As represented by the ESAI land classification system, the distribution of vulnerable land to desertification in Italy presents a relatively complex spatial pattern which basically reflects the above-mentioned gradients. Vulnerable land concentrated in flat, agriculture-specialized areas of the Po valley in northern Italy, along the coastal areas of both Adriatic and Tyrrhenian sea in central Italy, as well as in the inland areas of Basilicata, Sicily and Sardinia in southern Italy.

3.2. Multivariate analysis

Results of the Principal Components Analysis carried out on the matrix composed by the 8100 Italian municipalities and the 111 socioeconomic indicators are reported in Table 2. The Keiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity ($p < 0.001$) indicated that the factor model is appropriate to analyze the original data matrix. The PCA extracted five axes with absolute eigenvalues higher than 3 and accounting for a cumulated variance of more than 36% that is a relatively high proportion of variance considering the huge number of input variables. However, indicators' loadings > |0.6| have been observed for the first and second factorial axes only. Axis 1 explained 14% of the total extracted variance and was found associated to labor market variables (L1–L8), educational level of resident population (F5, F6, S15), disposable income and revenues from local taxes (Q8, Q11). Axis 2 explained 9% of the total variance and was found associated to population structure and settlement indicators (I5, P1, P3) together with specific land-use variables dealing with crop intensification, human pressure and (possibly unsustainable) land management (SR-P4 and SR-M4). The third, fourth and fifth factorial axes have been not characterized by specific variables since the observed loadings were, on average, lower than |0.3|. The remaining factors explained for a restricted proportion of variance.

As illustrated in Fig. 2, the first factorial axis represents a north–south gradient indicating socioeconomic disparities and polarization in urban and rural areas. The information captured by axis 2 is more articulated and should be interpreted as the result of different factors acting at the local scale, including the coastal-inland socioeconomic divide and the elevation gradient influencing agricultural systems and land-use distribution. Interestingly enough, the correlation analysis carried out between the two extracted factorial axes and selected supplementary variables (Table 2) indicates a significant negative relationship between the ESAI score and axis 2 ($r = -0.66$). Elevation and population density were found correlated to axis 2 (respectively $r = -0.55$ and $r = -0.37$) while latitude was found correlated to axis 1 ($r = 0.48$).

The correlation coefficients of the supplementary variables with axes 3, 4, and 5 were found not significant. This confirms that the contribution of these axes to the interpretation of the spatial distribution of vulnerable land to desertification in Italy is negligible. Based on these results, a dedicated analysis was developed to identify the ocioeconomic indicators discriminating between vulnerable and non-vulnerable land in the three geographical divisions of Italy.

3.3. The socioeconomic profile of vulnerable land in Italy

The average value of each of the 111 indicators analyzed by geographical division and land vulnerability class is shown in Table 3 together with results of a non-parametric Kruskal Wallis ANOVA statistic testing for variables' differences between vulnerable and non-vulnerable land. Based on the results of the statistical test, Fig. 3 ranked the twenty indicators with the highest discrimination power in vulnerable and non-vulnerable areas observed in each Italian division. Two results arise from this analysis: (i) a restricted number of variables were found important to discriminate land classified at high and low level of vulnerability and (ii) areas classified as vulnerable to desertification in northern and southern Italy are characterized by different socioeconomic profiles.

In the three divisions considered, areas classified in the highest category of land vulnerability are associated to variables indicating a

