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The local-scale impact of soil salinization on the socioeconomic context: An exploratory analysis in Italy

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ABSTRACT

Soil salinization is a relatively common form of soil degradation in Europe threatening coastal areas and fertile lowlands and altering the long-term interplay between natural and human factors at the local scale. While rural areas with degraded soils are often characterized by poverty, unemployment and subsidence agriculture, less information is available on the relationship between soil salinization and various socioeconomic profiles typically observed in Mediterranean Europe. Using a large set of territorial indicators made available at the municipal scale in Italy, the present study explores the spatial correlation between an index of vulnerability to soil salinization and six socioeconomic domains (population structure/dynamics and human settlements, labor market and human capital, economic specialization and competitiveness, quality of life, agriculture and rural development, landscape and environment). An exploratory data analysis was carried out to derive a socioeconomic profile of the municipalities with low and high vulnerability to soil salinization. Results indicate that the socioeconomic profile of vulnerable areas is characterized by specific rural development variables, income patterns and socio-demographic structure. Young population, density of bank deposits, crime intensity, high density of workers, and a land-use structure dominated by irrigated crop and discontinuous built-up areas with a lower per-worker crop surface are the indicators contributing the most to determine the profile of rural communities in areas vulnerable to soil salinization. An in-depth knowledge of the socioeconomic context and socio-environmental relationships on a local scale may contribute to design effective policies of soil conservation and sustainable land management strategies.

1. Introduction

Processes leading to irreversible phenomena of soil degradation affect progressively larger areas in developed regions (Millennium Ecosystem Assessment, 2005). Soil degradation depends on the multifaceted and dynamic interaction between natural factors (e.g. climate, topography, soil, vegetation) and anthropogenic processes (e.g. urbanization and soil sealing, deforestation, clearcutting and forest fires, overgrazing, habitat fragmentation and biodiversity loss). The role of human factors as a key driver of soil degradation has been occasionally studied (Marathianou et al., 2000; Geist, 2005; Gisladottir and Stocking, 2005; Wilson and Juntti, 2005; C. Ferrara et al., 2014). The unsustainable use of land together with poor management practices, has been considered an important factor in the degradation of the soil resource base (Blaikie and Brookfield, 1987; Reynolds and Stafford-Smith, 2002; Boardman et al., 2003; Portnov and Safriel, 2004; Iosifides and Politidis, 2005; Lazarus, 2014; Salvati et al., 2009). Soil degradation may be particularly intense in rural areas characterized by persisting poverty, 'locked' socio-demographic conditions, increased pressures on ecologically-fragile areas, and territorial disparities consolidated by weak economic performances and non-competitive production systems, mainly based on agriculture (Danfeng et al., 2006; Wang et al., 2006; Salvati, 2010; Abu Hammad and Tumeizi, 2012; A. Ferrara et al., 2014).

Soil salinization is a cause of land degradation leading to localized processes of desertification (Conacher and Sala, 1998). Although different salts (in particular, chlorides and sulfates of sodium and magnesium) are present in relatively high proportions in many of the lower soil layers, the excessive salt accumulation in the root layer results in a partial loss of crop productivity. The concentration of salts obstructs the normal absorption of water and nutrients, and it determines a change in the characteristics of the soil itself (Costantini and Dazzi, 2013).

The salts accumulated in the soil come from weathering processes of rocks (determined by different factors such as lithology, geomorphology, climate and human pressure) in which water plays a fundamental role, or from processes related to the accumulation of sea salts in the areas adjacent to the sea. The phenomenon of salinization is usually divided in two different issues: (i) a natural process (primary salinization), and (ii) a human-induced salinity (secondary salinization). The first is due to the substrate on which the pedogenic soil evolves (saline

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rock types or even soils consisting of clay substrates of sea origin: Dazzi, 2006). The second one is usually determined by irrigation with brackish water, but also derived from other forms of unsustainable use of land. The effect of salinity is exacerbated when these processes affect sensitive soils such as those formed by carbonates and clay (Costantini and Dazzi, 2013).

One of the main factors determining soil salinization is the unsustainable use of water resources. The negative impact is greater when high water consumption for drinking use is accompanied by an increasing supply by groundwater pumping near the coast, resulting in saline intrusion (Salvati et al., 2011). Different irrigation techniques can be more or less impacting with respect to secondary salinization (Herrero and Pérez-Coveta, 2005). Fruit and vegetables, vineyards, olive groves and, in some cases, arable land are crops determining a major water consumption (Perini et al., 2008; Ferrara et al., 2013). Increased groundwater pumping for civil use due to urban expansion and settlement sprawl, especially in flat and coastal areas, is another driver of soil salinization (Costantini et al., 2009). Particularly impactful is the water pumping determined by industry and tourism development in ecologically-fragile coastal areas (Darwish et al., 2005), which sometimes has the effect of limiting the water available for agriculture to lesser quality water (e.g. saline or polluted), thus determining a vicious spiral towards soil degradation (Dazzi, 2006). Lastly, overgrazing and deforestation are other important factors contributing to soil salinization and resulting in a longer-term action with consequent alteration of the hydrological cycle and soil fertility (European Soil Bureau, 2014).

Although raising concern at both global and regional levels, soil degradation cannot be convincingly explained as a phenomenon depending on changes in biophysical factors alone (Wessels, 2007), since it rarely occurs without the action of anthropogenic drivers (Sivakumar and N'diangui, 2007; Safriel and Adeel, 2008; Romm, 2011). Soil salinization provides an indirect confirmation to this hypothesis, since it is influenced by the socioeconomic context and in turn affects it in a variable manner according to the geographical context and the degree of development (Montanarella, 2007). Land-use transformations reflecting urbanization, industrialization, tourism and infrastructure development, and crop intensification determining the increased socioeconomic divide among coastal and internal regions are thus considered as candidate drivers for soil salinization (Conacher and Sala, 1998; Atis, 2006; Abu Hammad and Tumeizi, 2012).

In Europe, soil salinization is regarded as a major cause of desertification (Montanarella, 2007) and a serious form of soil degradation affecting 1 to 3 million hectares of land (primarily cropland) concentrated in the Mediterranean countries (European Soil Bureau, 2014). Unfortunately, the intimate link between rural development, local communities and the territorial context has been marginally explored in relation to the degree of soil salinization in southern Europe (Wilson and Juntti, 2005). Few studies using indirect approaches have dealt with specific territorial contexts (e.g. Iosifides and Politidis, 2005), and the description of the spatial conditions influencing, maybe, soil salinization was based on a restricted set of biophysical and socioeconomic indicators (Atis, 2006). By assessing the role of selected factors shaping the risk of desertification at the global scale, Kosmas et al. (2003) and Basso et al. (2010) identified some socio-demographic and institutional variables influencing over time and space the risk of soil salinization in a non-linear way. At the same time, Imeson (2012) reviewed the effect of selected socioeconomic drivers on land degradation in the Mediterranean region and provides evidence in line with what was found by Kosmas et al. (2003).

The present study proposes an exploratory analysis of the spatial distribution of an index of vulnerability to soil salinization in relation with a number of socioeconomic and territorial indicators in Italy, a Mediterranean country experiencing increased risk of soil salinization in the last decades (Perini et al., 2008). A multi-dimensional approach based on a large set of socioeconomic and territorial indicators analyzed through descriptive, inferential and multivariate statistics has been developed with the aim to identify the attributes that had better characterized the Italian municipalities experiencing high vulnerability to soil salinization. The in-depth knowledge of territorial characteristics and local community profiles allows one to assess latent socioeconomic patterns (Salvati et al., 2013) affecting (and in turn being influenced by) the spatial distribution of specific soil attributes (Iosifides and Politidis, 2005). The local-scale analysis covering the whole country at the scale of municipalities — intended as a spatial unit suitable to describe the main socioeconomic characteristics of the local communities and the related territorial context (Salvati, 2014), offers an original, joint contribution to soil science, geography and planning disciplines. In southern Europe, the socioeconomic profile of local communities – especially in rural areas – reflects the complexity of demographic, socio-cultural, political and economic factors shaped by the millenary interaction between nature and humans (Conacher and Sala, 1998; Salvati, 2010; Sirami et al., 2010).

2. Methodology

2.1. Study area

The investigated area covers the whole Italian territory (301,330 km^2 with 23% flat areas, 42% hilly areas, and 35% mountains). Italy is characterized by biophysical and socioeconomic disparities between northern and southern areas, with differences observed in climate regimes, landscapes, vegetation, soil and cropping systems, income and wealth, labor market and demography (Salvati and Carlucci, 2011). Italian land is administered by twenty regions and more than 8000 municipalities. The administrative asset of 2001 was selected in this study as the reference spatial unit (8100 municipalities) to enable an effective matching between environmental and socioeconomic data (Istat, 2006). The local governance system changed only moderately in 2013 (nearly 8070 municipalities).

