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

Luca Salvati *, Carlotta Ferrara

Consiglio per la Ricerca e la sperimentazione in Agricoltura-Centre for the Study of Plant–Soil Interactions (CRA-RPS), Via della Navicella 2-4, I-00184 Rome, 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 multi-faceted 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

* Corresponding author.
E-mail address: luca.salvati@entecra.it (L. Salvati).

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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