Table 3
Factor loadings of the Principal Components Analysis carried out by geographical division in Italy and correlation analysis with selected supplementary variables (italics). Loadings >0.6 are marked in bold.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
I1	−0.43	0.38	−0.30	0.01	−0.08	Q1	−0.30	0.03	0.13	−0.05	−0.09
I2	−0.22	0.16	−0.04	0.19	0.04	Q2	**−0.67**	−0.11	0.10	−0.07	0.09
I3	−0.07	0.33	−0.36	0.10	−0.18	Q3	−0.37	0.36	−0.41	−0.33	−0.10
I4	−0.13	0.07	−0.07	−0.07	−0.06	Q4	−0.47	0.26	−0.41	−0.37	−0.11
I5	0.43	**−0.64**	−0.29	−0.03	0.06	Q5	−0.50	0.32	−0.44	−0.37	−0.13
I6	−0.28	−0.40	0.43	−0.37	−0.06	Q6	−0.53	0.30	−0.37	−0.32	−0.08
P1	0.03	**0.76**	0.00	0.35	0.13	Q7	−0.49	0.21	−0.41	−0.35	−0.11
P2	0.23	−0.49	0.12	−0.46	−0.23	Q8	**−0.86**	−0.25	0.02	−0.08	−0.07
P3	0.32	**−0.60**	0.18	−0.55	−0.21	Q9	−0.43	−0.34	−0.34	−0.04	0.07
P4	0.19	−0.56	0.13	−0.50	−0.24	Q10	−0.32	−0.20	−0.31	−0.20	0.03
P5	0.51	−0.45	0.14	−0.48	−0.18	Q11	**−0.74**	−0.33	−0.03	−0.23	−0.10
P6	−0.48	−0.14	0.12	−0.02	0.15	Q12	−0.56	−0.34	−0.24	−0.10	0.02
P7	−0.05	−0.15	0.15	0.32	0.13	Q13	−0.58	0.02	−0.10	0.01	−0.13
L1	**−0.80**	0.13	0.09	0.37	0.20	D1	−0.28	0.56	−0.33	−0.19	−0.05
L2	**−0.88**	−0.12	0.19	0.26	0.14	D2	0.01	−0.18	0.16	0.01	−0.02
L3	**0.72**	0.49	−0.27	0.02	0.00	D3	−0.18	0.05	−0.18	−0.10	0.01
L4	**0.71**	0.45	−0.29	−0.05	−0.02	D4	−0.53	−0.09	0.19	0.05	−0.04
L5	**−0.79**	0.08	0.10	0.25	0.16	SR-A1	−0.43	−0.03	0.16	0.10	−0.33
L6	**−0.87**	−0.13	0.18	0.18	0.12	SR-A2	0.17	−0.41	−0.31	0.19	−0.10
L7	**0.72**	0.48	−0.25	0.03	−0.01	SR-A3	−0.08	−0.33	−0.05	0.06	−0.32
L8	**0.70**	0.43	−0.25	−0.04	−0.02	SR-A4	0.01	0.04	0.29	0.01	−0.05
L9	−0.41	0.45	−0.04	0.14	−0.22	SR-A5	−0.14	0.50	0.28	−0.14	−0.26
L10	−0.14	0.05	−0.16	−0.13	−0.06	SR-P1	−0.06	−0.16	−0.22	0.12	−0.16
L11	−0.01	−0.10	−0.01	−0.10	0.00	SR-P2	−0.29	0.39	0.42	−0.25	−0.39
L12	−0.16	0.10	0.08	0.06	−0.11	SR-P3	0.30	0.33	−0.08	−0.25	0.62
L13	0.14	−0.25	0.03	−0.10	−0.03	SR-P4	0.05	**−0.63**	−0.35	0.44	−0.09
L14	−0.08	0.11	0.08	0.10	−0.09	SR-P5	0.20	0.20	−0.13	0.10	0.26
F1	−0.23	0.17	−0.38	−0.40	0.05	SR-P6	0.00	−0.08	−0.03	0.03	0.05
F2	−0.49	0.07	−0.32	−0.19	0.14	SR-P7	−0.04	−0.08	0.03	0.05	−0.13
F3	−0.28	0.21	0.00	0.60	0.14	SR-P8	−0.11	0.47	0.51	−0.27	−0.09
F4	0.43	0.31	0.14	0.22	−0.08	SR-M1	−0.26	0.08	0.14	−0.09	0.38
F5	**0.64**	0.40	0.05	−0.06	−0.12	SR-M2	−0.33	0.32	0.19	−0.01	−0.07
F6	**0.66**	0.36	−0.04	−0.01	−0.07	SR-M3	0.18	−0.34	0.07	−0.04	−0.25
S1	−0.53	0.30	0.01	0.14	−0.18	SR-M4	−0.05	**0.63**	0.35	−0.43	0.09
S2	−0.42	0.32	−0.35	−0.11	−0.12	SR-Q1	0.15	−0.02	0.00	−0.03	−0.04
S3	0.03	−0.14	0.25	−0.25	0.35	SR-Q2	−0.12	−0.03	0.22	−0.32	0.64
S4	0.06	0.06	−0.08	0.00	0.03	SR-Q3	−0.05	−0.04	0.17	−0.24	0.45
S5	0.06	−0.07	0.01	0.08	−0.03	SR-Q4	−0.02	−0.05	−0.05	0.04	0.03
S6	−0.57	0.18	0.37	0.23	−0.16	SR-Q5	−0.10	−0.07	0.21	−0.27	0.43
S7	0.03	−0.05	−0.10	0.01	−0.08	SR-Q6	−0.13	−0.03	0.24	−0.33	0.57
S8	0.21	−0.29	0.12	0.17	0.10	SR-Q7	−0.01	0.01	−0.01	0.01	0.02
S9	0.21	0.26	−0.17	−0.21	0.10	SR-Q8	−0.18	0.29	0.09	−0.08	0.20
S10	0.09	−0.52	−0.31	0.02	0.21	SR-Q9	0.25	0.26	−0.24	−0.05	0.42
S11	0.07	−0.09	−0.05	−0.12	−0.04	SR-L1	0.49	−0.01	0.34	−0.16	0.12
S12	−0.22	0.16	−0.24	−0.26	0.02	SR-L2	−0.12	−0.03	0.21	−0.25	0.02
S13	−0.22	0.12	−0.26	−0.24	0.01	SR-L3	−0.18	−0.38	0.35	−0.11	−0.10
S14	0.52	−0.26	−0.15	−0.14	−0.11	SR-L4	−0.16	0.04	0.02	−0.18	−0.03
S15	**0.62**	0.27	−0.17	0.04	0.00	SR-L5	−0.08	−0.06	0.10	−0.08	−0.08
S16	0.01	0.12	−0.19	−0.19	−0.06	A1	−0.02	−0.45	−0.48	0.15	0.09
S17	0.06	−0.02	−0.14	−0.13	−0.01	A2	0.09	0.09	−0.06	−0.08	0.00
T1	−0.06	−0.34	−0.37	0.12	0.18	A3	−0.06	−0.45	−0.49	0.19	0.11
T2	−0.13	0.13	−0.40	−0.09	0.07	A4	0.02	−0.45	−0.46	0.17	0.12
T3	−0.37	0.00	−0.42	−0.16	0.11	A5	0.11	−0.54	−0.04	−0.02	0.02
T4	−0.08	−0.02	−0.12	−0.06	0.02	A6	0.13	−0.34	−0.10	0.00	0.09
T5	−0.21	−0.01	−0.25	−0.13	0.03	*ESAI*	*0.01*	***−0.66***	*−0.12*	*0.19*	*0.15*
T6	−0.02	−0.02	0.06	−0.07	0.08	*Pop_density*	*0.23*	*−0.37*	*0.31*	*0.06*	*0.04*
T7	0.06	0.54	0.15	0.08	−0.06	*Latitude*	*0.48*	*−0.23*	*−0.04*	*−0.31*	*−0.22*
						Elevation	*0.31*	*−0.55*	*−0.29*	*0.17*	*0.14*
						%variance	13.6	9.3	5.6	4.5	3.2
						%cum_var	13.6	22.8	28.5	32.9	36.1