Italy is considered a hotspot for land degradation in the Mediterranean region (Costantini and Dazzi, 2013). Consequently, salinization constitutes an important cause of soil degradation (Salvati et al., 2011), although a comprehensive map of saline soils is not yet available. According to Dazzi (2006) the areas with the highest concentration of saline soils in Italy are the lower Po valley, some long stretches of the Tyrrhenian coast (and especially the coastal plains of Pisa, Livorno and Grosseto), some areas in Latium and Campania (respectively close to Rome and Naples), and the coastline of Apulia, Basilicata and Sardinia, together with sparse agricultural districts formed by few municipalities in Sicily. Based on the results of a study on land degradation vulnerability driven by soil salinization in Italy and using the spatial distribution of potentially saline aquifers as a proxy indicator, Costantini et al. (2009) identified large areas at risk of salinization along the Tyrrhenian coast (Tuscany, Latium, Campania), and along the Adriatic and Ionian coasts of Apulia, Basilicata and Calabria, together with wide areas of Sicily and Sardinia. In recent years soil salinization consolidated in southern Italy with some well documented case-studies such as the traditionally cultivated plains of Sybaris in Calabria and Metapontum in Basilicata (see Perini et al., 2008 and the references therein). During the last decades, the majority of the above-mentioned areas experienced crop intensification. This relatively rapid process has led to an unsustainable use of groundwater for irrigation to fulfill the water requirement of both herbaceous crops (sugar beet, corn, sunflower, vegetables) and specialized high-income tree crops (vineyards, peach orchards, citrus groves) during the dry season (Perini et al., 2008; Costantini et al., 2009; Salvati, 2014).

2.2. Assessing vulnerability to soil salinization

The salinization of the soil is a process by which water-soluble salts (sodium, magnesium, calcium, chloride, sulfate, carbonate and bicarbonate) accumulate in the soil reducing its fertility (Tóth et al., 2008). Salt decreases the osmotic potential of the soil so that plants find progressively difficult to take up water from it. Salts can also have a direct effect being toxic for plants: the consequence is a serious reduction of soil fertility. According to Van-Camp et al. (2004), salinization may occur naturally ('primary' salinization) or due to unsustainable management practices ('secondary' salinization). The multifaceted association of soil salinization with the socioeconomic local context is difficult to define and assess objectively because soils are inherently variable over space and susceptible to multiple uses (Montanarella, 2007).

Since there are limited and localized field data quantifying these processes, proxies are generally used for the definition of areas exposed to salinization risk or the identification of vulnerable land to soil salinization (see Salvati et al., 2011 and the references therein). Given the lack of data suitable to provide a comprehensive overview of this phenomenon at both the national and regional levels in Italy, Costantini et al. (2009) proposed a Geographic Information System approach to define the potential saline areas, or where excessive water pumping can lead to a progressive salinization of the soil. This indicator was constructed by overlapping a 'buffer' strip of land within 6 miles from the coastline, potentially vulnerable to soil salinization, with areas characterized by a share of less than 10 m above sea level and the presence of salt rock types. The resulting areas were considered at risk of primary salinization.

Based on these premises, the present study classified the Italian municipalities into areas with soil potentially exposed to soil salinization. According to Salvati et al. (2011), the surface area, potentially exposed to primary salinization, was determined by the spatial intersection between (i) areas with saline rock types, thanks to the Geological Map of Italy (produced at the 1:500,000 scale by the national Institute of Environmental Protection and Research: ISPRA, Rome) and (ii) areas < 10 km distant from the sea coast with elevation < 10 m, based on the global digital elevation model at 30-m resolution scale generated from stereoscopic pairs of optical Advanced Spaceborne Thermal Emission and Reflection Radiometer images and freely available online at http://www.gdem.aster.ersdac.or.jp/ (Salvati et al., 2013). Areas potentially exposed to secondary salinization have been identified as the spatial overlay among particularly sensitive soils to saline water use (class derived from the Geological Map of Italy), and three proxies of unsustainable water use for irrigation: (i) farms practicing groundwater irrigation and (ii) equipped with obsolete irrigation systems, and (iii) farms with no diversification in the source of water used for irrigation (Salvati et al., 2011). These variables were calculated at the municipal scale based on data provided by the Italian National Census of Agriculture (2000) held by the Italian National Statistical Institute (Istat).

The percent area classified as potentially exposed to soil salinization in each Italian municipality has been finally determined through the spatial statistics tool provided with ArcGIS software (ESRI Inc., Redwoods, USA) after the overlap between the soil salinization vector map and the shapefile describing the administrative boundaries of each municipality in Italy provided by Istat (Salvati et al., 2013). The resulting output was mapped at the municipal scale and compared for spatial coherence with previous studies carried out at the national level (Dazzi, 2006; Costantini et al., 2009) and with the European Soil Bureau map of saline soils in Europe (European Soil Bureau, 2014). The percent area classified as potentially exposed to soil salinization was verified for completeness and reliability together with indicators assessing different soil degradation processes (Salvati et al., 2011) and then used in a multi-temporal geographic information system monitoring soils in Italy (Salvati et al., 2013).

Two proxy indicators for soil salinization have been derived from this variable. A binary indicator of vulnerability to soil salinization was developed with the aim to identify non-vulnerable municipalities (i.e. with 0% vulnerable surface area) and vulnerable municipalities (i.e. with a surface area potentially exposed to soil salinization ranging between 1% and 100%). Since the impact of soil salinization on the socioeconomic context may increase with the extent of vulnerable areas in each municipality (Perini et al., 2008), the percent area classified as potentially exposed to soil salinization (ranging from 1% to 100%) was considered as a proxy indicator for soil degradation intensity.

Additional physical, chemical or biological variables may contribute to represent soil salinization spatial patterns but these indicators are based on local scale surveys or on larger scale surveys with a low spatial resolution (Montanarella, 2007). Therefore, these variables were not considered in the analysis. The rationale was to guarantee high temporal and spatial data coverage collecting indicators from available technical services and official data sources with no additional mapping costs (Salvati, 2014; Marzaioli et al., 2010). Moreover, working on a national scale provides results potentially more interesting than a single pilot study on a local scale (Salvati and Bajocco, 2011).

2.3. Socioeconomic and territorial indicators

Data used in the present study (see list in Appendix A) have been derived from official statistical sources (primarily from Istat), and refer to 2000 or 2001. These years represent the most recent point in time with enough large availability of socioeconomic indicators on a municipal scale in Italy. Changes in census techniques, the unavailability of some variables for the most recent years, the dissemination program for several variables encompassing 2014 or, in some cases, 2015 have prevented us to collect a comparably wide and comprehensive dataset for the most recent period. At the same time, working with 2000–2001 data allows a direct match with soil data collected along the 1990s (Perini et al., 2008) which formed the primary information base for developing soil salinization indicators in Italy (Salvati et al., 2011).

122 indicators have been calculated from the collected variables for each Italian municipality. They are classified into six thematic domains (population dynamics and human settlement, labor market and human capital, economic specialization and competitiveness, quality of life, agriculture and rural development, territory and environment) and 16 analysis' dimensions (see list in Table 1). The collected set of indicators is intended to provide a comprehensive profile of the social, demographic, economic, cultural, political and institutional structure of Italian municipalities (Salvati, 2014). The selection of indicators, adequate to describe the local socioeconomic context affecting (and in turn being influenced by) soil salinization, was set up following Salvati (2014), according to the suggestions provided by Rubio and Bochet (1998), Trisorio (2005), Perini et al. (2008) and Salvati et al. (2013).

Table 1
Thematic domains and analysis dimensions referring to the indicators considered in the present study (see Appendix A for the complete list of indicators).