gradient from high-intensity cropland to disadvantaged areas characterized by economic marginality and high proportion of natural and semi-natural land (SR-P8, SR-P2, SR-P6, SR-M4, SR-M2). As a matter of fact, crop intensity was found higher in vulnerable areas than in non-vulnerable areas throughout Italy, and the same result was observed for specific land-uses (e.g. the share of arable land was higher in areas classified as vulnerable to desertification while the reverse pattern was observed for the share of forests, pastures and meadows).

Apart from agricultural landscape variables, a number of socioeconomic indicators were found important in the discrimination between high- and low-vulnerability areas. This is the case for human settlement variables (I5, S2, I1, and partly T7) indicating exurban development as the process mostly associated with the intermediate and high levels of land vulnerability to desertification. Other socioeconomic variables (D1, S10, T1 and partly L1) associated to the urban–rural gradient and indicating participation to the labor market, economic specialization in tourism, and high crime density were found associated to the land vulnerability gradient in northern Italy only. In southern Italy, the importance of the indicators describing urban form and human settlements decreased compared to what observed in northern Italy (only two variables, I1 and I5, resulted significant in the comparison) while the role of indicators describing the structure of population (P2 and P3) and

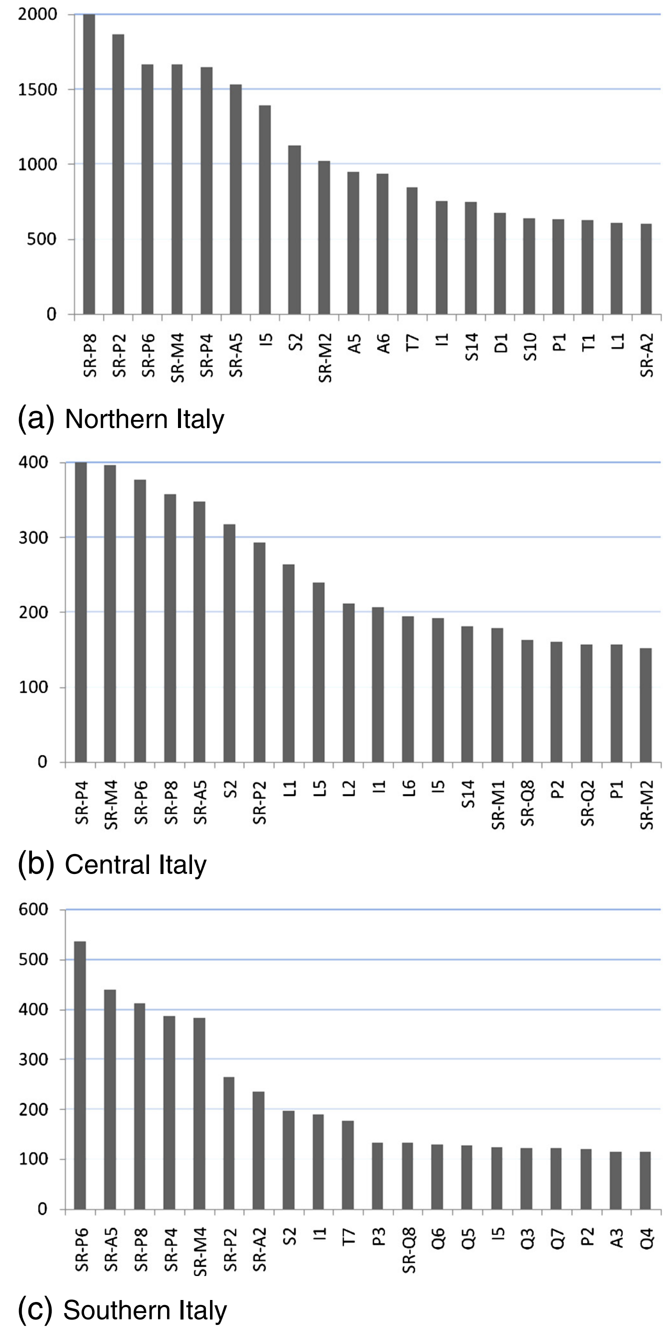

Fig. 3. Ranking of the twenty most important socioeconomic indicators discriminating among the three ESAI vulnerability classes (see paragraphs 2.2 and 2.4) based on the Kruskal–Wallis non-parametric test (values reported on y-axis) by geographical division in Italy.

disposable income (Q3, Q4, Q5, Q6 and Q7) was growing. As a matter of fact, vulnerable land to desertification showed, on average, higher levels of disposable income compared to non-vulnerable land (Table 4).

Interestingly enough, water management variables (mainly A3 and SR-Q8) also play a key role in discriminating between low- and high-vulnerability areas with special mention to the higher diffusion of unsustainable irrigation practices and the lower availability of water distributed for civil uses in vulnerable areas. Water infrastructures for civil use showed a significantly different distribution in the Italian municipalities possibly indicating diverging water availability in low- and high-vulnerability areas. In central Italy the importance of labor market variables (L1, L2, L5, L6) increases together with selected demographic variables (P1, P2). Vulnerable areas in central Italy are mainly characterized by higher participation rate (total and female), higher average family size, and lower elderly index compared to non-vulnerable areas.

4. Discussion

The present study investigates the proximate and underlying socioeconomic factors determining conditions for land vulnerability to desertification in Italy. Based on a large set of indicators describing several research dimensions and covering the whole country at two spatial scales (8100 local municipalities and three geographical divisions), emphasis was given to the social, demographic, economic, political and cultural factors that affect land degradation processes at the local scale (e.g. Rubio and Bochet, 1998). Exploratory multidimensional techniques and inferential data analysis were developed in this study to assess the importance of socioeconomic factors predisposing land to degradation.

The use of administrative spatial partitions (of interest for stakeholders and politicians working at the local scale) is a relatively novel issue in the analysis of socioeconomic-environmental interactions (but see also Morse et al., 2011) and allows investigating the responses implemented by local communities to contrast desertification (Briassoulis, 2011). Although the National Action Plans to combat desertification in northern Mediterranean countries assigned the administrative regions or river basin authorities powers for land management in the field of soil degradation (Briassoulis, 2011), municipalities seem to be the most relevant spatial unit for environmental reporting of land vulnerability to desertification informing sustainable management of rural and peri-urban land (Salvati and Zitti, 2009).

In order to interpret complexity in the anthropogenic drivers of land degradation and desertification, a number of socioeconomic factors can be analyzed in a descriptive statistical analysis to evaluate the relevant links with the environmental sphere. These factors, however, influence the environmental conditions through non-linear paths and are often implicated in feedback relations with exogenous variables (Patel et al., 2007). The unpredictability of territorial actors' behavior which is focused on some possible decision variables (e.g. prices, investments, institutions and services) complicates the assessment framework. These variables are themselves influenced by broader forces acting through several channels, including market, dissemination of new technologies and information, and infrastructural development (Kok et al., 2004). The methodology proposed in the present study takes into account these aspects by using exploratory techniques suited to identify non-linear, multiple relationships among the studied variables. An implementation of the methodology can be developed by using a time series approach that assesses the socioeconomic evolution of the local communities based on a restricted number of key indicators, *e.g.* those identified in the non-parametric analysis described in Section 3.3.

As the results of the Principal Components Analysis documents, the complexity of land degradation processes is particularly evident in Mediterranean countries due to their special set of environmental problems and to the long-term interaction between the biophysical and the human dimensions (Helldén and Tottrup, 2008). Vogt et al. (2011) demonstrated how the socioeconomic factors predisposing land to desertification act, alone or together, at different spatial scales determining hardly-predictable impacts. The picture is complicated by the rapid changes in societies and modifications in the economic structure with impact on the spatial organization of the whole region (Salvati et al., 2011).

After World War II, southern Europe experienced a rapid population increase, agricultural intensification, and industrial concentration that consolidate the existing gap between dynamic regions (generally placed along the coast, in lowland areas and around the main urban centers) and economically-disadvantaged regions (mainly located in the internal mountainous areas). Since the 1980s, however, urban diffusion, land abandonment and tourism development took place in

Table 4
Average value of the selected socioeconomic variables by ESAI land vulnerability class and geographical division in Italy (Kruskal–Wallis non-parametric ANOVA is reported together with the *p* value of each comparison).