Thematic domains	Analysis dimension	Number of indicators
Population dynamics and human settlement	Settlement characteristics (I)	6
	Population structure (P)	7
Labor market and human capital	Job market (L)	14
	Education (F)	6
Economic specialization and competitiveness	Economic structure (S)	17
	Tourism (T)	7
Quality of life	Income and wealth (Q)	17
	Crime and society (D)	4
Agriculture and rural development	Land tenure (SR-A)	5
	Landscape characters (SR-P)	8
	Crop intensity (SR-M)	4
	Innovation and quality in agriculture (SR-Q)	9
	Human capital in agriculture (SR-L)	5
	Water use/management (A)	6
Territory and environment	Spatial and functional structure of regions	7
	Soil degradation	3

2.4. Data analysis

Fig. 1 illustrates the main analysis steps carried out in the present study. First, the surface area, the resident population and the number of municipalities classified as vulnerable and non-vulnerable to soil salinization have been calculated. Second, a Mann–Whitney non-parametric test was carried out separately for each socioeconomic and territorial indicator to identify differences among vulnerable and non-vulnerable municipalities. Indicators showing significant differences between vulnerable and non-vulnerable municipalities were identified testing at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

The subsequent steps have been developed by considering only municipalities classified as 'vulnerable' to soil salinization (i.e. by removing municipalities with 0% vulnerable surface area from the analysis). This step allowed one to consider only municipalities with similar biophysical conditions concentrated in specific Italian areas (e.g. along the coastline: see Fig. 2) but with possibly different socioeconomic contexts (Salvati et al., 2013) shaped by e.g. the north–south divide previously described (see Section 2.1). A partial data matrix with 1269 rows corresponding to the municipalities identified as vulnerable to soil salinization and the 122 socioeconomic and territorial indicators have been used as the input matrix for this analysis step. A non-parametric pairwise Spearman analysis was carried out with the aim to correlate the percent area classified as potentially exposed to soil salinization (ranging from 1% to 100%) in every vulnerable municipality with each socioeconomic indicator separately. Significant correlation coefficients were identified testing at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

Based on correlation matrix, a Principal Component Analysis (PCA) was developed on the data matrix composed of 122 socioeconomic indicators measured at 1269 vulnerable municipalities with the aim to summarize the latent factors that profile the different socioeconomic contexts found in Italy, and to identify the eventual relation with the spatial distribution of municipalities classified at different degree of vulnerability to soil salinization. The number of relevant components (m) was chosen by selecting those with eigenvalue > 5 owing to the high number of input variables. To evaluate the appropriateness of the factor model to analyze the original data, the Keiser–Meyer–Olkin 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.

Component loadings were used to assess the latent relationships among socioeconomic/territorial indicators and soil degradation variables. Loadings close to $|1|$ identify the indicators mostly associated with the percent area potentially exposed to soil salinization in each municipality. Indicators are considered correlated to a given component when the respective loading is $>|0.5|$. Finally, a hierarchical clustering using Euclidean distance and Ward's agglomeration rule was carried out on the same matrix to assess the similarity in the spatial distribution of the investigated socioeconomic indicators and the percent area potentially exposed to soil salinization at the municipal scale in Italy. Results of the multivariate analysis provide relevant information to assess the socioeconomic profile of municipalities with different extent of potential soil degradation driven by soil salinization (Salvati, 2014).

3. Results

3.1. Descriptive statistics

The distribution of percent land potentially exposed to soil salinization is mapped in Fig. 2 at the municipal scale in Italy and shows a homogeneous spatial pattern with vulnerable municipalities concentrated along the coastal areas and in specific flat areas close to the sea. 1269 municipalities have been identified with at least 1% of the administered land classified as potentially exposed to soil salinization. Vulnerable municipalities cover 24.3% of the country surface area, and host 37.5% of Italian resident population (Table 2). Population density in the 1269 vulnerable

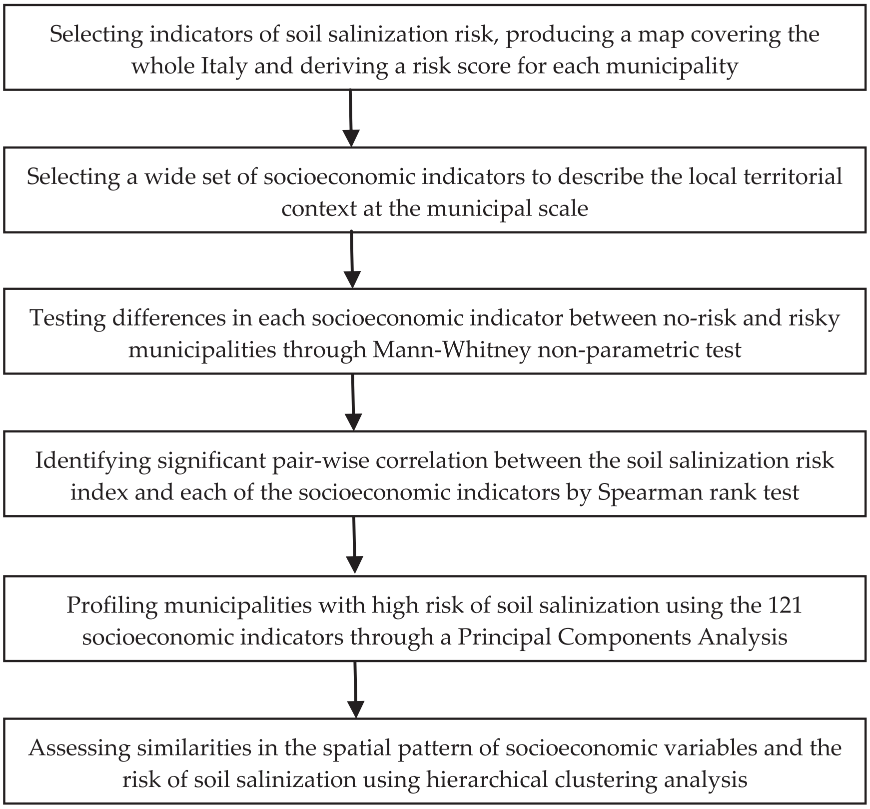

Fig. 1. A flow-chart describing the main steps of this study.

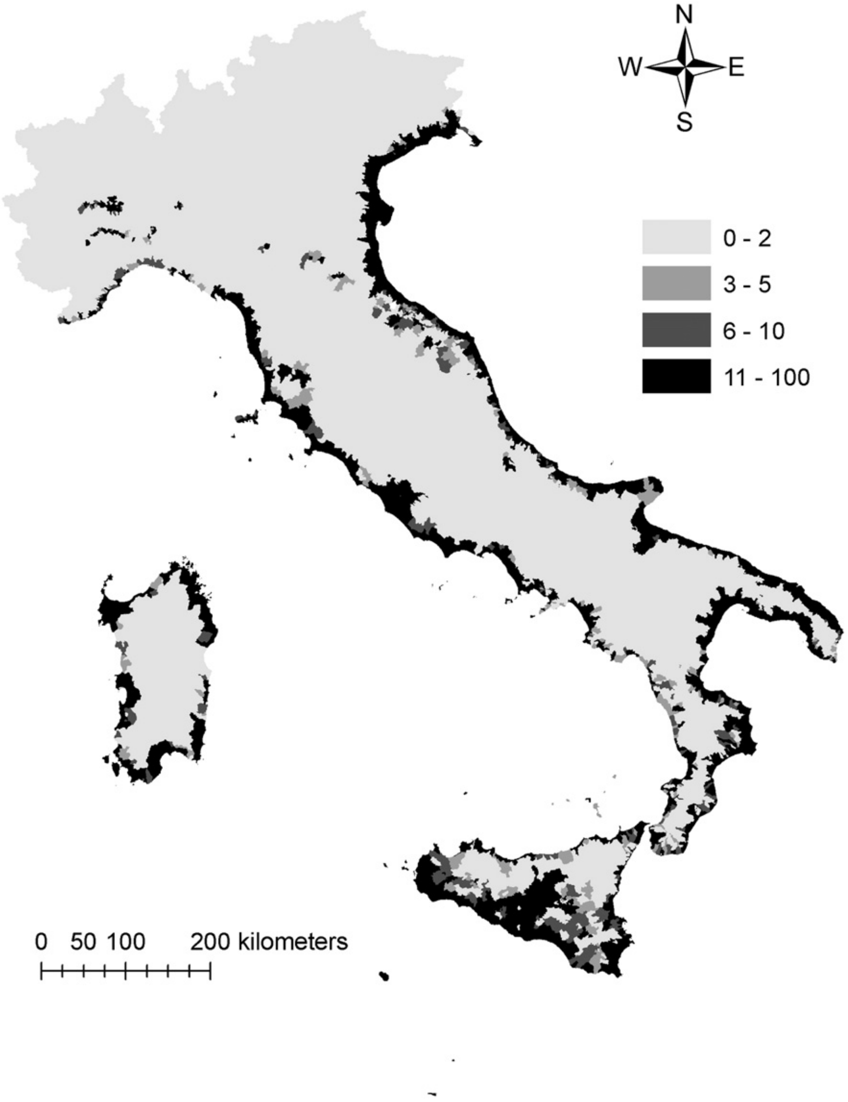

Fig. 2. Percentage of vulnerable area to soil salinization in each Italian municipality.

municipalities was found higher (292 inhabitants/km^2) than that observed in the remaining 6831 non-vulnerable municipalities (156 inhabitants/km^2). Only 8% of northern Italian municipalities are vulnerable to soil salinization, but the percentage increases in central Italy (25%) and in southern Italy (39%). Municipalities with >10% of land potentially exposed to soil salinization are primarily distributed along the Italian coasts and in Sicily and Sardinia lowlands.

Table 2
Selected demographic and territorial attributes of the Italian municipalities classified as vulnerable or non-vulnerable to soil salinization.

Variable	Non-vulnerable	Vulnerable
Resident population (inhabitants)	35,642,295	21,351,182
% distribution in Italy	62.5	37.5
Population density (inhabitants/km^2)	156	292
Total surface area (km^2)	228,260	73,074
% distribution in Italy	75.7	24.3
% distribution in northern Italy	91.8	8.2
% distribution in central Italy	74.5	25.5
% distribution in southern Italy	60.7	39.3
Number of municipalities	6831	1269

3.2. Testing differences in the spatial distribution of socioeconomic indicators among vulnerable and non-vulnerable municipalities

Pair-wise Mann–Whitney tests comparing the spatial distribution of each of the 122 socioeconomic indicators in vulnerable and non-vulnerable municipalities (Table 3) identified 62 indicators with significant differences in the two classes. The research dimensions with the highest number of significant indicators were territory/environment (60% of indicators are significantly different in vulnerable and non-vulnerable municipalities), labor market/human capital (60%), agriculture and rural development (49%), population dynamics/human settlements (46%), economic specialization and competitiveness (45%) and quality of life (38%). The largest differences were observed for Ele, L2, Q8, L6, and Q4 (higher values found in non-vulnerable municipalities) and for S4, SR-P3, L3, L4 and L7 (higher values found in vulnerable municipalities). These findings suggest that vulnerable municipalities share a specific socioeconomic profile (based on agriculture, labor market and quality of life variables) compared with the remaining Italian municipalities. Attributes mostly discriminating between vulnerable and non-vulnerable areas include perennial crop area (prevailing on other crops in vulnerable areas), unemployment rate and participation rate (respectively higher and lower in vulnerable areas) and revenues from income tax (higher in vulnerable areas).

Table 3
Results of pair-wise Mann–Whitney tests (adjusted Z statistic) applied to the distribution of the selected socioeconomic indicators in vulnerable and non-vulnerable municipalities to soil salinization (only significant comparisons at $p < 0.05$ after Bonferroni's correction for multiple comparisons are shown; see Table 1 and Appendix A for abbreviations).

Variable	Adj-Z	Variable	Adj-Z	Variable	Adj-Z
Ele	24.6	Q5	−10.5	P1	−15.6
L2	24.1	SR-L1	−10.9	SR-Q2	−16.6
Q8	23.1	S7	−11.0	S15	−16.9
L6	22.5	I5	−11.1	S9	−18.2
Q11	21.2	SR-M2	−11.1	SR-Q8	−18.4
SR-A3	19.9	SR-Q3	−11.4	T2	−18.6
I6	19.5	T4	−11.5	SR-M4	−19.3
SR-P4	19.2	SR-P5	−11.7	F5	−21.2
SR-L3	18.9	Q3	−12.3	SR-Q9	−21.2
L1	17.0	S16	−12.4	Esa	−21.3
L5	16.0	Sup	−12.6	D1	−21.6
SR-A1	15.0	SR-Q6	−12.7	Cou	−23.8
S6	14.3	I1	−12.9	F6	−23.9
Q2	13.9	Den	−12.9	L8	−26.2
D4	12.8	F4	−13.0	Sou	−26.3
P6	12.8	T1	−13.1	L4	−27.7
SR-P6	11.9	F1	−13.2	L7	−28.0
A5	11.1	D3	−13.4	L3	−28.8
P4	10.7	S17	−14.1	SR-P3	−29.9
T6	−10.3	SR-Q1	−14.6	S4	−31.8
SR-P8	−10.4	SR-Q5	−14.9		

3.3. Exploring latent relationships between the socioeconomic context and vulnerability to soil salinization

By restricting the analysis to the 1269 vulnerable municipalities, non-parametric Spearman rank tests were used to correlate pair-wise the percentage of land potentially exposed to soil salinization (1%–100%) and the spatial distribution of each socioeconomic indicator (Table 4). The analysis identified 38 indicators with significant (positive or negative) correlation with soil salinization. Among these indicators, the research dimensions with the highest number of significant correlations were population dynamics/human settlements (54%), territory/environment (50%), quality of life (43%), economic specialization and performances (33%) and agriculture/rural development (22%). No significant indicators were observed for labor market/human capital domain. The percentage of land potentially exposed to soil salinization was negatively associated with the elevation gradient. The highest positive correlation coefficients were observed for SR-Q8, SR-M2, S4, D1 and I1. The positive correlation among the extent of areas exposed to soil salinization in each municipality, the percentage of cultivated land and sustainable irrigation (i.e., using water collected from other sources rather than groundwater, e.g. from open reservoirs collecting rain water) are particularly interesting for policy implementation. The share of irrigated land to the total utilized agriculture area, the share of developed land to the total municipal surface area and crime intensity index also increased with the extent of soil salinization. Negative correlations have been observed for P5, SR-P6,-A5, SR-P4 and P3; this indicates a specific land-use composition for the areas potentially exposed to soil salinization together with lower water reservoir density for urban uses and younger population structure (lower dependency ratio and share of population > 75 years).

Table 4
Results of pair-wise non-parametric Spearman rank correlation analysis applied to the percent area classified as vulnerable to soil salinization in each municipality and the spatial distribution of each selected socioeconomic indicator (only significant comparisons at $p < 0.05$ after Bonferroni's correction for multiple comparisons were showed; see Table 1 and Appendix A for abbreviations).

Variable	Spearman ρ	Variable	Spearman ρ
SR-Q8	0.39	S7	0.20
Low	0.38	S13	0.19
SR-M2	0.35	I3	0.19
S4	0.33	Q9	0.18
D1	0.31	S9	0.18
I1	0.30	I2	0.17
Den	0.30	Var	0.17
S2	0.30	Q10	0.17
D3	0.30	S17	0.16
Esa	0.29	S12	0.16
SR-A5	0.27	P4	−0.17
SR-M4	0.26	P2	−0.19
Q6	0.25	SR-M3	−0.23
Q5	0.25	P3	−0.26
Q7	0.24	SR-P4	−0.27
Q3	0.24	A5	−0.32
SR-P2	0.23	SR-P6	−0.33
Q4	0.22	P5	−0.35
T2	0.21	Ele	−0.47

3.4. Multivariate exploratory analysis

The results of the Principal Component Analysis carried out on the matrix composed by the 1269 Italian municipalities classified as vulnerable to soil salinization and the 122 socioeconomic indicators are reported in Table 5. The Keiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity ($p < 0.001$) indicate that the factor model is appropriate to analyze the original data matrix. The PCA extracted four components with eigenvalue > 5, which explain a cumulated variance of more than 34% of the total variance (Fig. 3). The variance explained by the four principal components is high enough if considering the large number of input variables. Component 2 (9.3% of the total variance) is particularly relevant for our study owing to the positive correlation with the percentage of land potentially exposed to soil salinization (loading = 0.55). Other 16 indicators were found (positively or negatively) associated to component 2 (I1, S2, Q3–Q7, D1, and SR-M2 with positive loadings, and I6, P2–P5, SR-M3 and Ele with negative loadings). This output underlines the evidence from Spearman correlations, showing a specific socioeconomic profile for the communities that are exposed to soil salinization (young-population structure, economic wealth, high-crime intensity, high density of workers, and a land-use type with a larger proportion of irrigated crop and discontinuous built-up areas).

The other three components identify socioeconomic attributes of Italian local communities not related to soil salinization. Component 1 (15% of the total variance) identifies the north–south gradient shaping disparities in labor market, education and quality of life indicators as well as in specific agricultural and economic variables. Component 3 (7% of the total variance) represents an urban–rural gradient based on (i) the share of cultivated land on total municipal area and agricultural landscape diversity in turn associated positively with the share of workers in manufacture and negatively with the share of workers in tourism, (ii) a lower percentage of non-occupied houses, (iii) families with more than 3 components, and (iv) lower per-capita real estate tax revenues and per-capita water consumption. Finally, component 4 (4% of the total variance) identifies marginal and economically disadvantaged municipalities with population decline, low education level, and a less-than-average percentage of discontinuous settlements.