Variable	Northern Italy						Central Italy						Southern Italy					
	<1.3	1.3–1.45	>1.45	Total	KW	*p*	<1.3	1.3–1.45	>1.45	Total	KW	*p*	<1.3	1.3–1.45	>1.45	Total	KW	*p*
I1	0.02	0.07	0.17	0.06	755	0.000	0.02	0.04	0.15	0.04	207	0.000	0.01	0.03	0.05	0.04	191	0.000
I2	0.68	0.71	0.70	0.69	13	0.001	0.66	0.65	0.62	0.65	1	0.775	0.48	0.60	0.51	0.57	15	0.001
I3	0.79	0.79	0.87	0.79	91	0.000	0.73	0.75	0.85	0.76	7	0.027	0.90	0.87	0.91	0.88	42	0.000
I4	0.01	0.01	0.03	0.01	293	0.000	0.01	0.01	0.01	0.01	8	0.015	0.01	0.01	0.01	0.01	24	0.000
I5	0.44	0.19	0.08	0.28	1392	0.000	0.39	0.21	0.17	0.24	192	0.000	0.44	0.30	0.26	0.29	125	0.000
I6	39.35	42.07	40.75	40.91	232	0.000	39.36	38.68	36.47	38.61	22	0.000	35.70	35.26	34.31	35.04	4	0.118
P1	2.34	2.45	2.57	2.42	630	0.000	2.43	2.55	2.64	2.53	157	0.000	2.53	2.72	2.80	2.73	97	0.000
P2	5.69	5.24	3.43	5.28	374	0.000	6.61	5.31	3.57	5.42	161	0.000	5.99	4.16	3.41	4.05	121	0.000
P3	10.84	10.34	8.15	10.38	436	0.000	13.30	11.16	8.31	11.34	144	0.000	12.10	9.27	8.14	9.10	134	0.000
P4	212.9	206.9	143.4	204.6	356	0.000	240.1	200.8	140.7	203.4	138	0.000	209.3	146.0	122.0	142.6	107	0.000
P5	55.35	52.60	45.94	53.18	521	0.000	62.38	55.37	48.14	56.18	142	0.000	62.22	55.59	53.47	55.33	101	0.000
P6	2.24	2.82	3.31	2.63	86	0.000	2.39	3.00	3.20	2.89	63	0.000	1.36	0.69	0.79	0.74	35	0.000
P7	97.87	96.78	95.57	97.12	20	0.000	96.30	95.16	93.91	95.28	7	0.034	94.21	95.83	95.01	95.56	11	0.004
L1	49.17	50.84	54.93	50.49	608	0.000	43.16	47.14	51.28	46.69	264	0.000	40.97	42.42	42.72	42.44	37	0.000
L2	46.94	48.58	52.67	48.24	576	0.000	39.56	43.48	46.63	42.94	212	0.000	34.74	33.60	33.40	33.60	5	0.105
L3	4.59	4.51	4.16	4.52	19	0.000	8.48	7.91	9.10	8.15	24	0.000	15.09	20.72	22.10	20.83	57	0.000
L4	12.88	13.44	12.48	13.15	21	0.000	24.68	23.68	27.75	24.31	25	0.000	42.31	50.46	53.48	50.88	42	0.000
L5	37.66	40.19	44.89	39.55	568	0.000	31.76	36.71	41.31	36.09	240	0.000	28.73	30.28	29.63	30.06	12	0.003
L6	35.15	37.61	42.31	37.00	543	0.000	27.81	32.55	36.42	31.90	195	0.000	22.66	21.78	20.77	21.56	9	0.009
L7	6.81	6.54	5.81	6.60	30	0.000	12.90	11.88	12.04	12.12	33	0.000	21.04	28.21	30.71	28.54	64	0.000
L8	16.85	16.76	14.75	16.64	24	0.000	31.08	29.87	30.84	30.23	30	0.000	48.47	59.79	63.35	60.22	40	0.000
L9	56.96	63.59	70.26	61.49	347	0.000	58.76	62.25	70.05	62.26	52	0.000	55.59	61.65	64.67	62.15	38	0.000
L10	36.37	37.48	38.76	37.14	9	0.010	35.86	38.17	39.39	37.79	18	0.000	35.08	34.92	34.87	34.91	1	0.547
L11	3.53	3.82	4.29	3.74	75	0.000	4.11	4.11	4.49	4.15	3	0.197	4.08	3.20	2.97	3.18	27	0.000
L12	0.34	0.59	0.74	0.50	520	0.000	0.49	0.43	0.60	0.46	62	0.000	0.54	0.34	0.49	0.39	52	0.000
L13	64.67	38.59	18.78	47.28	265	0.000	52.88	40.47	17.24	40.87	34	0.000	53.39	42.15	31.32	39.90	8	0.016
L14	0.13	0.20	0.21	0.17	489	0.000	0.15	0.13	0.15	0.14	70	0.000	0.17	0.17	0.25	0.19	54	0.000
F1	3.93	4.87	6.70	4.64	159	0.000	4.46	5.89	8.53	5.84	66	0.000	5.12	4.84	5.51	5.02	16	0.000
F2	22.89	23.44	26.43	23.44	140	0.000	23.03	24.29	28.39	24.42	33	0.000	23.85	20.57	21.70	20.98	39	0.000
F3	31.73	31.11	31.00	31.34	61	0.000	27.68	28.20	28.53	28.12	11	0.004	26.73	30.12	29.80	29.90	57	0.000
F4	9.15	9.64	8.41	9.36	48	0.000	9.21	9.48	8.22	9.30	4	0.141	10.22	13.63	14.22	13.64	46	0.000
F5	6.77	8.36	8.39	7.74	344	0.000	11.58	11.63	9.83	11.44	4	0.172	13.47	14.91	14.72	14.80	30	0.000
F6	0.35	0.68	0.57	0.54	319	0.000	1.30	1.25	0.77	1.21	30	0.000	2.57	3.84	3.39	3.67	60	0.000
S1	2.95	3.67	4.37	3.44	512	0.000	2.90	3.32	4.33	3.33	106	0.000	2.57	2.93	3.20	2.98	62	0.000
S2	21.25	102.31	354.86	89.18	1125	0.000	14.71	51.14	304.63	68.34	318	0.000	9.24	30.51	65.73	38.41	198	0.000
S3	0.01	0.01	0.01	0.01	138	0.000	0.01	0.01	0.00	0.01	6	0.058	0.01	0.01	0.01	0.01	11	0.003
S4	0.00	0.00	0.00	0.00	28	0.000	0.00	0.00	0.00	0.00	46	0.000	0.00	0.00	0.01	0.00	41	0.000
S5	0.01	0.00	0.00	0.01	8	0.018	0.01	0.01	0.00	0.01	29	0.000	0.00	0.01	0.00	0.01	8	0.022
S6	0.22	0.33	0.36	0.29	410	0.000	0.22	0.26	0.25	0.25	83	0.000	0.13	0.15	0.16	0.15	26	0.000
S7	0.01	0.01	0.00	0.01	11	0.004	0.00	0.01	0.01	0.01	18	0.000	0.01	0.01	0.01	0.01	29	0.000
S8	0.16	0.12	0.09	0.13	244	0.000	0.14	0.11	0.08	0.12	50	0.000	0.15	0.13	0.11	0.12	32	0.000
S9	0.13	0.15	0.16	0.14	74	0.000	0.15	0.17	0.16	0.16	6	0.042	0.17	0.18	0.19	0.18	39	0.000
S10	0.14	0.07	0.04	0.09	640	0.000	0.08	0.07	0.05	0.07	68	0.000	0.10	0.06	0.04	0.05	87	0.000
S11	0.06	0.05	0.05	0.05	6	0.056	0.05	0.05	0.08	0.05	0	0.803	0.05	0.05	0.05	0.05	1	0.601
S12	0.01	0.02	0.02	0.02	89	0.000	0.02	0.02	0.03	0.02	38	0.000	0.01	0.01	0.02	0.01	91	0.000
S13	0.05	0.07	0.10	0.07	177	0.000	0.05	0.07	0.11	0.07	54	0.000	0.06	0.06	0.07	0.06	9	0.012
S14	0.06	0.03	0.02	0.04	751	0.000	0.08	0.04	0.05	0.05	182	0.000	0.08	0.08	0.07	0.08	26	0.000
S15	0.07	0.06	0.05	0.06	56	0.000	0.11	0.09	0.07	0.09	56	0.000	0.15	0.16	0.16	0.16	22	0.000
S16	0.04	0.05	0.05	0.05	49	0.000	0.04	0.06	0.06	0.05	24	0.000	0.04	0.06	0.07	0.06	31	0.000
S17	0.03	0.03	0.03	0.03	31	0.000	0.03	0.04	0.04	0.04	20	0.000	0.04	0.03	0.04	0.04	29	0.000
T1	0.80	0.22	0.06	0.44	630	0.000	0.27	0.15	0.13	0.17	6	0.055	0.18	0.09	0.04	0.08	17	0.000
T2	29.44	27.68	44.16	29.56	123	0.000	30.65	39.80	63.54	40.16	24	0.000	28.56	43.75	47.15	43.98	1	0.648
T3	17.93	17.93	25.61	18.49	76	0.000	16.88	22.51	30.02	22.02	9	0.013	8.76	10.02	12.46	10.57	2	0.305