Similarities in the spatial distribution of the socioeconomic indicators mostly associated with vulnerability to soil salinization in Italy have been investigated through hierarchical clustering (Fig. 4). A homogeneous group of variables (SR-Q8, SR-M4, SR-A5, P1, SR-P3, S2, I1, Cou) was identified with a spatial distribution similar to the percentage of land exposed to soil salinization. Clustering confirms the results of Spearman's correlations and the PCA depicting a quite comprehensive picture of the socioeconomic characteristics of vulnerable municipalities to soil salinization.

Table 5
Principal Component (PC) loadings of the socioeconomic and territorial indicators in Italy (see Table 1 and Appendix A for abbreviations).

Variable	PC 1	PC 2	PC 3	PC 4	Variable	PC 1	PC 2	PC 3	PC 4
I1	0.00	0.55	−0.04	0.12	T7	−0.38	0.12	0.41	0.20
I2	0.26	0.27	0.30	−0.60	Q1	0.50	−0.09	0.16	0.26
I3	−0.33	0.49	−0.19	0.22	Q2	0.68	0.10	0.21	0.01
I4	0.10	0.03	0.00	0.05	Q3	0.19	0.71	0.05	0.37
I5	−0.19	−0.19	−0.57	−0.20	Q4	0.43	0.61	−0.03	0.39
I6	0.53	−0.50	0.07	0.13	Q5	0.38	0.66	0.02	0.41
A1	0.15	0.14	−0.58	−0.14	Q6	0.44	0.61	0.03	0.32
A2	0.04	0.05	0.04	0.08	Q7	0.50	0.54	−0.03	0.36
A3	0.16	0.15	−0.57	−0.20	Q8	0.92	0.02	−0.07	0.13
A4	0.09	0.08	−0.56	−0.24	Q9	0.53	0.17	−0.50	−0.23
A5	0.19	−0.44	−0.19	−0.22	Q10	0.46	0.22	−0.47	−0.14
A6	0.01	−0.10	−0.24	−0.18	Q11	0.86	−0.02	−0.27	0.18
P1	−0.51	0.45	0.50	−0.18	Q12	0.71	0.13	−0.28	0.01
P2	0.39	−0.56	−0.37	0.36	Q13	0.38	0.14	0.06	−0.02
P3	0.38	−0.64	−0.31	0.45	D1	0.02	0.72	0.03	0.14
P4	0.50	−0.55	−0.35	0.36	D2	0.05	−0.37	−0.09	−0.16
P5	−0.03	−0.62	−0.24	0.49	D3	0.26	0.39	−0.23	−0.09
P6	0.63	−0.11	0.03	−0.14	D4	0.64	−0.07	0.28	−0.05
P7	−0.08	−0.08	0.29	−0.56	SR-A1	0.40	−0.03	0.18	−0.07
L1	0.63	0.20	0.41	−0.36	SR-A2	−0.12	−0.07	−0.15	0.01
L2	0.87	−0.03	0.31	−0.22	SR-A3	0.22	−0.14	0.17	0.01
L3	−0.86	0.26	−0.08	0.02	SR-A4	0.04	−0.39	0.47	0.21
L4	−0.84	0.28	−0.19	0.06	SR-A5	−0.12	0.14	0.52	0.21
L5	0.69	0.09	0.31	−0.20	SR-P1	0.08	−0.03	−0.32	−0.09
L6	0.87	−0.07	0.23	−0.12	SR-P2	0.38	0.04	0.46	0.11
L7	−0.85	0.26	−0.03	0.00	SR-P3	−0.28	0.11	−0.24	−0.03
L8	−0.85	0.25	−0.15	0.06	SR-P4	−0.18	−0.23	−0.33	−0.11
L9	0.07	0.34	0.38	0.14	SR-P5	−0.38	−0.05	0.11	0.07
L10	0.23	0.06	−0.13	0.16	SR-P6	0.03	−0.09	−0.33	−0.13
L11	0.10	−0.04	−0.06	0.00	SR-P7	0.03	−0.18	0.18	0.16
L12	0.02	−0.03	0.10	0.00	SR-P8	0.09	−0.15	0.66	0.27
L13	−0.01	−0.29	−0.07	0.04	SR-M1	0.46	0.05	0.14	−0.11
L14	−0.04	−0.03	0.09	−0.01	SR-M2	−0.05	0.52	0.05	−0.18
F1	0.32	0.37	−0.35	0.32	SR-M3	−0.10	−0.56	0.15	0.19
F2	0.51	0.38	−0.26	0.07	SR-M4	0.18	0.22	0.33	0.10
F3	−0.08	0.18	0.19	−0.51	SR-Q1	−0.09	−0.11	0.00	−0.04
F4	−0.69	0.04	0.25	−0.09	SR-Q2	0.33	−0.30	0.08	0.02
F5	−0.72	−0.14	0.24	0.10	SR-Q3	0.18	−0.21	0.01	0.00
F6	−0.72	−0.15	0.00	0.12	SR-Q4	0.03	−0.01	−0.10	−0.15
S1	0.24	0.24	0.26	0.07	SR-Q5	0.30	−0.36	0.11	0.13
S2	0.19	0.61	−0.08	0.20	SR-Q6	0.32	−0.32	0.12	0.08
S3	0.18	−0.35	0.10	0.08	SR-Q7	0.02	0.02	−0.08	−0.10
S4	−0.06	0.08	−0.02	−0.14	SR-Q8	−0.03	0.42	0.16	−0.15
S5	−0.07	−0.05	0.03	−0.06	SR-Q9	−0.15	0.31	−0.41	−0.14
S6	0.39	−0.12	0.56	−0.06	SR-L1	−0.37	−0.40	0.19	0.01
S7	−0.01	0.03	−0.06	0.05	SR-L2	0.41	−0.21	0.04	0.12
S8	−0.04	−0.29	0.01	−0.20	SR-L3	0.61	−0.23	0.09	−0.07
S9	−0.23	0.25	−0.13	−0.02	SR-L4	0.14	0.04	−0.14	0.11
S10	0.15	−0.01	−0.59	−0.37	SR-L5	0.07	−0.01	−0.06	0.07
S11	0.05	0.07	−0.10	−0.03	Den	0.00	0.41	−0.04	0.12
S12	0.19	0.46	−0.09	0.39	Var	0.26	0.27	0.30	−0.60
S13	0.24	0.36	−0.10	0.12	Cou	−0.36	0.20	0.03	0.27
S14	−0.42	−0.11	−0.29	0.31	Low	0.01	0.38	0.29	−0.05
S15	−0.71	−0.03	−0.09	0.16	Esa	−0.13	0.41	0.39	0.11
S16	−0.02	0.20	−0.09	0.31	Ele	−0.25	−0.52	0.05	0.28
T1	0.21	0.09	−0.43	−0.29	Sou	−0.86	0.16	0.00	0.01
T2	−0.06	0.29	−0.15	−0.13	Sup	−0.01	0.22	0.04	0.29
T3	0.36	0.39	−0.29	−0.03	Sqi	−0.05	0.01	0.00	0.00
T4	0.18	0.21	−0.19	0.04	Ero	0.00	−0.04	0.05	−0.02
T5	0.29	0.33	−0.18	−0.02	Sal	0.05	0.55	0.12	−0.11
T6	0.07	−0.11	0.06	0.02	*Var%*	*15.0*	*9.3*	*6.6*	*4.3*

4. Discussion and conclusions

In-depth knowledge of local communities and the territorial characteristics of land with vulnerable soils may contribute to inform policies mitigating human pressure on ecologically fragile areas (e.g. Nadal et al., 2009). Soil salinization is one of the most relevant degradation processes jeopardizing the potential use of European soils. The present study has developed an exploratory data analysis to investigate a 'territorial profile' – based on more than 100 input indicators – most likely associated with soil salinization in Italy. The analysis seems to be suitable to ascertain the multifaceted interactions among soil, landscape and local communities, providing information useful to design effective responses to contrast land degradation driven by soil salinization (Salvati, 2010).