T4	17.80	12.80	24.51	15.60	214	0.000	12.59	23.64	13.28	20.21	9	0.012	4.61	7.78	6.91	7.44	44	0.000
T5	21.41	20.25	29.15	21.35	60	0.000	18.24	22.56	26.84	22.05	7	0.025	8.83	13.42	14.87	13.59	1	0.716
T6	0.09	0.10	0.03	0.09	18	0.000	0.55	1.00	0.08	0.81	34	0.000	0.06	0.09	0.11	0.10	3	0.274
T7	139.3	229.7	275.2	197.9	848	0.000	156.8	208.6	254.1	201.8	100	0.000	178.8	294.5	363.6	307.0	177	0.000
Q1	72.16	76.40	77.53	74.84	239	0.000	71.11	76.90	74.25	75.38	61	0.000	70.26	68.40	69.87	68.84	8	0.020
Q2	53.09	56.72	57.92	55.40	201	0.000	52.42	57.74	60.39	56.85	136	0.000	44.66	44.12	44.71	44.29	10	0.007
Q3	2290	6998	13,280	5625	474	0.000	2831	8902	18,946	8575	85	0.000	1161	5517	9452	6320	123	0.000
Q4	2.20	4.59	8.61	3.96	395	0.000	1.78	4.85	9.26	4.62	75	0.000	0.78	1.81	3.09	2.09	115	0.000
Q5	3093	10,083	24,105	8387	516	0.000	3300	10,906	35,614	11,699	90	0.000	548	4404	8523	5273	129	0.000
Q6	0.28	0.73	1.47	0.61	513	0.000	0.25	0.73	1.37	0.69	89	0.000	0.05	0.26	0.49	0.31	130	0.000
Q7	3.19	6.84	16.79	6.15	456	0.000	1.98	6.00	17.98	6.31	83	0.000	0.40	1.52	2.91	1.82	123	0.000
Q8	8077	8936	10,059	8683	324	0.000	6603	7390	8352	7314	47	0.000	5308	4322	4521	4411	70	0.000
Q9	201.3	163.0	185.9	179.5	44	0.000	116.9	140.9	212.8	142.8	42	0.000	121.2	67.1	74.2	71.0	61	0.000
Q10	55.85	61.12	76.95	60.22	87	0.000	61.98	61.31	69.87	62.30	6	0.054	49.92	35.06	38.49	36.52	49	0.000
Q11	11,058	11,522	12,168	11,389	76	0.000	9819	10,346	10,772	10,274	26	0.000	8422	7905	7607	7852	61	0.000
Q12	10,240	9632	10,644	9942	93	0.000	8185	8612	9906	8647	37	0.000	7902	6911	6857	6937	60	0.000
Q13	9557	11,335	14,219	10,854	322	0.000	7512	9749	12,856	9570	99	0.000	5844	6191	6738	6314	15	0.001
D1	2.46	4.37	6.26	3.76	678	0.000	2.97	4.80	7.37	4.66	113	0.000	2.79	4.92	6.21	5.15	101	0.000
D2	0.10	0.08	0.04	0.08	36	0.000	0.08	0.05	0.04	0.06	16	0.000	0.09	0.07	0.05	0.07	10	0.007
D3	19.12	22.55	32.15	21.92	129	0.000	10.39	20.52	46.83	20.92	55	0.000	11.01	18.02	22.25	18.79	18	0.000
D4	1.46	1.79	1.98	1.67	159	0.000	1.64	1.66	1.44	1.63	16	0.000	0.69	0.74	0.74	0.74	3	0.218
SR-A1	0.21	0.30	0.32	0.27	317	0.000	0.12	0.17	0.23	0.16	105	0.000	0.09	0.12	0.10	0.11	15	0.000
SR-A2	0.25	0.05	0.00	0.12	605	0.000	0.23	0.04	0.03	0.08	120	0.000	0.49	0.10	0.01	0.09	236	0.000
SR-A3	22.20	19.63	11.28	20.02	43	0.000	12.55	8.67	10.39	9.69	6	0.061	31.93	8.60	6.03	8.91	43	0.000
SR-A4	0.54	0.68	0.69	0.62	277	0.000	0.65	0.72	0.62	0.69	13	0.002	0.62	0.66	0.65	0.66	2	0.408
SR-A5	0.42	0.75	0.88	0.63	1534	0.000	0.46	0.62	0.83	0.61	348	0.000	0.51	0.70	0.88	0.73	439	0.000
SR-P1	0.23	0.14	0.13	0.18	52	0.000	0.25	0.16	0.21	0.19	16	0.000	0.39	0.14	0.04	0.13	46	0.000
SR-P2	0.09	0.63	0.79	0.43	1869	0.000	0.29	0.60	0.81	0.56	294	0.000	0.18	0.39	0.62	0.44	265	0.000
SR-P3	0.07	0.11	0.12	0.10	57	0.000	0.15	0.21	0.11	0.19	39	0.000	0.15	0.27	0.29	0.27	55	0.000