Our results indicate that municipalities vulnerable to soil salinization are characterized by higher human pressure due to crop intensification, population density and a younger demographic structure, discontinuous urban settlements, high unemployment rate, high crime intensity and medium–high wealth conditions. Although density of water reservoirs decreases rapidly with the percentage of areas potentially exposed to soil salinization, the percent area of cropland applying sustainable irrigation practices shows the reverse spatial pattern, possibly indicating

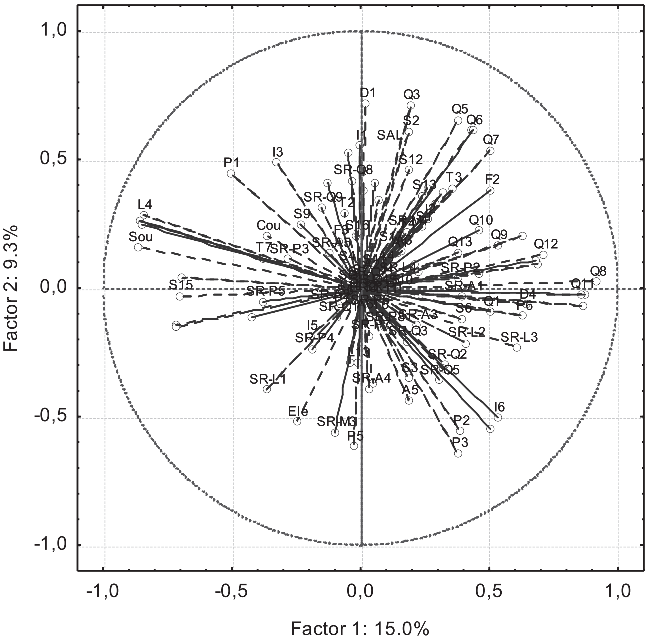

Fig. 3. Component loading plot (PC 1 and 2).

farmers' adaptation to specific environmental conditions (Abu Hammad and Tumeizi, 2012). The application of sustainable irrigation practices may reduce the risk of soil degradation in sensitive and ecologically fragile areas (Trisorio, 2005).

Remarkably, our results do not corroborate the hypothesis on a latent nexus between rural poverty and soil degradation formulated in previous studies (Salvati, 2014; but see also Wilson and Juntti, 2005; Salvati and Carlucci, 2011; Imeson, 2012). Rather, the results suggest that each soil degradation process is characterized by specific relations with the local socio-demographic and economic context (Boardman et al., 2003; Iosifides and Politidis, 2005; orbelle-Rico et al., 2012). Identifying socioeconomic factors and understanding the relation with the environment are multifaceted issues that require a careful definition of the ecological processes under investigation (Safriel and Adeel, 2008). They usually have effects on the environmental context through non-linear paths, and to feedback interactions with exogenous variables affected by broader forces (Patel et al., 2007). The framework adopted in the present study proved to be suitable to investigate local communities–soil interactions in Italy, exploring complex and possibly non-linear relationships between biophysical and human dimensions (Hubacek and van den Bergh, 2006; Helldén and Tottrup, 2008). It is important to notice that statistical analyses based on correlation sometimes fail to identify causation processes and may represent a partly biased picture of the intimate socio-environmental relationships in rural systems. An assessment framework incorporating descriptive, inferential and multivariate statistical techniques may provide a more comprehensive and realistic representation of the latent relationships between soil, landscape and rural communities compared with e.g. purely economic approaches based on econometric techniques (Salvati and Zitti, 2009).

At the same time, frameworks assessing socio-environmental complexity should consider the unpredictability of territorial actors' behavior in Mediterranean countries (Kok et al., 2004). This requires thorough efforts to integrate the socioeconomic path of local communities and the evolution of relevant environmental variables in a framework based on a restricted, policy-relevant indicator set (Geist, 2005; Ibáñez et al., 2013). While these analyses may contribute to define multi-scale and multi-sector policy strategies (Barbayiannis et al., 2011; Salvati et al., 2011, 2013; Corbelle-Rico et al., 2012) — considered as the most effective measures contrasting soil degradation in southern Europe (Briassoulis, 2011), improving the effectiveness of local communities' responses to soil salinization cannot be achieved without a full comprehension of the different socioeconomic contexts existing at the local scale (Salvati, 2014).

For example, environmental policies should consider more tightly the intrinsic ability shown by local communities to adapt to potentially worse ecological conditions e.g. determined by specific soil degradation

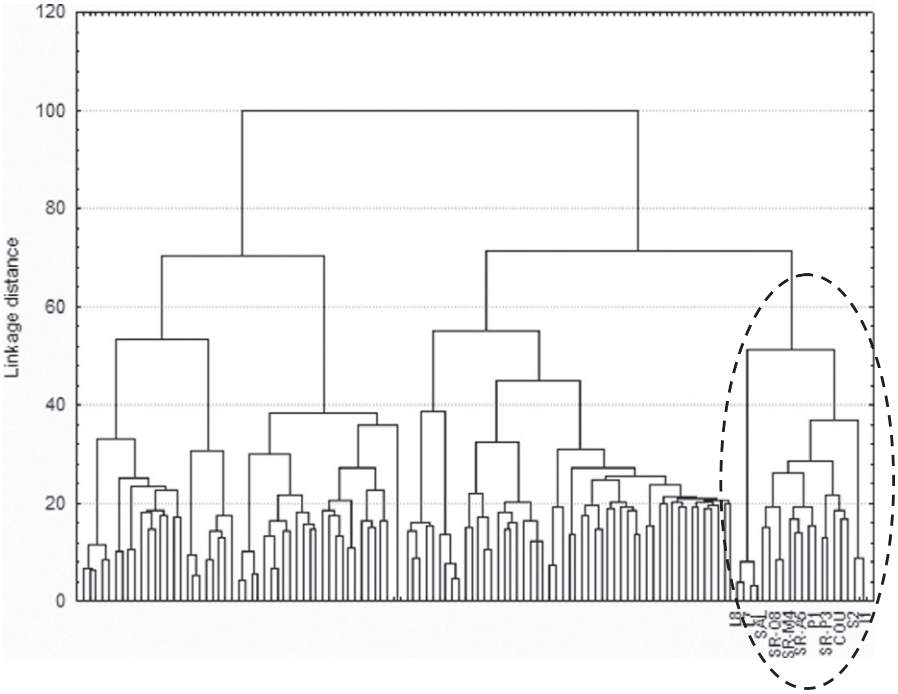

Fig. 4. Similarity in the spatial distribution of the socioeconomic indicators mostly associated with vulnerability to soil salinization in Italy (see Table 1 for abbreviations; the dotted line indicates the indicators most similar with Sal variable).

processes such as soil salinization. Measures dedicated to support the diffusion of sustainable irrigation practices in vulnerable areas may be more effective in socioeconomic contexts where awareness of local environmental problems, endogenous knowledge skills and practical solutions are already developed as a response to adverse territorial conditions, market dynamics, social change or as the consequence of long-established human–nature interactions (Boardman et al., 2003; Danfeng et al., 2006; Abu Hammad and Tumeizi, 2012). Only a comprehensive knowledge of the influence of the local socioeconomic context on basic soil attributes and processes (taken as key targets for soil conservation measures) may inform effective land management strategies for a sustainable development of vulnerable regions.

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Appendix A. The list of socioeconomic indicators used in the present study

Acronym	Name	Dimension	Source	Year
Population dynamics and human settlement				
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 market and human capital				
L1	Participation rate	Job market	Census of population	2001
L2	Activity 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 participation rate	Job market	Census of population	2001
L6	Female activity 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	Education	Census of population	2001
F2	% population graduated in high-school	Education	Census of population	2001
F3	% population with secondary education	Education	Census of population	2001
F4	% population with primary education	Education	Census of population	2001
F5	% literate population without formal education degree	Education	Census of population	2001
F6	% illiterate population	Education	Census of population	2001
Economic specialization and competitiveness				
S1	Average number of workers per industrial local unit	Economic structure	Census of Industry and Services	2001
S2	Density of workers per municipality surface area (km^2)	Economic structure	Census of Industry and Services	2001
S3	% workers in the agricultural and forestry sectors	Economic structure	Census of Industry and Services	2001
S4	% workers in fishing and complementary activities	Economic structure	Census of Industry and Services	2001
S5	% workers in mining industry	Economic structure	Census of Industry and Services	2001
S6	% workers in manufacturing industry	Economic structure	Census of Industry and Services	2001
S7	% workers in energy production and distribution industry	Economic structure	Census of Industry and Services	2001
S8	% workers in construction industry	Economic structure	Census of Industry and Services	2001
S9	% workers in commerce sector	Economic structure	Census of Industry and Services	2001
S10	% workers in hotel and restaurant services	Economic structure	Census of Industry and Services	2001
S11	% workers in transportation and logistics services	Economic structure	Census of Industry and Services	2001
S12	% workers in financial, insurance and banking services	Economic structure	Census of Industry and Services	2001
S13	% workers in informatic, renting and real estate services	Economic structure	Census of Industry and Services	2001
S14	% workers in the public sector	Economic structure	Census of Industry and Services	2001
S15	% workers in education services	Economic structure	Census of Industry and Services	2001
S16	% workers in health sector	Economic structure	Census of Industry and Services	2001
S17	% workers in other social services	Economic structure	Census of Industry and Services	2001
T1	Number of beds in hotels and campings/resident population	Tourism	Census of Industry and Services	2001
T2	Average number of beds per hotel	Tourism	Census of Industry and Services	2001