SR-P4	0.83	0.25	0.08	0.47	1651	0.000	0.55	0.18	0.08	0.25	400	0.000	0.67	0.33	0.09	0.29	386	0.000
SR-P5	20.87	17.10	17.24	18.57	19	0.000	22.82	24.98	21.23	24.14	23	0.000	20.39	25.65	25.28	25.34	23	0.000
SR-P6	4.36	0.45	0.03	1.94	1669	0.000	1.45	0.63	0.11	0.75	377	0.000	1.50	0.57	0.08	0.48	536	0.000
SR-P7	0.96	0.95	0.96	0.96	104	0.000	0.92	0.92	0.82	0.91	3	0.257	0.90	0.85	0.83	0.85	0	0.850
SR-P8	0.03	0.43	0.56	0.28	2012	0.000	0.13	0.37	0.49	0.33	358	0.000	0.10	0.32	0.53	0.36	412	0.000
SR-M1	0.11	0.16	0.19	0.14	156	0.000	0.08	0.13	0.13	0.12	179	0.000	0.04	0.06	0.09	0.07	97	0.000
SR-M2	0.06	0.32	0.40	0.22	1019	0.000	0.02	0.08	0.12	0.07	152	0.000	0.06	0.10	0.17	0.12	84	0.000
SR-M3	0.96	1.02	0.21	0.94	186	0.000	1.22	0.89	0.27	0.90	83	0.000	1.15	1.01	0.92	0.99	43	0.000
SR-M4	0.17	0.75	0.92	0.53	1669	0.000	0.45	0.82	0.92	0.75	396	0.000	0.33	0.67	0.91	0.71	383	0.000
SR-Q1	0.03	0.04	0.03	0.04	46	0.000	0.07	0.05	0.04	0.05	19	0.000	0.02	0.09	0.05	0.08	51	0.000
SR-Q2	0.01	0.03	0.02	0.02	170	0.000	0.00	0.03	0.02	0.02	157	0.000	0.00	0.01	0.01	0.01	73	0.000
SR-Q3	0.00	0.00	0.00	0.00	133	0.000	0.00	0.02	0.00	0.01	97	0.000	0.00	0.00	0.00	0.00	55	0.000
SR-Q4	0.00	0.00	0.00	0.00	1	0.533	0.00	0.00	0.00	0.00	4	0.153	0.00	0.00	0.00	0.00	23	0.000
SR-Q5	0.03	0.05	0.05	0.05	81	0.000	0.01	0.08	0.02	0.06	110	0.000	0.00	0.02	0.03	0.02	74	0.000
SR-Q6	0.02	0.04	0.04	0.03	198	0.000	0.01	0.06	0.02	0.04	123	0.000	0.00	0.01	0.02	0.01	60	0.000
SR-Q7	0.08	0.31	0.45	0.23	2	0.364	0.07	0.15	0.09	0.13	7	0.038	0.05	0.14	0.07	0.12	21	0.000
SR-Q8	0.04	0.13	0.19	0.10	544	0.000	0.02	0.07	0.11	0.06	163	0.000	0.04	0.08	0.14	0.09	134	0.000
SR-Q9	8.08	6.67	7.73	7.29	23	0.000	11.06	10.65	6.71	10.35	7	0.031	9.37	13.84	14.22	13.76	35	0.000
SR-L1	0.07	0.09	0.05	0.08	218	0.000	0.08	0.10	0.05	0.09	26	0.000	0.10	0.16	0.14	0.15	73	0.000
SR-L2	0.21	0.25	0.26	0.23	236	0.000	0.24	0.25	0.28	0.25	39	0.000	0.20	0.20	0.21	0.20	26	0.000
SR-L3	0.55	0.55	0.50	0.55	68	0.000	0.57	0.51	0.45	0.52	8	0.019	0.46	0.39	0.43	0.41	46	0.000
SR-L4	0.16	0.21	0.21	0.19	168	0.000	0.21	0.23	0.22	0.22	27	0.000	0.19	0.17	0.18	0.17	4	0.117
SR-L5	77.61	80.15	79.75	79.13	38	0.000	73.34	74.49	76.33	74.42	8	0.020	71.67	74.69	75.93	74.88	10	0.007
A1	220.1	119.8	99.4	157.3	449	0.000	177.4	111.3	125.7	127.1	67	0.000	196.7	107.8	96.7	108.6	113	0.000
A2	15.04	15.54	15.70	15.36	6	0.039	17.84	18.76	18.43	18.53	1	0.762	20.98	19.40	20.51	19.74	14	0.001
A3	498.5	266.9	230.1	354.3	428	0.000	384.9	242.2	260.9	275.2	61	0.000	388.0	226.6	200.4	226.6	115	0.000
A4	345.2	198.8	166.5	253.3	485	0.000	297.5	189.4	207.3	214.7	69	0.000	291.2	188.0	170.4	187.8	111	0.000
A5	0.52	0.22	0.02	0.32	946	0.000	0.46	0.17	0.06	0.22	106	0.000	0.14	0.08	0.04	0.07	104	0.000
A6	55.96	24.33	9.82	35.57	936	0.000	38.25	22.09	16.41	25.05	53	0.000	25.14	28.81	27.46	28.33	43	0.000

the region determining a further increase in socioeconomic disparities (Conacher and Sala, 1998). Although the economic geography of Mediterranean Europe progressively changed as far as income levels, population density, and land-use distribution are concerned, the intensity of territorial disparities maintained stable confirming the strong influence local socioeconomic contexts have on environmental factors and landscapes (Salvati and Zitti, 2008).

At the national level, the results of the present study indicate how land vulnerability to desertification is associated to increasing population density, crop intensification, unsustainable agricultural practices (as far as irrigation and water distribution are concerned) and fragile economies. According to previous studies (Trisorio, 2005), the main underlying drivers may include the lack of capital and investments especially in marginal rural areas, shortage of labor, poor extension services, inadequate incentives for sustainable practices and restricted institutional support. However, our results pointed out also how the socioeconomic factors associated to economically-disadvantaged rural areas experiencing depopulation, are generally less important in the discrimination of vulnerable areas in Italy than factors associated to intensive-farming, peri-urbanization and sprawl. These findings are quite interesting since 'land abandonment' has often been considered as a crucial driver of land degradation in developed areas (Conacher and Sala, 1998; Boardman et al., 2003; Iosifides and Politidis, 2005; Corbelle-Rico et al., 2012).

Results highlight also a diverging socioeconomic profile of vulnerable areas in northern and southern Italy; this could be due to the different long-term path of economic development experienced by these regions. Results can be generalized to other contexts with similar characteristics in the Mediterranean basin. As a matter of fact, a renewed understanding of the north–south divide in Italy (and likely in the whole southern Europe) could reveal its wide-range impacts and causes, extending well beyond the industry-service dichotomy, and involving socioeconomic processes acting at the regional scale (Salvati and Zitti, 2008).

Even if rural development and agricultural variables maintained their role in discriminating areas classified at low- and high-vulnerability, the importance of demographic processes (e.g. population structure and dynamics, aging, family size) and wealth (e.g. disposable income, revenues from taxes, infrastructures) is higher in southern Italy than in northern Italy where, on the contrary, the human settlement dimension is gaining strength. This suggests a role for peri-urbanization in shaping the future vulnerable areas in Italy (Salvati and Zitti, 2009). Interestingly, the *proxies* for natural resource management (including water, soil, and crop systems) considered in the present study indicate, especially in southern Italy, a possible impact of unsustainable agricultural practices on land quality and desertification risk. This confirms the hypothesis of an environmental downward spiral driven by land mismanagement (Salvati et al., 2011). On the other hand, natural areas and high-quality landscapes, usually under strict environmental regulations (e.g. national parks), are mainly found in non-vulnerable areas. This indicates the need for effective policies protecting the relict natural land in vulnerable areas (Sirami et al., 2010).

5. Conclusions

The development of prospective socioeconomic scenarios in vulnerable and non-vulnerable areas could be a tool informing multi-target sustainable land management policies against desertification. In order to explore future scenarios under various assumptions dealing with *e.g.* climate changes, urbanization, demographic trends, social and economic changes, it seems meaningful to consider the links between current and past land-uses, territorial contexts and land degradation in a diachronic perspective (Marathianou et al., 2000; Danfeng et al., 2006; Corbelle-Rico et al., 2012). The methodology illustrated in the present study may contribute to shed lights to these links. A further implementation of these studies could be to develop a map of land vulnerability to desertification according to the socioeconomic profile of each local area. This could improve also permanent monitoring programs of land vulnerability at the country scale based on the ESAI.

In the coming future, scenario analysis at the local scale will be also necessary to define a policy strategy aimed at improving the environment conditions according to the bargaining power of the social actors concerned by land degradation. The local municipality is a meaningful unit of analysis, as demonstrated in the present study. Comparative case studies concerning the responses to land degradation in different local contexts are integrative tools (Briassoulis, 2011), in so far as the understanding of these policies is underpinned by a comprehensive presentation of the political, cultural, socioeconomic, and institutional settings of land vulnerable to desertification.

Conflict of interest

The author declares no conflict of interest.

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