Appendix A (*continued*)

Acronym	Name	Dimension	Source	Year
Economic specialization and competitiveness				
T3	Hotel occupancy level (five-years average)	Tourism	ISTAT (2006)	2001
T4	Camping occupancy level (five-years average)	Tourism	ISTAT (2006)	2001
T5	Agri-tourism occupancy level (five-years average)	Tourism	ISTAT (2006)	2001
T6	Number of beds in agri-tourism accommodation/beds in hotel	Tourism	ISTAT (2006)	2001
T7	Resident population/total number of stores	Tourism	ISTAT (2006)	2000
Quality of life				
Q1	% subscriptions on state radio-television channels	Income and wealth	Banca d'Italia and Istituto Tagliacarne	1999
Q2	Number of cars/inhabitants	Income and wealth	Banca d'Italia and Istituto Tagliacarne	1999
Q3	Number of deposits/banks	Income and wealth	Banca d'Italia and Istituto Tagliacarne	1999
Q4	Number of deposits/inhabitants	Income and wealth	Banca d'Italia and Istituto Tagliacarne	1999
Q5	Value of bank deposits/banks (euros)	Income and wealth	Banca d'Italia and Istituto Tagliacarne	1999
Q6	Average value of bank deposits (euros)	Income and wealth	Banca d'Italia and Istituto Tagliacarne	1999
Q7	Value of bank deposits/inhabitants (euros)	Income and wealth	Banca d'Italia and Istituto Tagliacarne	1999
Q8	Per capita income tax amount (euros)	Income and wealth	Istituto Tagliacarne	1998
Q9	Per capita real estate tax amount (euros)	Income and wealth	Istituto Tagliacarne	1998
Q10	Per capita municipal solid waste tax amount (euros)	Income and wealth	Istituto Tagliacarne	1998
Q11	Per capita disposable income (euros)	Income and wealth	Istituto Tagliacarne	2000
Q12	Per capita consumption (euros)	Income and wealth	Istituto Tagliacarne	2000
Q13	Total value added per municipality (euros)	Income and wealth	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
Agriculture and rural development				
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 characters	Census of agriculture	2000
SR-P2	Arable land/agricultural utilized area (%)	Landscape characters	Census of agriculture	2000
SR-P3	Perennial crop/agricultural utilized area (%)	Landscape characters	Census of agriculture	2000
SR-P4	Pastures and meadows/agricultural utilized area (%)	Landscape characters	Census of agriculture	2000
SR-P5	Farm size diversity (Shannon index)	Landscape characters	Census of agriculture	2000
SR-P6	% woodland surface area in total farm surface	Landscape characters	Census of agriculture	2000
SR-P7	% change in agricultural utilized area (1990–2000)	Landscape characters	Census of agriculture	2000
SR-P8	Agricultural landscape diversity (Shannon index)	Landscape characters	Census of agriculture	2000
SR-M1	Number of agricultural machines per farm	Crop intensity	Census of agriculture	2000
SR-M2	Irrigated land/total agricultural utilized area (%)	Crop intensity	Census of agriculture	2000
SR-M3	Agricultural utilized area per worker in agriculture	Crop intensity	Census of agriculture	2000
SR-M4	Crop intensity index	Crop intensity	Census of agriculture	2000
SR-Q1	Agricultural utilized area under organic farming (%)	Innovation and quality and innovation	Census of agriculture	2000
SR-Q2	Area cultivated with DOC designation of origin grapevines (%)	Innovation and quality	Census of agriculture	2000
SR-Q3	Area cultivated with DOCG designation of origin grapevines (%)	Innovation and quality	Census of agriculture	2000
SR-Q4	Livestock organic farms/total farms (%)	Innovation and quality	Census of agriculture	2000
SR-Q5	Agricultural utilized area under good agronomic practices (%)	Innovation and quality	Census of agriculture	2000
SR-Q6	Agricultural utilized area under sustainability certification (%)	Innovation and quality	Census of agriculture	2000
SR-Q7	Number of cattle/agricultural utilized area	Innovation and quality	Census of agriculture	2000
SR-Q8	Agricultural utilized area applying sustainable irrigation (%)	Innovation and quality	Census of agriculture	2000
SR-Q9	Index of economic marginalization of farms	Innovation and quality	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 use/management	Census of water resources	1999
A2	Water dispersion index	Water use/management	Census of water resources	1999
A3	Consumed water/inhabitants	Water use/management	Census of water resources	1999
A4	Proportion of water distributed to civil uses	Water use/management	Census of water resources	1999
A5	Number of reservoirs/100 inhabitants	Water use/management	Census of water resources	1999
A6	Reservoir capacity/100 inhabitants	Water use/management	Census of water resources	1999
Environment and territory variables				
Den	Population density (inhabitant/km^2)	Spatial and functional structure of regions	Census of population	2001
Var	Population growth (%)	Spatial and functional structure of regions	Census of population	2001
Cou	Compact settlements (%)	Spatial and functional structure of regions	Corine Land Cover	2000
Low	Lowland (%)	Spatial and functional structure of regions	Census of population	2001
Ele	Average elevation (m)	Spatial and functional structure of regions	Census of population	2001

(*continued on next page*)

Appendix A (*continued*)

Acronym	Name	Dimension	Source	Year
Environment and territory variables				
Sup	Municipal surface area (km^2)	Spatial and functional structure of regions	Census of population	2001
Sou	Dummy for southern Italy (1: southern Italy)	Spatial and functional structure of regions	Territorial statistics	2000
Esa	Environmentally Sensitive Area Index	Soil degradation	Salvati and Bajocco (2011)	2000
Sqi	Soil Quality Index	Soil degradation	Salvati et al. (2011)	2000
Ero	Erosion risk	Soil degradation	Salvati et al. (2011)	2000
Sal	Risk of soil salinization	Soil degradation	Salvati et al. (2011)	2000

References

Abu Hammad, A., Tumeizi, A., 2012. Land degradation: socioeconomic and environmental causes and consequences in the eastern Mediterranean. Land Degrad. Dev. 23, 216–226.

Atis, E., 2006. Economic impacts on cotton production due to land degradation in the Gediz Delta, Turkey. Land Use Policy 23, 181–186.

Barbayiannis, N., Panayotopoulos, K., Psaltopoulos, D., Skuras, D., 2011. The influence of policy on soil conservation: a case study from Greece. Land Degrad. Dev. 22, 47–57.

Basso, B., De Simone, L., Ferrara, A., Cammarano, D., Cafiero, G., Mei-Ling, Y., Tien-Yin, C., 2010. Analysis of contributing factors to desertification and mitigation measures in Basilicata region. Ital. J. Agron. 5 (3S), 33–44.

Blaikie, P., Brookfield, H.C., 1987. Land Degradation and Society. Methuen, Methuen, London.

Boardman, J., Poesen, J., Evans, R., 2003. Socio-economic factors in soil erosion and conservation. Environ. Sci. Pol. 6, 1–6.

Briassoulis, H., 2011. Governing desertification in Mediterranean Europe: the challenge of environmental policy integration in multi-level governance contexts. Land Degrad. Dev. 22 (3), 313–325.

Conacher, A.J., Sala, M., 1998. Land Degradation in Mediterranean Environments of the World. Wiley, Chichester.

Corbelle-Rico, E., Crecente-Maseda, R., Santé-Riveira, I., 2012. Multi-scale assessment and spatial modelling of agricultural land abandonment in a European peripheral region: Galicia (Spain) 1956–2004. Land Use Policy 29, 493–501.

Costantini, E.A.C., Dazzi, C., 2013. The Soils of Italy. Springer, Dordrecht.

Costantini, E.A.C., Urbano, F., Aramini, G., Barbetti, R., Bellino, F., Bocci, M., Bonati, G., Fais, A., L'Abate, G., Loj, G., Magini, S., Napoli, S., Nino, P., Paolanti, M., Perciabosco, M., Mascone, F., 2009. Rationale and methods for compiling an atlas of desertification in Italy. Land Degrad. Dev. 20, 261–276.

Danfeng, S., Dawson, R., Baoguo, L., 2006. Agricultural causes of desertification risk in Minquin, China. J. Environ. Manag. 79, 348–356.

Darwish, T., Atallah, T., El Moujabber, M., Khatib, N., 2005. Salinity evolution and crop response to secondary soil salinity in two agro-climatic zones in Lebanon. Agric. Water Manag. 78, 152–164.

Dazzi, C., 2006. Acque saline e qualità del suolo. Ital. J. Agron. 1 (3, Suppl.), 467–474.

European Soil Bureau, 2014. Soil Themes. Soil Salinisation. Joint Research Centre, Ispra (http://eusoils.jrc.ec.europa.eu/library/themes/Salinization/ accessed April 2014).

Ferrara, C., Barone, P.M., Steelman, C., Pettinelli, E., Endres, A.L., 2013. Monitoring shallow soil water content under natural field conditions using the early-time GPR signal technique. Vadose Zone J. 12 (4), 1–9. http://dx.doi.org/10.2136/vzj2012.0202.

Ferrara, A., Salvati, L., Sabbi, A., Colantoni, A., 2014a. Soil resources, land cover changes and rural areas: towards a spatial mismatch? Sci. Total Environ. 478, 116–122.

Ferrara, C., Salvati, L., Tombolini, I., 2014b. An Integrated evaluation of soil resource depletion from diachronic settlement maps and soil cartography. Geoderma 232–234, 394–405.

Geist, H., 2005. The Causes and Progression of Desertification. Ashgate Studies in Environmental Policy and PracticeAshgate Publishing Limited, Aldershot.

Gisladottir, G., Stocking, M., 2005. Land degradation control and its global environmental benefits. Land Degrad. Dev. 16, 99–112.

Helldén, U., Tottrup, C., 2008. Regional desertification: a global synthesis. Glob. Planet. Chang. 64, 169–176.

Herrero, J., Pérez-Coveta, O., 2005. Soil salinity changes over 24 years in a Mediterranean irrigated district. Geoderma 125, 287–308.

Hubacek, K., van den Bergh, J.C.J.M., 2006. Changing concepts of 'land' in economic theory: from single to multi-disciplinary approaches. Ecol. Econ. 56, 5–27.

Ibáñez, J.J., Zinck, J.A., Dazzi, C., 2013. Soil geography and diversity of the European biogeographical regions. Geoderma 192, 142–153.

Imeson, A., 2012. Desertification, Land Degradation and Sustainability. Wiley, Chichester.

Iosifides, T., Politidis, T., 2005. Socio-economic dynamics, local development and desertification in western Lesvos, Greece. Local Environ. 10, 487–499.

Istat, 2006. Atlante statistico dei comuni. Istituto Nazionale di Statistica, Roma.

Kok, K., Rothman, D.S., Patel, M., 2004. Multi-scale narratives from an IA perspective: Part I. European and Mediterranean scenario development. Futures 38, 261–284.

Kosmas, K., Tsara, M., Moustakas, N., Karavitis, C., 2003. Identification of indicators for desertification. Ann. Arid Zone 42, 393–416.

Lazarus, E.D., 2014. Land grabbing as a driver of environmental change. Area 46 (1), 74–82.

Marathianou, M., Kosmas, K., Gerontidis, S., Detsis, V., 2000. Land-use evolution and degradation in Lesvos (Greece): an historical approach. Land Degrad. Dev. 11, 63–73.

Marzaioli, R., D'Ascoli, R., De Pascale, R.A., Rutigliano, F.A., 2010. Soil quality in a Mediterranean area of Southern Italy as related to different land use types. Appl. Soil Ecol. 44, 205–212.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Desertification Synthesis. World Resources Institute, Washington, DC.

Montanarella, L., 2007. Trends in land degradation in Europe. In: Sivakumar, M.V., N'diangui, N. (Eds.), Climate and Land Degradation. Springer, Berlin, pp. 83–104.

Nadal, J., Pèlachs, A., Molina, D., Soriano, J.-M., 2009. Soil fertility evolution and landscape dynamics in a Mediterranean area: a case study in the Sant Llorenç Natural Park (Barcelona, NE Spain). Area 41 (2), 129–138.

Patel, M., Kok, K., Rothman, D.S., 2007. Participatory scenario construction in land use analysis: an insight into the experiences created by stakeholder involvement in the Northern Mediterranean. Land Use Policy 24, 546–561.

Perini, L., Salvati, L., Zitti, M., Sorrenti, S., Ceccarelli, T., 2008. La desertificazione in Italia. Bonanno, Roma-Acireale.

Portnov, B.A., Safriel, U.N., 2004. Combating desertification in the Negev: dryland agriculture vs. dryland urbanization. J. Arid Environ. 56, 659–680.

Reynolds, J.F., Stafford-Smith, D.M., 2002. Global Desertification. Do Humans Cause Deserts? Dahlem University Press, Berlin

Romm, J., 2011. Desertification: the next dust bowl. Nature 478, 450–451.

Rubio, J.L., Bochet, E., 1998. Desertification indicators as diagnosis criteria for desertification risk assessment in Europe. J. Arid Environ. 39, 113–120.

Safriel, U., Adeel, Z., 2008. Development paths of drylands: thresholds and sustainability. Sustain. Sci. 3, 117–123.

Salvati, L., 2010. Economic causes and consequences of Land Degradation and desertification risk in southern Europe. Integrating Micro–macro approaches into a geographical perspective. Int. J. Ecol. Econ. Stat. 18 (S10), 20–63.

Salvati, L., 2014. A socioeconomic profile of vulnerable lands to desertification in Italy. Sci. Total Environ. 466–467, 287–299.

Salvati, L., Bajocco, S., 2011. Land sensitivity to desertification across Italy: past, present, and future. Appl. Geogr. 31 (1), 223–231.

Salvati, L., Carlucci, M., 2011. The economic and environmental performances of rural districts in Italy: are competitiveness and sustainability compatible targets? Ecol. Econ. 70 (12), 2446–2453.

Salvati, L., Zitti, M., 2009. Multivariate analysis of socio-economic indicators to estimate land degradation sensitivity: a case study applied to a Mediterranean area. Int. J. Ecol. Econ. Stat. 15 (F09), 93–102.

Salvati, L., Venezian Scarascia, M.E., Zitti, M., Ferrara, A., Urbano, V., Sciortino, M., Giupponi, C., 2009. The integrated assessment of land degradation. Ital. J. Agron. 4 (3), 77–90.

Salvati, L., Perini, L., Ceccarelli, T., Zitti, M., Bajocco, S., 2011. Towards a process-based evaluation of soil vulnerability to degradation: a spatio-temporal approach in Italy. Ecol. Indic. 11 (5), 1216–1227.

Salvati, L., Ceccarelli, T., Bajocco, S., Perini, L., 2013. Amplifying (or consolidating) territorial disparities in the quality of the environment: the case of land degradation in Italy. Prof. Geogr. 65 (4), 647–663.

Sirami, C., Nespoulous, A., Cheylan, J.-P., Marty, P., Hvenegaard, G.T., Geniez, P., Schatz, B., Martin, J.-L., 2010. Long-term anthropogenic and ecological dynamics of a Mediterranean landscape: impacts on multiple taxa. Landsc. Urban Plan. 96, 214–223.

Sivakumar, M.V., N'diangui, N., 2007. Climate and Land Degradation. Springer, Berlin.

Tóth, G., Adhikari, K., Várallyay, Gy, Tóth, T., Bódis, K., Stolbovoy, V., 2008. Updated map of salt affected soils in the European Union. In: Tóth, G., Montanarella, L., Rusco, E. (Eds.), Threats to Soil Quality in Europe. Office for Official Publications of the European Communities, Luxembourg, pp. 65–77 (EUR 23438 EN 151 pp.).

Trisorio, A., 2005. The Sustainability of Italian Agriculture. Italian National Institute of Agricultural Economics, Rome.

Van-Camp, L., Bujarrabal, B., Gentile, A.-R., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.-K., 2004. Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection. Office for Official Publications of the European Communities, Luxembourg (EUR 21319, EN/3, 872 pp.).

Wang, X., Chen, F., Dong, Z., 2006. The relative role of climatic and human factors in desertification in semiarid China. Glob. Environ. Chang. 16, 48–57.

Wessels, K.J., 2007. Can human-induced land degradation be distinguished from the effects of rainfall variability? A case study in South Africa. J. Arid Environ. 68, 271–297.

Wilson, G.A., Juntti, M., 2005. Unravelling Desertification. Wageningen University Press, Wageningen.